Agriculture & Environment Research Unit
School of Life and Medical Sciences
University of Hertfordshire

Guidance and tool to support farmers in taking aware decisions on Ecological Focus Areas

Invitation to Tender: JRC/IPR/2014/H.4/0022/NC

Final Report

Agriculture and Environment Research Unit
School of Life and Medical Sciences
University of Hertfordshire
United Kingdom

15 December 2015

Report Preparation:

Title:	Guidance and tool to support farmers in taking aware decisions on Ecological Focus Areas
Subtitle:	Final report
Reference:	JRC/IPR/2014/H.4/0022/NC
Report to:	Joint Research Centre (JRC)
Date:	Draft submitted: 29 September 2015; revised 13 October; final revision 15 December 2015
Project co-ordinator:	University of Hertfordshire, UK
Organisation:	Agriculture and Environment Research Unit School of Life and Medical Sciences, University of Hertfordshire, UK.
Written by:	Tzilivakis, J., Warner, D.J., Green, A. and Lewis, K.A.
Release authorisation (Administration, Finance, Quality):	K.A. Lewis
Release authorisation (Scientific and technical):	
Please cite as:	Tzilivakis, J., Warner, D.J., Green, A. and Lewis, K.A. (2015) *Guidance and tool to support farmers in taking aware decisions on Ecological Focus Areas*. Final report for Project JRC/IPR/2014/H.4/0022/NC. Joint Research Centre (JRC), European Commission

Contents

List of Tables

List of Figures

Glossary

Acronym / term	Description
AERU	UH Agriculture and Environment Research Unit
BIA	Baseline Impact Assessment
C	Carbon
CAP	Common Agricultural Policy
CFC	Cross Feature Calibration
CICES	Common International Classification of Ecosystem Services
EC	European Commission
EFA	Ecological Focus Area
EU	European Union
FDI	Feature Diversity Index
FIA	Functional Impact Assessment
ha	Hectare
JRC	Joint Research Centre
GAEC	Good Agricultural and Environmental Condition
MEA	Millennium Ecosystem Assessment
MS	Member State
N	Nitrogen
OSR	Oilseed rape
QRAF	Quality and Relevance Assessment Framework
SMR	Statutory Management Requirement
SRC	Short Rotation Coppice
UH	University of Hertfordshire

Executive summary

Farming has a significant role to play in the delivery of a number of desirable outcomes, including ecosystem services and biodiversity. Regardless of past agri-environmental policy and its intentions, there are still ongoing ecological problems that need attention, as demonstrated by the decline in populations of birds and mammals across the EU. The introduction of Ecological Focus Areas (EFAs) on the farm has potential to deliver tangible environmental improvements. However, it is also recognised that the extent of such improvements, and so the success of the policy, will ultimately depend on the specific EFA elements a farmer selects as well as the particular characteristics of the holding. To address this issue the JRC commissioned a project to develop a software tool to help farmers select EFA elements that can deliver the optimal environmental benefits considering the farms site specific characteristics and the pragmatic requirements of ensuring that the EFA solution overall are realistic in terms of farm management. There were four main tasks to the project: an extensive literature review; impact assessment; software development; and testing of the software application. This document constitutes the final report for this project (Ref. JRC/IPR/2014/H.4/0022/NC). It provides a description of the approach taken, a synthesis of the knowledge collated and a description of the outputs that have emerged, including the prototype software that has been developed.

The literature review involved collating the scientific evidence that forms the foundation for the software tool. Over 350 papers, reports and guides were collated and reviewed, resulting in synthesis provided herein, which is structured using the 19 individual EFA elements specified in the legislation. Although the synthesis itself was a valuable output from the project, it was not in a form that could be used to support the software tool. Thus the objective of the second task was to convert this knowledge into a form that could be utilised within the software.

The impact assessment task analysed the knowledge synthesised in the first stage and converted it into a set of guidelines, criteria and rules that could be embedded in the core database that underpins the software. There were no established techniques available that could be used to undertake this task, so a bespoke approach had to be developed, albeit utilising established frameworks where possible. For example, the Common International Classification of Ecosystem Services (CICES) was used as the basis for the ecosystem service impact categories. A bespoke scoring system was developed, which although relatively simple, distilled a lot of complex, and data intensive, parameters. The potential impact of each EFA feature on ecosystem services, biodiversity and management was determined. Then for each feature-impact, a set of parameters (and classes within those parameters) were determined, which affect the relative significance of the impact of that feature on the specified impact. For example, the parameter 'soil texture' with classes of: coarse, medium, medium-fine, fine, and very fine, will affect the impact on soil erosion, thus these classes were used to derive different impact scores (in combination with other parameters). In so doing, when the user of the EFA software describes their farm and features using such parameters, it is then possible to derive a potential impact score that is relevant for that farm. There were two approaches to the scoring of impacts: quantitative (using meta-modelling) and qualitative (using a risk factor approach). The quantitative approach was a more objective means to determine the scores, but it could only be undertaken for a few ecosystem service impacts (due to modelling limitations). Consequently, the majority of the scoring was done using the qualitative approach. Currently there are a total of 230 feature-impact combinations that have been created in the core the database. These are characterised using 138 different parameters containing 708 parameter classes.

The software developed is known as the EFA calculator. It is a standalone Windows application that has been created using MS Visual Studio 2010 with the core database developed using MS Access. The software is freely available to download from the web (https://sitem.herts.ac.uk/aeru/efa/). The user downloads a setup file which then installs the application locally on the PC. The software has three key functions: to calculate the contribution of different farm features to meeting the 5% EFA target (including checking implementation rules); to calculate the potential impact of different features on ecosystem services, biodiversity and

management; and to steer farmers towards features which offer the greatest potential benefits (with respect to minimising burdens and maximising benefits). As with any tool that attempts to make an assessment of potential environmental impacts the knowledge it is attempting to capture and communicate is inherently complex, which works against the criterion of designing a 'simple to use' to tool. To overcome this issue, the design philosophy from the outset was to provide the user with options to customise the tool to the level of detail they require. Therefore the user can decide to have 'basic' settings, or activate more advanced options to increase the level of detail to a level they desire. Using the basic settings the software only displays the necessary detail to undertake the core function of calculating the 5% EFA target. The impact assessment is still undertaken in the background, but the user is not presented with the detailed data input that is used to increase the accuracy of the impact assessment. In the advanced mode the user can obtain more accurate assessment of impacts, but this requires more data to be entered.

The software has undergone two phases of testing: functionality testing and testing with hypothetical farm data. The first phase has been an ongoing task and involves checking for faults, errors and bugs; validity testing; usability (ease of use, support and help, interpretation and readability); testing of the installation routine; and performance and stability tests. The second phase was split into two parts and involved setting up hypothetical farm data to run through the software. The first part used simple case study farms to test all EFA elements activated in each Member State (32 in total including regions) to ensure all combinations functioned correctly. The second part involved creating 25 detailed scenarios, based on real locations, in 16 Member States. As well as providing a test of the software, the detailed scenarios also generated some interesting findings, in particular that for the majority of the 25 farms, their existing features would not be enough to reach the 5% EFA target, and thus they would need to create new features on the farm.

There is little doubt that this was an ambitious project to undertake in a relatively short period of time. A substantial amount of work has been undertaken and some practical outputs developed. However, it is important to acknowledge that the tool is a prototype, has strengths and weaknesses, and scope for development in the future. Firstly, there is scope to improve the knowledge base. Scientific understanding is continually growing and evolving and thus we need to acknowledge this evolution and ensure that it is reflected in the tools and information that are made available to farmers across the EU. In terms of ecosystem service impacts, there scope to make improvements with respect to understanding impacts on provision of water, biomass and energy; global climate regulation by reduction of greenhouse gas concentrations; flood protection and other cultural services. For biodiversity, this project has reinforced the need to find a common and/or established framework for assessing impacts on biodiversity, and within this project there is scope for greater harmonisation across the different features with regard to impact categories used, albeit this is partly reflection of the inconsistencies in the scientific evidence. For management, difficulties were experienced in gaining evidence specifically on the management implications of EFA features. Assessments were largely confined to crude evaluations of the potential impact on labour. Consequently there is considerable scope for improvement for this impact category.

The prototype EFA calculator software that has emerged from this project has scope to be developed in the future. Feedback from users will be important to steer any future developments and it would also be valuable to ground truth the tool, i.e. to see how well the outputs from the tool match up to what is observed on the ground. The tool has been designed for farmers and farm advisors to use, although the latter are more likely to be the main users. It should also be acknowledged that in the long term, widespread adoption of this tool (and others of a similar nature) ideally needs to be achieved in cooperation with commercial software companies. Seamless integration with existing management activities and software applications will aid the process of integrating environmental issues into the decision making processes of agricultural businesses, thus increasing the scope for widespread improvements in environmental performance.

Executive summary (French)

L'agriculture a un rôle important à jouer dans la prestation d'un certain nombre de résultats souhaitables, y compris les services écosystémiques et la biodiversité. Indépendamment de la politique agro-environnementale passée et de ses intentions, il y a encore des problèmes écologiques en cours qui nécessitent attention, démontré par le déclin des populations d'oiseaux et de mammifères à travers l'UE. L'introduction de Surfaces d'intérêt écologique (SIE) à la ferme a le potentiel d'apporter des améliorations tangibles pour l'environnement. Cependant, il est également reconnu que l'ampleur de ces améliorations, et donc le succès de la politique, dépendra en fin de compte sur les éléments spécifiques de SIE qu'un agriculteur sélectionne ainsi que les caractéristiques particulières de sa ferme. Pour résoudre ce problème, le CCR a commandé un projet pour développer un outil logiciel pour aider les agriculteurs à sélectionner les éléments de SIE qui peuvent fournir les avantages environnementaux optimaux, compte tenu des caractéristiques spécifiques des fermes du site et les exigences pragmatiques de veiller à ce que le choix de SIE soit globalement réaliste en termes de gestion. Le projet consistait de quatre tâches principales: une revue approfondi de la littérature; évaluation de l'impact; développement de logiciel; et le test de l'application logicielle. Ce document constitue le rapport final pour ce projet (Réf. JRC / IPR / 2014 / H.4 / 0022 / NC). Il fournit une description de l'approche adoptée, une synthèse des connaissances rassemblées et une description des résultats du projet, y compris le logiciel prototype qui a été développé.

La revue de la littérature a impliqué rassembler les preuves scientifiques qui pourraient constituer le fondement de l'outil logiciel. Plus de 350 documents, rapports et guides ont été agrégés et examinés, résultant dans la synthèse fournie ici, qui est structurée selon les 19 éléments des SIE individuels précisés dans la loi. Malgré le fait que la synthèse ait produit des résultats précieux, ils n'étaient pas dans un format qui pouvait être utilisé pour le fondement de l'outil logiciel. Ainsi, l'objectif de la deuxième tâche a consisté à transformer ces résultats en un format qui pouvait être utilisé dans le logiciel.

La tâche d'évaluation de l'impact a donc consisté de l'analyse des résultats de la première tâche, produisant un ensemble de lignes directrices, critères et règles qui pourraient être intégrés dans la base de données étayant le logiciel. Il n'y avait pas de techniques établies qui pouvaient être utilisées pour entreprendre cette tâche, donc une approche sur mesure a dû être développée, utilisant toutefois des cadres établis lorsque c'était possible. Par exemple, la Classification internationale commune des services écosystémiques (CICES) a été utilisée comme base pour les catégories d'impact des services écosystémiques. Un système de notation a été développé sur mesure; bien que relativement simple, il a raffiné beaucoup de paramètres de données complexes et intensives. L'impact potentiel de chaque SIE sur les services écosystémiques, la biodiversité et la gestion a été déterminé. Ensuite, pour chaque fonction d'impact, un ensemble de paramètres (et de classes au sein de ces paramètres) ont été déterminés, qui affectent l'importance relative de l'impact de cette fonction sur l'impact spécifié. Par exemple, le paramètre «texture du sol» avec les classes de: grossier, moyen, moyen-fine, fine et très fine, affectera l'impact sur l'érosion des sols, donc ces classes ont été utilisées pour dériver différents scores d'impact (en combinaison avec d'autres paramètres). Ce faisant, lorsque l'utilisateur du logiciel décrit sa ferme et ses caractéristiques en se servant de ces paramètres, il est alors possible de dériver un score d'impact potentiel pertinent. Il y avait deux méthodes pour la notation des impacts: quantitative (méta-modélisation) et qualitative (utilisant une approche de facteur de risque). La méthode quantitative était une approche plus objective pour déterminer les scores, mais pouvait seulement être utilisée pour quelques impacts de service écosystémique (en raison des limitations de la modélisation). Par conséquent, la majorité de la notation a été réalisée avec la méthode qualitative. Il y a couramment un total de 230 combinaisons de fonction d'impact dans la base de données. Ces combinaisons sont caractérisées par l'utilisation de 138 paramètres différents, contenant 708 classes.

Le logiciel qui a été créé peut être considéré comme la calculatrice des SIE. C'est une application autonome Windows qui a été créée en utilisant MS Visual Studio 2010, et la base de données a été développée grâce à MS Access. Le logiciel est librement disponible au téléchargement sur le site web

(https://sitem.herts.ac.uk/aeru/efa/). L'utilisateur télécharge un fichier de configuration et installe ensuite l'application localement sur son ordinateur. Le logiciel dispose de trois fonctions-clés: calculer la contribution des différentes caractéristiques agricoles pour répondre à la cible 5% de SIE (y compris la vérification des règles de mise en œuvre); calculer l'impact potentiel des différentes caractéristiques sur les services écosystémiques, la biodiversité et la gestion; et orienter les agriculteurs vers des fonctionnalités qui offrent potentiellement les plus grands avantages (à l'égard de minimiser les charges et maximiser les bénéfices). Comme pour tout outil qui tente d'évaluer les impacts environnementaux potentiels, les données qu'il tente de capter et de communiquer sont par nature complexes, ce qui va à l'encontre des critères de conception d'un outil 'simple à utiliser'. Pour surmonter ce problème, la philosophie de conception dès le départ était de fournir à l'utilisateur des options pour personnaliser l'outil. Par conséquent, l'utilisateur peut décider d'avoir des paramètres de base, ou d'activer des options plus avancées pour modifier ces valeurs de 'base' selon le niveau de détail désiré. En utilisant les paramètres de base, le logiciel affiche uniquement les détails nécessaires pour procéder à la fonction de base de calcul de l'objectif de 5% de SIE. L'évaluation d'impact est quand même réalisée à l'arrière-plan, mais l'utilisateur n'est pas requis de procéder à l'entrée de données détaillée requise pour augmenter la précision de l'évaluation d'impact. Utilisant les options avancées, l'utilisateur peut obtenir une évaluation plus précise des impacts, mais cela nécessite plus d'entrée de données.

Le logiciel a subi deux phases de tests: des tests de fonctionnalité, et des tests utilisant des données agricoles hypothétiques. La première phase a été une tâche en cours et consistait à vérifier pour les fautes de logiciel, les erreurs et les bogues informatiques; test de validité; utilisabilité (facilité d'utilisation, de soutien et d'aide, l'interprétation et la lisibilité); tests sur la routine de l'installation; et tests de performance et de stabilité. La deuxième phase a été divisée en deux parties et concernait l'usage de données hypothétiques agricoles pour vérifier le logiciel. La première partie a utilisé de simples cas pour tester toutes les exploitations agricoles de SIE dans chaque État membre (32 en total, y compris les régions) pour confirmer que toutes les combinaisons fonctionnaient correctement. La deuxième partie comprenait l'usage de 25 scénarios détaillés, basés sur des lieux réels dans 16 États membres. Ainsi que de fournir un test du logiciel, les scénarios détaillés ont également produit des résultats intéressants, en particulier que pour la majorité des 25 fermes, leurs fonctionnalités existantes ne seraient pas suffisantes pour atteindre l'objectif de 5% de SIE, et ils auraient donc besoin de créer de nouvelles fonctionnalités.

Il ya peu de doute que c'était ambitieux d'entreprendre un tel projet dans une période de temps relativement courte. Une quantité importante de travail a été entreprise et quelques résultats de recherche pratiques ont été produits. Cependant, il est important de reconnaître que l'outil est un prototype, avec ses forces et ses faiblesses, et qu'il possède des perspectives de développement futur. Tout d'abord, il est possible d'améliorer la base de connaissances.

La compréhension scientifique ne cesse de croître et d'évoluer, et donc nous devons reconnaître cette évolution et veiller à ce que cela se reflète dans les outils et les informations qui sont mises à la disposition des agriculteurs à travers l'UE

En termes d'impacts sur les services écosystémiques, il est possible de faire des améliorations en ce qui concerne la compréhension des impacts sur l'approvisionnement en eau, de la biomasse et de l'énergie; la régulation du climat mondial par la réduction des concentrations de gaz à effet de serre; protection contre les inondations et d'autres services culturels. Pour la biodiversité, ce projet a renforcé la nécessité de trouver un cadre commun et / ou mis en place pour évaluer les impacts sur la biodiversité, et le projet a démontré qu'il y a place pour une plus grande harmonisation entre les différentes fonctions à l'égard de catégories d'impacts utilisées, mais cela est en partie le reflet des incohérences dans les preuves scientifiques. En ce qui concerne la gestion, il a été difficile d'obtenir des preuves spécifiques sur les implications pour la gestion des caractéristiques de SIE. Les évaluations ont été largement confinées à des évaluations grossières de l'impact potentiel sur le travail. Par conséquent, il existe des possibilités considérables d'amélioration pour cette catégorie d'impact.

Le logiciel prototype 'calculatrice des SIE' qui a émergé de ce projet peut continuer à être développé. Les commentaires des utilisateurs seront importants pour diriger les développements futurs et il serait également bénéfique de mesurer la réalité de terrain de l'outil, à savoir, comment les résultats de l'outil correspondent à ce qui est observé sur le terrain. L'outil a été conçu pour l'usage des agriculteurs et des conseillers agricoles, bien que ces derniers soient plus susceptibles d'être les principaux utilisateurs. Il devrait également être admis que dans le long terme, l'adoption généralisée de cet outil (et d'autres de nature similaire) devrait idéalement être réalisée en coopération avec des entreprises de logiciels commerciaux. L'intégration transparente avec les activités de gestion et des applications logicielles existantes faciliterait le processus d'intégration de décisions environnementales avec la prise de décision des entreprises agricoles, augmentant ainsi les possibilités d'amélioration générale de la performance environnementale.

1.0. Introduction

1.1. Background

Ecological Focus Areas (EFAs) have been introduced as part of the so called 'greening' measures of the Common Agricultural Policy (CAP) in order to "safeguard and improve biodiversity on farms" (EC, 2013). They were formally established under Regulation (EU) No 1307/2013 adopted in December 2013, with the relevant rules being laid down in Article 46 (EC, 2013). Table 1.1 lists the 19 EFA elements that are currently available.

Table 1.1: EFA elements

	EFA element
1.	Land lying fallow
2.	Terraces
3.	Hedges or wooded strips
4.	Isolated trees
5.	Trees in line
6.	Trees in groups and field copses
7.	Field margins
8.	Ponds
9.	Ditches
10.	Traditional stone walls
11.	Other landscape features under GAEC or SMR
12.	Buffer strips
13.	Hectares of agroforestry
14.	Strips of eligible hectares along forest edges - NO PRODUCTION
15.	Strips of eligible hectares along forest edges - WITH PRODUCTION
16.	Areas with short rotation coppice
17.	Afforested areas
18.	Areas with catch crops or green cover
19.	Areas with nitrogen fixing crops

Member States can select (activate) the elements that they wish to be applicable within the area for which they are the competent authority, so not all will be available throughout the EU. Farms (with an arable area 15ha or more) then have to select EFAs from those activated in their Member State and these need to account 5% by area of the total arable land declared (which includes fallow land, temporary grassland and crop land, but does not include permanent grassland or crops). A number of the elements above may also have conversion and/or weighting factors intended either to convert features not measured by area (e.g. linear features) into to equivalent areas (conversion), or to reflect the greater or lesser than average biodiversity benefits of certain elements (weighting). Consequently determining the EFA area of a farm is not always as simple as direct measurement in hectares.

The introduction of EFAs on the farm has potential to deliver tangible environmental improvements. However, it is also recognised that the extent of such improvements will ultimately depend on the specific EFA elements a farm selects as well as the particular characteristics of the holding. Consequently, JRC commissioned a project to develop a software tool that aims to help farmers select EFA elements that can deliver the optimal environmental benefit considering, if possible, the farms site specific characteristics and the pragmatic requirements of ensuring that the EFA solution overall and the specific EFA elements selected are realistic in terms of management and control.

1.2. Aims and objectives

The overall aim of this project was to develop and test a software tool that aims to help farmers identify the most ecologically sound and pragmatic solution for implementing the EFAs on their farm. The tool will provide an estimate of how each choice made contributes to improved farm environmental performance and enhanced ecosystem services taking into account the ease of management and control.

More specifically individual objectives were:

1. To conduct an extensive knowledge and literature review for all the different EFA elements in order to define their contribution to (a) biodiversity maintenance and enhancement and (b) the provision and enhancement of ecosystem services taking account of various characteristics such as size, location, connectivity etc.
2. To design and develop a simple software tool that will support farmers calculate their 5% EFA and include various user functions for ranking potential solutions in terms of their contribution to biodiversity, ecosystem services and the ease of management and control.
3. To assess the functionality and usability of the developed tool and pilot it using data for 40 theoretical farms. The theoretical farms will cover a range of common farming types in the EU and be geospatially positioned in a range of different Member States to account for climatic and topographical considerations.

1.3. Methodology, tasks and activities

The project consisted for 4 key tasks:

1. Literature review: Collating and synthesising knowledge on the effects of EFA elements on ecosystem services, biodiversity and management.
2. Impact assessment: structuring the collated knowledge and establishment of impact criteria and guidelines.
3. Software development: creation of software application and its associated core database.
4. Testing: Testing of the software application, including functionality testing and testing using hypothetical scenarios/case study farms, and refining of the software based on feedback.

Figure 1.1 shows the flow of these tasks and Table 1.2 shows the time line of when they were undertaken, and also shows the planned schedule compared to the actual time line that emerged. The project started with the literature review which resulted in the evidence, and this largely ran to schedule. The evidence was synthesised and this formed the bulk of the interim report (submitted 19 March 2015) and is also presented herein (Section 2). This evidence was then analysed in Task 2 (impact assessment) and structured into a format that can underpin the EFA software (see Section 3). This process took longer than originally anticipated, partly due to the quantity of evidence gathered, but also because it needed to develop alongside the development of the software and core database. The development of the software (Task 3) started at the outset of the project, even though it was dependent on the completion of Tasks 1 and 2. This is because some of the software could be put in place prior to the development and population of the core database. The testing of the software (Task 4) started earlier than originally scheduled. As the software development began early in the project, a pre-Alpha (untested) version of the software was available earlier than originally anticipated, thus this was made available for testing. The testing process was then an ongoing process till the end of the project.

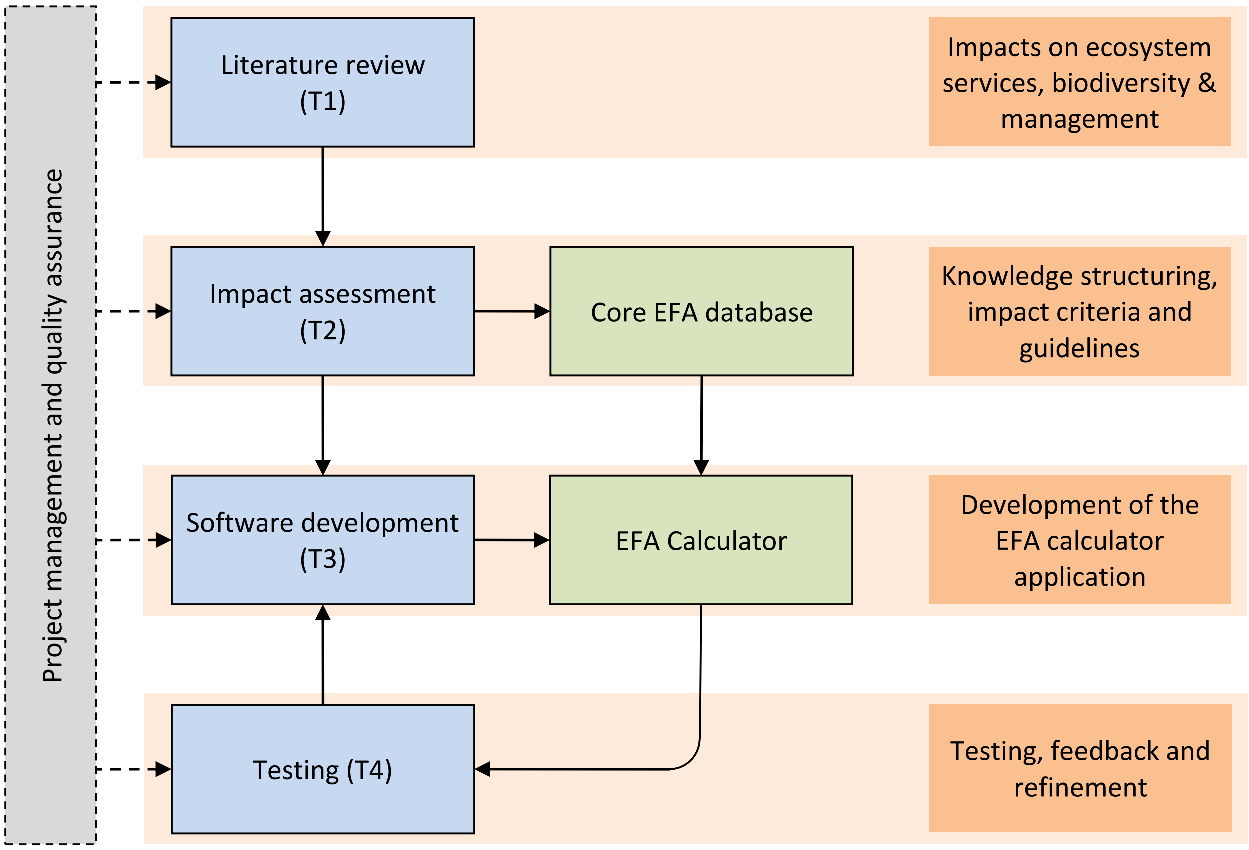
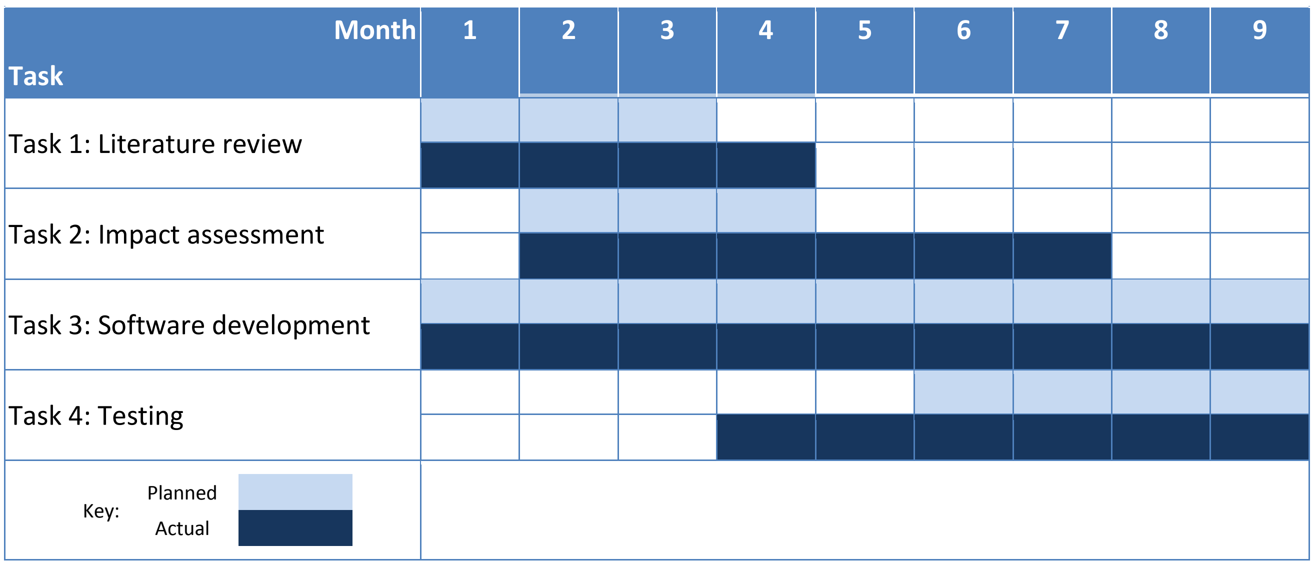


Figure 1.1: Overview of the approach

Table 1.2: Project timeline



A number of meetings (video conferences) between the project team (UH) and the JRC were held throughout the project including:

- 21 January 2015 (Month 1): Kick-off meeting: To clarify and confirm the aims and objectives of the project and discuss the specification for the EFA software.
- 27 March 2015 (Month 3): Interim meeting: To discuss the interim report and the pre-Alpha version of the software.

- 24 September 2015 (Month 9): Final meeting: To discuss the software and completion of this report.

A workshop was also held (at JRC, Ispra, Italy) on 10 June 2015 (Month 6). This workshop included three external experts, as well as staff from JRC and the project team. The approach to the project was presented and discussed and a Beta version of the software was demonstrated. The feedback from the workshop was valuable and was used to refine and improve the approach and the software.

2.0. Literature review on the effects of EFA elements

2.1. Introduction

The objective this task was to undertake a literature review to identify knowledge that will help characterise the different EFA elements in terms of their effects on ecosystem services, biodiversity and management (ease of implementation, management and control). This knowledge will then be 'transformed' into a set of criteria and guidelines (Section 3) that will underpin the EFA Calculator tool and enable it to qualify and approximate the potential impact of each EFA element.

A detailed description of the approach to the literature review (similar to a review protocol) is provided in Annex A. The sections below synthesise the findings from the literature review. The review is separated into two sub-sections. The first sub-section is structured by each individual EFA element. This includes a brief description of each element, including a summary of the specification details that have been provided to date by JRC. The second sub-section takes a whole landscape perspective with the acknowledgement that many benefits, especially for biodiversity, can only be maximised by accounting for the whole landscape, i.e. the combination of different elements, rather than the simple existence of EFA elements. Due to the nature of topic, there is inevitably some discussion on the effects of EFA elements in the context of the wider landscape within Section 2.2, but this is more explicitly explored in Section 2.3.

2.2. Individual EFA elements

2.2.1. Fallow land

Title:	Land lying fallow
Description:	This is land on which there shall be no agricultural production.
No. of MS activated[1]:	30
Dimension limits:	Other than Hungary, which specifies a minimum size of land lying fallow of 0.25 ha, no other dimension limits are specified by any MS.
Implementation rules:	Various rules which vary with MS including: minimum fallow periods; timing of fallow periods; whether pesticides and fertilisers are allowed; voluntary seeding of wild flower mixtures; rules on previous crops; control noxious weeds and invasive species; and maintaining land in a condition suitable for agricultural production.

The value of bare or sparsely vegetated soil to pollinator species tends to be provision of nest sites for solitary bees (Roulston & Goodell, 2011; Wuellner, 1999). A number of MS permit the sowing of non-crop mixtures on fallow land. Where these are specifically formulated for pollinators, for example as previously used under Environmental Stewardship in the UK (Natural England, 2013) there is potential to enhance pollinator abundance. Carvell *et al* (2007) found that different mixture compositions enhanced different pollinator groups, although the precise impact may be subject to the surrounding landscape and habitat types (Heard *et al*., 2007). Combinations of sown nectar and pollen plants (four agricultural legume and four grass species) attracted greater numbers of bumblebees than areas allowed to regenerate naturally or sown with grass mixtures alone. Legumes (also applicable to Section 2.2.18) attracted the greatest number of bumblebee species, and had the most rapid positive impact. Plant species diversity within sown mixtures appears to be a key requirement. A native wildflower mixture of 21 species provided the longest period of continuous flowering, coupled with resource provision early in the season. These two factors have been highlighted by

[1] When counting the number of Member States this includes Belgium: Flanders; Belgium: Walonia; UK: England; UK: Northern Ireland; UK: Scotland; and UK: Wales as individual Member States.

Goulson *et al*. (2005) as critical in the enhancement and maintenance of bumblebee populations due to the risk that any gap in flowering during the spring and summer poses to the starvation and loss of the colony. Generalist hemi-parasitic plants are semi-parasitic plants that help prevent dominance by any one plant species and perform an important function in the maintenance plant species diversity (Joshi *et al*. 2000). Their inclusion in a mixture of perennial legumes increased the diversity of invertebrates, pollinators and predatory arthropods (Pywell *et al*., 2011). The maintenance of predatory arthropod populations (e.g. carabid beetles) has implications for pest control.

Carabid (ground) beetles may act as beneficial insects, consuming both pest prey and weed seeds (Kromp, 1999). Luff (1994) concludes that crop cover is a key variable in determining their presence or absence within a given area, and that the decrease in soil humidity associated with bare exposed soil is detrimental to the survival of carabid larvae, increasing mortality during the early life phase and decreasing adult numbers. The impact of annual cultivation was also a critical factor, however Luff (1994) does not comment on the potential impact of long term fallow without cultivation. Kromp (1999) states that tillage and insecticide and herbicide applications reduce carabid species diversity and abundance, due to both direct toxicity, mechanical damage and the removal of hibernation sites associated with ground cover. In a comparison of boundary features, the greatest numbers of carabids occurred in an undisturbed, five year old strip where succession was allowed to proceed uninterrupted. Numbers were greater than a two year old deliberately sown wildflower strip, and an annually cultivated area with natural regeneration. The presence of vegetation cover and the frequency of cultivation are key underlying factors, with weed root systems considered to act as potential refuges. Hoverflies (Syriphids) are predatory at the larval stage (Colley & Luna, 2000). Their presence in agricultural areas may be enhanced by the planting of species such as phacelia (*Phacelia tanacetifolia*), mustard (*Brassica juncea*) and fennel (*Foeniculum vulgare*) (Lovei *et al*. 1993). These plant species attract adult females who then lay their eggs, positioning the larvae within the target area. Longer term fallow with ground cover was most beneficial to carabid populations. Ground cover may be manipulated with different species mixtures within designated fallow areas. They will be beneficial to various groups of naturally occurring predator (or pollinators) depending on the species composition and the frequency that it requires re-establishment.

Many studies that assess the impact of fallow soils on soil erosion have been undertaken in response to land abandonment and certain crop types (e.g. vineyards) where bare soils exist for a significant proportion of the year. Avoidance of zero vegetation cover is a key factor however the magnitude of impact is spatially variable, with a number of location specific factors contributing to soil erosion rates in combination with no plant cover:

- Fallow soils on negligible gradients may be susceptible to wind erosion where there is limited ground cover (López *et al*., 2002).
- Water erosion from fallow soils on steep gradients resulted in soil losses of up to 10 times that on lower gradients (García-Ruiz *et al*., 1995), although Bienes *et al*. (1996) report losses from fallow soils caused by extreme rainfall events up to 50 times greater compared to land with a barley crop cover.

García-Ruiz (2010) report that alternating fallow periods with cultivation increases the risk of soil erosion due to the prevention of natural succession, and that continuity of land within fallow needs to be maintained without soil disturbance to allow vegetation growth and succession to proceed. Extreme rainfall events in combination with bare soil immediately post crop sowing in early winter caused rilling (Casalí *et al*., 1999), mostly in the same location each year (Valcárcel *et al*., 2003).

Ruiz-Flaño *et al*. (1992) consider that the colonisation of bare ground by native plants has a significant mitigation role in runoff and sediment reduction on sloping ground but there also needed to be sufficient rainfall to allow plant growth. This may be a potential issue in areas susceptible to drought such as southern Spain. Increased plant cover enhances soil organic matter content which was correlated with improved infiltration rates and reduced surface flow. Erosion rates were reduced further with the development of dense shrub communities in later successional phases (Lasanta *et al*., 2006a,b). Gyssels *et al*. (2005) distinguish the above or below ground components of vegetation in their importance in preventing different types of erosion. Splash and interrill erosion were prevented by above ground vegetation and maintenance of adequate surface cover, while rill and ephemeral gully erosion were mitigated by the presence of an extensive plant root system in addition to surface vegetation cover. This has implications for sown mixtures on fallow land where plants may be selected based on their leaf area and/or root system.

The underlying soil geology also exerts an influence on the vulnerability of soils to erosion, largely in part due to their influence on the natural regeneration of vegetation. On calcareous soils, the development of an extensive native plant cover was achieved quickly (Romero-Díaz., 2003) and erosion rates reduced to ones comparable with those measured on natural or semi-natural habitats. Soils with a high sodium content and limited permeability have unstable aggregates resulting in the formation of a surface crust when left bare, this also inhibits natural plant colonization and increases the risk of erosion (Romero-Díaz, 2003; Lesschen *et al*., 2007). Sub-surface runoff also occurs through cracks in the soil, resulting in the formation of gullies. Where rainfall and natural plant colonisation is potentially limited, the soils have poor structure and low organic matter content, correlated with low infiltration rates and a higher risk of surface run-off (Pugnaire *et al*., 2006).

Unsown fallow areas tend to have a low but potentially specialised associated fauna and flora, which may be rare. The overall species richness of invertebrates tends to be lower where soils are bare (Luff, 1994) however rarities with specialist habitat requirements for disturbed land have been recorded in fallow agricultural land. Notable rare (Red Data Book) specialist invertebrate species of open disturbed environments are cited by Schnitter (1994) in Germany including *Harpalus zabroides*, *Amara littorea* and *A. municipalis*. In a similar theme, rare arable flora such as the ground pine (*Ajuga chamaepitys*) and fine-leaved fumitory (*Fumaria parviflora*) require areas of bare but frequently cultivated soils (Plantlife, 2000; Still & Byfield, 2007). At the higher trophic levels, Suárez-Seoane *et al*. (2002) assess the impact of land abandonment in Spain on bird populations and make a general distinction of habitat preference between birds indigenous to northern Europe and those in the south (Mediterranean species). A greater number of species in the Mediterranean region preferred open land, conducive with fallow areas, while the northern species preferred later successional stages (scrub and woodland). A number of species in northern Europe do however exhibit a preference for bare soils and open areas, for example the skylark (*Alauda arvensis*) (Wilson *et al*., 1997).

2.2.2. Terraces

Title:	Terraces
Description:	Terraces are a series of flat areas formed on sloping land, resembling a series of steps. They can be limited to features that are protected by GAEC 7 depending on the Member State.
No. of MS activated:	8
Dimension limits:	Minimum height specified, varies with MS: 0.5 – 3m
Implementation rules:	None other than in Hungary where terraces must be maintained in such a way so that their drainage capacity is not affected, and controls are put in place to avoid the risk of silting up and gully formation. It is also forbidden to significantly alter the structure of the land except for certain agricultural reasons, including the construction of banks and irrigation facilities associated with the production of rice.

Terrace cultivation, or terrace farming, is one of the oldest types of land and water resource management for large-scale farming and a common feature in Mediterranean landscapes. The approach converts hill sides into stepped linear units of relatively flat ground thus allowing farming to be conducted on strongly sloped landowner and helps improve profitability. With respect to the management of terraces they are costly to establish and can represent a large capital investment which is expected to remain in place for a very long time (Bevan & Conolly, 2012).

One of the principal advantages of terrace cultivation is that it can protect the terraced area's soil from overly rapid erosion. The terraced approach aims to reduce the velocity of water runoff and thereby soil erosion by breaking the length of the slope that runoff has available. Terraces usually reduce sheet and rill erosion between terraces and trap part of the eroded soil by deposition. The benefit of this deposition in reducing soil deterioration from erosion depends upon both the amount of deposition and terrace spacing (Foster & Highfill, 1983).

Terraced land not only reduces the rate of soil erosion but can also trap and hold rainwater. This allows for the cultivation of water-intensive crops, such as rice, in these areas. Terracing creates flat spaces for crops and canals for water to flow between these areas. Water collected in the terraces can then be absorbed into the soil and utilised by the crop. A study undertaken by Chow *et al*. (1999) showed that terracing reduced runoff in a contoured potato field by as much as 150mm of rainfall equivalent and thereby increased soil moisture for crop growth and improved yields. This is supported by Lui *et al*. (2011) who conducted a study of terraces in western China and found that the structures store and retain significantly more water than surrounding slopes promoting a more favourable environment for crops.

Terraces vary considerably in shape, complexity and in the degree of labour investment required, as well as in the topography and climatic conditions under which they are used. Their ubiquity, variability, and importance for agricultural productivity have motivated a range of studies designed to understand them better both as cultural and ecological features however most of these have been undertaken in areas unlike those that prevail in Europe (e.g. Evans, 1990; Dunning & Beach, 1954; Beven & Conolly, 2012) and so their relevancy in the context of this study is questionable. There is some published literature regarding the flora associated with abandoned terraces. For example, Bevan *et al*. (2013) found that recently abandoned terraces in Antikythera, Greece had been recolonized by a relatively rich, low herbaceous flora while longer abandoned terraces were typically populated by more scrubby vegetation. The ecological benefit of stone walls, which can form part of terraces, is covered in Section 2.2.10.

2.2.3. Hedges or wooded strips

Title:	Hedges or wooded strips
Description:	These are hedges or strips of woodland that do not exceed the maximum width specified (see below). They can be limited to features that are protected by GAEC 7, SMR 2 or SMR 3 depending on the Member State.
No. of MS activated:	16
Dimension limits:	Maximum width specified, varies with MS: 2 to 30m. A minimum length of 10m is also stipulated in Germany.
Implementation rules:	None

Where hedgerows are connected to other wildlife areas (e.g. woodlands, margins, ditches etc.) their value for nesting habitat and foraging for pollinators and biodiversity generally is significant but at its greatest when the hedge is composed of a diversity of species. Research undertaken over a long period of time has categorically showed the overall importance of hedgerows as habitats for plants (Richards, 1928; Helliwell, 1975; Mountford *et al*., 1994; Morandin & Kremen, 2013), breeding birds (Yahner, 1982; O'Connor, 1987; Parish *et al*., 1994 & 1995), small mammals (Boone & Tinklin, 1988) and invertebrates (Lewis, 1969).

Cranmer *et al*. (2012) observed bumblebee (*Bombus* spp.) flight behaviour along hedges and other linear features and found that these influenced the flight direction of visiting bees. Bumblebees were much more likely to fly along the hedgerow than across adjacent open land. As a consequence benefits such as significant enhancements in pollinator activity, pollen receipt and set seeds were observed. Cranmer *et al.* (2012) also concluded that overall hedgerow connectivity in a landscape is important to bumblebee movement and therefore to plants that require pollinator bumblebee services. The connectivity of habitat patches was much more important that the attractiveness of the patches in terms of habitat and foraging opportunities. Connected patches were visited significantly more frequently by bumblebees than isolated patches and pollinator abundance increased as the number of connections per patch increased. Generally plants in habitat patches with four or five connections produced between 7-23% more seeds than similar plants in isolated patches. However, scientific opinion is not wholly conclusive as Hunter (2002) undertook a literature review and concluded that pollinating bees are more concerned with quality than to area or fragmentation although these issues are also important. The authors found that floral diversity was the most important factor.

Morandin & Kremen (2013) showed that a hedgerow comprised of diverse plants, shrubs and trees as well as deadwood provided a number of biodiversity benefits. Flora-richness in the hedgerow in terms of both total-richness and insect-pollinated plant richness are both important for birds, mammals and insects (Morandin & Kremen, 2013; Shackleford *et al*., 2013; Wratten *et al*., 2012). Wolton *et al*. (2013) agree and emphasised the importance of hedges incorporating both trees and a dense shrub layer. The authors found that 60% of species (which included butterflies, birds and bats) visiting the hedge are dependent on the tree layer and 56% are dependent on the shrub element of the hedge either alone or in combination with other hedge components. Overall the majority (65%) of species are dependent on more than one hedge component, with over a third (35%) being dependent on three or more. However, for species with a restricted distribution, over half (57%) were shown to be dependent on just one component. The great majority (81%) of species with a widespread distribution need a diverse hedge structure. In a study of the local distributions of large moths Merckx *et al.* (2009) found that presence of hedgerow trees had a large positive impact on the abundance and diversity of moths. Hedges without trees supported significantly smaller moth populations.

Related to this is work is a study undertaken by Hinsley and Bellamy (2000) that sought to identify the most important factors positively affecting the species richness and abundance in hedgerows. They concluded that the size of the hedge in terms of its height, width and overall volume and the presence and abundance of trees were all significant. A lack of trees will result in fewer bird nesting opportunities (Sparks *et al*., 1996). The greater the hedge volume the greater area there is to support plant species diversity and this will also mean more berries for forage. However, large hedges do not suit all bird species and birds tend to prefer hedges that most closely match their natural preferred habitats. For example, woodland species may live in the hedge itself and will prefer hedges with a strong tree presence. Whereas hedges closely linked to other habitats such as margins and headlands will be preferred by game birds. This study supports the findings of earlier work conducted by Sparks *et al*. (1996) who identified substantial differences in hedge height preferences across different bird species. Woodland species tend to prefer taller trees and hedgerows. Bird species associated with scrub land prefer those with intermediate height. Open country species preferred grassy or scrub type boundaries. Hinsley and Bellamy (2000) highlight the fact that good ground cover at the base of the hedge is equally important and that this will also increase bird species richness.

Deadwood provides nesting opportunities for bees but as new hedgerows are unlikely to have an abundance of deadwood it is the older more established ones that provide the most benefit in this respect. Diverse hedgerows will attract a greater diversity of pollinators. Hinsley and Bellamy (2000) found that the presence of well-grown, dead and decaying trees is beneficial to many species providing nest holes, foraging and perches thus supporting the view that older established (but well managed) hedges will have a greater value to biodiversity than new hedges. Invertebrates such as spiders, ground beetles and hoverflies are often found in large quantities in hedge bottoms (TBP, 2002) where deadwood residue accumulates.

In a review of bat distribution covering 315 studies Boughey *et al.* (2011) assessed the value of hedgerows in terms of width, tree density, the presence and proximity of water and woodland. The authors found that the incidence of bats was significantly affected by tree density and the proximity of woodland. The more trees present the greater the population and diversity of bats visiting. Boughey *et al.* (2011) also found that the benefits of hedgerow trees to biodiversity are closely linked to their use of and dependency on different species on the tree canopy. For example, rodent species found in hedgerows are generally unaffected by the density of hedgerow trees as they spend most time in the undergrowth and lower areas of the hedge, whereas the abundance and diversity of birds, bats and larger moth species will be affected by density of hedgerow trees.

The importance of flowering plants in hedgerows for pollinators is highlighted by many authors. Rare native bees have been shown to be more common on hedgerow flowers than on weedy, unmanaged sites (Morandin & Kremen, 2013). Hannon & Sisk (2009) investigated the value of hedgerows as foraging habitat for bees (albeit in the USA) and concluded that they are an attractive foraging habitat for native bees especially in early summer when flowering species are more abundant.

The significance of flowering plants on pollinator abundance and diversity was considered in the context of 'mass flowering crops' (such as oilseed rape, linseed and beans) by several authors. Hanley *et al*., (2011) concluded that 'mass flowering crops' play an important role in bumblebee conservation and in maintaining pollination services in arable crops. Twice as many bumble bees were identified visiting flowers in hedgerows close to 'mass flowering crops' compared to other crops (e.g. wheat). However, the effect was found to be short-lived and not bee species specific. Mass flowering crops only enhance pollinator services to native plant species during the crop flowering period and so will probably not have a great effect on conserving bee populations. This emphasises the importance of flowering plants in the hedgerow (Hannon & Sisk, 2009; Hunter, 2002). Le Féon *et al.* (2013) undertook a study to consider solitary bee abundance and species richness and in particular the role of semi-natural habitats including hedgerows, 'mass flowering crops' (i.e. oilseed rape - OSR) and other crops. The study concluded that OSR fields strongly determine the spatial distribution of solitary bees mainly because of the early flowering of the OSR crop which coincides with the emergence of solitary bees, a view supported by Wratten *et al*. (2012).

Menz *et al*. (2011) reviewed a number of studies and concluded that the needs of local species in terms of plant-pollinator interactions should be carefully considered when restoring hedges and other semi-natural areas. Pollinator colonisation and persistence in restored natural areas requires that the ecological needs of pollinators are met either entirely within the restoration site or within foraging distance of it.

Whilst not an EFA element per se, 'green lanes' have come under increasing study in recent years. Green lanes can be best described as linear landscape features comprised of a relatively narrow track-way or grass strip or margin bounded by hedgerows (or walls or ditches) on both side. In order to be eligible for EFA, each element (e.g. hedgerows, ditches, field margins) in the green lane would need to adjacent to arable land (i.e. the 'green lane' would have arable land on each side). EFA elements arranged in this manner could provide added ecological benefits. Studies have shown that these features are particularly valuable for wildlife. For example, an observational survey undertaken by Croxton *et al*. (2002) found that far more bees were recorded in the green lanes (1935) compared with those in field margins (392). It was suggested by the authors that this was due to the greater abundance of flowers in the green lane. Significant differences were seen between the enclosed area inside the green lanes and the more exposed field margin hedges (i.e. a single hedge on wide side of the margin) for both the total number of bumblebees and the total number of bees. In a later study (Croxton *et al.,* 2005) the vascular flora and butterfly fauna of green lanes was compared with that of singe hedged tracks and grass verges. It found that green lanes supported >30% more diverse flora in a 200m transect that the other linear features. In addition a greater number of butterflies were identified in the green lanes, which was thought to be due to the greater abundance of flowering plants that could support butterfly larva. Dover *et al.* (2000) reached similar conclusions in a study investigating the importance of linear features to butterflies. They found that the interior of the green lane had lower wind speeds and more bramble nectar resources than a single hedgerow or grass bank. Walker *et al*. (2005) undertook a review of the benefits of green lanes to bird population and species diversity. They found that bird abundance, and species richness was greater in green lanes compared to a standard hedgerow. Significantly more birds and a greater diversity were recorded in the inner area than on the outside of the 'lane'. Seventeen of the eighteen most abundant bird species recorded in this study were found to occur in greater numbers in green lanes rather than in single hedgerows; for half of these species the difference was significant. Walker *et al.* (2005) also found that the hedge width as well as surrounding land use affected bird species and populations found inside the lane. Alley cropping, where crops are grown in relatively narrow strips between trees or tall hedges on either side is discussed in Section 2.2.5.

In addition to the hedgerow value described herein relating mainly to biodiversity there are other benefits relating to soil erosion, acting as a pollution barrier and offering considerable reductions in noise (Fang & Ling, 2003; Forman & Baudry, 1984; Baudry, 2000; Pimentel *et al*., 1992). Forman and Baudry (1984) suggested that hedgerows exert a major control of many landscape fluxes – improving flows of animals, birds, plants and insects and dampening wind speed, evapotranspiration, soil desiccation, soil erosion and nutrient run-off. Baudry *et al*. (2000) discuss the broader social value of hedgerows including their provision of wood for heating, cooking and timber and their aesthetic and cultural value.

Literature relating to the use of natural barriers such as hedgerows to mitigate pesticide drift was investigated by Ucar and Hall (2001). The authors concluded that properly designed hedges for this purpose are effective in reducing drift and protecting non-target areas, sensitive features, crops and people. However, the complex wind flow near hedges and other tall natural features, such as tree lines, is governed by the local climate and topography and this makes it difficult for recommendations for windbreak design to be made. However, important factors were reported to be hedgerow height, length, vegetation density and composition and orientation, as shape and dimensions will greatly affect the aerodynamics of the windbreak. Height is the parameter most frequently considered as critical as sheltering efficiency is related to the hedge height. Hedges will give a sheltering effect over a distance of 15 times the height upwind and 60 times the height downwind (Rider, 1952). However, density (also termed vegetation porosity) is also important. Dense hedgerows act like a wall and force the wind and so the pesticide drift over the top (Schwartz *et al*., 1995; Hagen *et al*., 1971) decreasing the wind shelter effect. In contrast a very porous hedge will allow the wind and the drift to pass through it whilst still deflecting some over the top. A medium dense windbreak offers the best protection. Similarly Forman and Baudry (1984) determined that field microclimate downwind of a hedgerow is modified for around 16 times the hedgerow height for evaporation and 28 times the height for wind speed.

It may be perceived that the greater demands on hedgerow management the greater the cost in terms of resources and financial implications However, positive management and conservation of hedgerows does not necessarily mean more work for the land manager. Staley *et al*. (2012) undertook a long term study to consider the effects of various management options on the abundance of flower and berry resources for pollinators, insects, mammals and birds. They concluded that uncut hedges provide more flowers and berries than cut hedges. Hedgerow cutting reduced the number of flowers by up to 75% and the biomass of berries available over winter by up to 83% compared to monitored uncut hedges. Reducing the cutting frequency from every year to every three years resulted in 2.1 times more flowers and a 3.4 times greater berry mass over five years. Cutting every two years had an intermediate effect on flower and berry abundance, but the increase in biomass of berries depended on cutting in winter rather than autumn. Within the United Kingdom the most popular agri-environment scheme option is cutting every two years (32% of English managed hedgerow length). If these hedges were managed under a three year cutting regime instead, Staley *et al*. (2012) estimated that the biomass of berries would increase by about 40%, resulting in a substantial benefit for pollinators and other wildlife.

In their review, Hinsley and Bellamy (2000) concluded that good hedgerow management has costs and is unlikely to be applied widely without support. However, with respect to hedges 'under-management' is generally considered to be better for birds than 'over-management'. Typically, large, wide, bushy hedges support about 19 different species of bird whilst tidy, frequently mechanically cut hedges support only about

8 breeding species (TBP, 2002). A slightly later study considering the effects of land use and agricultural management found that very there were relatively few bird species on intensively managed sites compared to sites that were abandoned or under-managed especially where there was a high tree hedge density (Woodhouse *et al*., 2005).

There are some practical considerations for hedgerow management that may increase management time. For example the establishment of new emergent trees within hedgerows creates additional costs and workloads to land managers as they impede mechanical trimming and increase shading of adjacent crops (Boughey *et al.*, 2011).

2.2.4. Isolated trees

Title:	Isolated trees
Description:	These are single trees following the dimension limits below. They can be limited to features that are protected by GAEC 7, SMR 2 or SMR 3 depending on the Member State.
No. of MS activated:	13
Dimension limits:	Crown diameter minimum of 4m. MSs may include trees recognised by them as valuable landscape features with a crown diameter below 4 meters.
Implementation rules:	None

Many authors believe that isolated and scattered trees unconnected to other habitats will have limited value to biodiversity and ecosystem services. Their value is enhanced if they are part of a network of habitats across the farm landscape providing a 'stepping' stone from one patch of habitat to another. However, not all researchers agree and suggest that the ecological importance of single trees should not be underestimated. Several authors highlight the range of ecosystem functions isolated trees provide at the local scale, not least their biodiversity value (e.g. Manning *et al*., 2006; Gibbons *et al.*, 2008). Fischer *et al.* (2010) discusses the disproportionate value of scattered, isolated trees and point out their decline in agricultural landscapes worldwide. Whilst Gibbons *et al.* (2008) described isolated mature trees as ecologically important due to their low abundance and identified their value in providing habitat for shade-loving plants. A wide range of species including birds, mammals and arthropods, depend on trees, isolated (or otherwise) as a food resource, shelter and/or nesting site (Manning *et al*., 2006; Trews *et al*., 2004). Old remnant trees i.e. those that have not been removed for one reason or another whilst others around them have, provide particular value to wildlife. These types of trees often contain basal hollows which are used by roosting bats and nesting birds and small as well as climbing mammals albeit these creatures often prefer the basal areas of such trees (Mazurek & Zielinski, 2004).

Demars *et al*. (2010) found that landscape context was unimportant in predicting how often birds used an isolated tree. They found that tree architecture, in particular tree size, and tree cover in the surrounding landscape were the best predictors of bird use of isolated remnant trees. The authors demonstrated that individual trees contributed to landscape-level conservation of bird diversity, acting as keystone habitat structures by providing critical resources for species that could not persist in otherwise treeless agricultural fields.

Gibbons *et al.* (2008) discuss the value of single mature trees for providing other valuable ecosystem services including shade for stock and wildlife and as a buffer against soil acidity. In a study conducted by Oliver *et al*. (2006) it was shown that there were significant differences in the assemblages of terrestrial invertebrates under isolated trees compared with surrounding grazed pastures. This in part was due to the greater soil fertility, lower pH and litter layer beneath trees. Litter depth and complexity is well known to be an important influence on ground-active and soil invertebrate assemblages (Huhta, 1976; Uetz, 1979). This is true for trees generally (e.g. groups and lines of trees) but is especially valuable in a landscape where trees are sparse.

Several studies have demonstrated the value of scattered trees for soil fertility. Soil fertility (in terms of extractable phosphorus, total nitrogen and organic carbon) tend to be relatively high beneath a tree canopy due to decaying tree leaf accumulation and animal litter – both from livestock and wildlife (Manning *et al*., 2006; Wilson, 2002; Oliver *et al*., 2006). This enhanced nutrient status can be beneficial to a range of plant species including the regeneration of trees. A study undertaken by Graham *et al*. (2003) investigated the influence of three Eucalyptus species on surface soil properties at both stocked and unstocked sites, collecting soil and litter samples at intervals up to twice the canopy radius away from the tree trunk. The study showed soils under two of the Eucalyptus species (*E. melliodora* and *E. viminalis*) had higher pH (decreased acidity) and increased carbon and phosphorus concentrations close to the tree trunk irrespective of grazing. Soils under the third type (*E. caliginosa*) had similar patterns of carbon and phosphorus but more variable acidity patterns. Spatial patterns in soil pH were associated with the ash alkalinity of the tree litter, indicating litter as a source of alkalinity addition to the soil surface and an acid amelioration capacity of Eucalyptus trees.

Individual trees provide a distinct microclimate and refuge to a wide range of wildlife species. In terms of the micro-climate they create, it is usually cooler and damper beneath a tree than in the more exposed landscape. Stem flow, water uptake through the root system from below and around the tree, and increased infiltration of water into the soil further enhance the concentration of water near a given tree, especially in otherwise dry environments (Vetaas, 1992; Eldridge & Freudenberger, 2005). Tree roots transfer significant quantities of water downward to dry soil layers when surface soil layers become wet following rain. Amounts of water stored at depth are not likely to be significant for drought avoidance by plants. However, downward transfer of water may be important to plant establishment and the reduction of waterlogging in certain soil types (Burgess *et al*., 2001). Whilst these benefits are increased in proportion to the number of trees present, individual trees still offer significant benefits.

It should be noted that in a landscape where there is already a significant number of isolated / scattered trees the value of adding one more will be limited. Manning *et al.* (2006) argue that it is precisely because isolated / scattered trees are not part of a large consolidated patch, that their local and landscape effects are more pronounced. A study by Fischer *et al.* (2010) supports this conclusion. The authors considered bird and bat populations on a large number of survey sites (n=108, each 2-ha in size) in relation to tree density. The value of individual trees to both species was highest when tree density was low. On the sites without trees, bird richness doubled with the presence of the first tree and the presence of 3-5 trees trebled bat richness and increased bat activity by a factor of 100. Thereafter, the marginal effect of additional trees on birds and bats diminished rapidly.

2.2.5. Trees in line

Title:	Trees in line
Description:	These are trees in a line following the dimension limits below. They can be limited to features that are protected by GAEC 7, SMR 2 or SMR 3 depending on the Member State.
No. of MS activated:	16
Dimension limits:	Crown diameter minimum of 4m, space between crowns must be 5m or less. MSs may include trees recognised by them as valuable landscape features with a crown diameter below 4 meters. In Hungary, trees in a line should be at least 40 meters long.
Implementation rules:	None

Lines of trees are a frequent feature in European landscapes (McNaughton *et al*. 1989). They are planted predominately for the shelter they provide from wind and strong sunlight, to provide boundary distinction, to dampen noise and hide undesirable features. They also offer a range of biodiversity and ecosystem services. Whilst many of these benefits are common with those associated with trees in both hedgerows and existing in isolation (see Sections 2.2.3 and 2.2.4) there are other benefits that tree lines offer specifically.

In common with all trees biodiversity use them for habitat, forage and shelter. They can help form corridors providing safe passage from one habitat to another. As is the case with hedgerows, bats prefer to fly alongside tree lines rather than across open fields (Boughey *et al.*, 2011; TBP, 2002). One of the important factors governing the value of a tree line for biodiversity is the age of the trees which in turn will be related to the foliage density. Jerzy (2004) undertook a study to consider the effect of a shelterbelts age, the presence or absence of tree litter and the specific composition of the tree line. It was found that the abundance, biomass and diversity of wintering insects increase with the age of the shelterbelt. It typically takes 4–7 years for a shelterbelt to reach values comparable or even higher than those typical for 100–150 years old shelterbelts. The study also found that developing a large basal layer of herbaceous vegetation and selecting fast growing trees improved the conditions for over-wintering insects as this increased the formation of a litter layer. Jerzy (2004) estimated that the treeline over-wintered ten times as many insects than adjacent open fields. This sheltering effect is beneficial to biodiversity but is also beneficial to crops and provides shelter to livestock.

Long-term studies undertaken in Poland demonstrated the importance of tree shelterbelts as places of refuge for a wide diversity and abundance of fauna (Ryszkowski *et al.*, 2002). Studies from elsewhere in Europe and further afield agree with this conclusion and confirm the positive role of shelterbelts for biodiversity in the agricultural landscape (Paoletti & Lorenzoni 1989; Paoletti 2002) as places favourable for overwintering and survival of often beneficial species (Dix *et al*. 1988; Gange & Llewellyn 1989; Wratten 1998) and as barriers obstructing the penetration of crops by harmful species (Prevost & West, 1990).

In addition to biodiversity benefits, tree lines offer a range of other ecosystem services. There have also been studies that have sought to identify the benefit of tree shelterbelts on agricultural land for reducing flood risk. A study of this nature reported by Carroll *et al.* (2004) demonstrated that strategically placed, small scale planting of tree lines for shelter can be used to improve the infiltration capacity of extensive areas of grazed permanent pasture and so they could contribute towards reducing run-off even when present as a small proportion of the land cover.

Another benefit is their ability to reduce soil loss from wind erosion (Jose, 2009). Pimentel *et al.* (1992) and others (e.g. Skidmore, 1986; Jose, 2009) describe tree windbreaks as an effective erosion control technique. Bicknell (1991) describe tree line windbreaks as providing a more long-term solution to wind erosion rather than short-term management decisions such as cover cropping. The author also points out that tree windbreaks, by protecting soils from wind erosion, have an indirect value in the treatment of water repellent soils. Deep cultivation is one of the methods that can overcome water repellence. This technique is not often used because soils with water repellence are highly susceptible to wind erosion. In addition, recent studies have suggested that extreme events, such as droughts and prolonged dry spells, under climate change could increase the water repellency of soils. In the long-term, this could reduce the capacity of soils to sequester carbon (EC, 2011) hence the planting of trees may improve soil carbon sequestration as well as that of the tree biomass. Studies have shown that the potential of trees to sequester soil carbon increases with species richness and tree density. These factors also deliver the greatest biodiversity value (Jose, 2009).

Literature relating to the use of natural barriers such as tree lines to mitigate pesticide drift was investigated by Ucar and Hall (2001). The authors concluded that properly designed tree wind barriers are effective in reducing drift and protecting non-target areas, sensitive features, crops and people but the complex wind flow near tall natural features, such as tree lines, is governed by the local climate and topography and this makes it difficult for recommendations for windbreak design to be made. However, important factors were reported to be tree height, length, canopy density and composition and orientation, as shape and dimensions will greatly affect the aerodynamics of the windbreak and consequently its effectiveness at reducing pesticide drift. Height is the parameter most frequently considered as critical as sheltering efficiency is related to the treeline height. The tree line will give a sheltering effect over a distance of 15 times the height upwind and 60 times the height downwind (Rider, 1952). However, density (also termed vegetation porosity) is also important. Dense tree foliage, especially when coupled with dense vegetation at the trunk base, will act like a wall and force the wind and so the pesticide drift over the top decreasing the wind shelter effect (Schwartz *et al*., 1995; Hagen *et al*., 1971). In contrast a very porous tree line will allow the wind and the drift to pass through it whilst still deflecting some over the top. A medium dense windbreak offers the best protection.

Bicknell (1991) describe management problems related to establishing windbreaks on old or well established agricultural land. Positioning the windbreak in the right location can often be difficult due to other established features. However, once established there is little management cost.

The noise reduction effect offered by tree belts has also been studied (Fang & Ling, 2003; Jose, 2009; Harris & Cohn, 1985). They found factors important for noise reduction include visibility, width, height and length of the tree belts and found that the greater the biomass density the greater the noise reduction effect. Foliage density, height, length and width of tree belts are the most effective factors in reducing noise rather than leaf size and branching characteristics. In addition, tree belts are an aesthetic long-term and relatively low cost means of hiding undesirable landscape features (Kuwano *et al*., 2001).

Like green lanes (see Section 2.2.3), tree alleys have also been studied in recent years. These can be best described as linear landscape features comprised of a relatively narrow track-way, grass strip or margin bounded by lines of trees on both side. In many instances these linear tree arrangements do not have narrow grass or road tracks in the centre but are used for cropping (alley cropping). Alley cropping is reported to be a valuable approach in areas prone to soil erosion as the trees provide shelter (Quinkenstein *et al*., 2009; Kang, 1997). There are additional benefits in that the tree roots help increase water infiltration. The trees also create a cooler microclimate over the crops and so can be valuable in dry areas (Quinkenstein *et al*., 2009; Tsonkova *et al*., 2012). In addition tree litter adds organic matter and nutrients and so improves the soil fertility (USDA, 2012; Kang, 1997; Tsonkova *et al*., 2012). Studies have also shown that these types of features are particularly valuable for wildlife albeit most of it has considered hedgerows rather than specifically trees (see Section 2.2.3) (e.g. Croxton *et al*., 2002; Walker *et al*., 2005; Kang, 1997; Tsonkova *et al*., 2012). In one three year study that did specifically consider tree alleys Seddon *et al*. (2008) found that after the three years several benefits had been noted. General site condition in terms of soil fertility and in the non-cropped tree edges there was higher plant species richness than in comparable traditionally farmed sites which improved structure, composition and so its ecological value. In Europe alley cropping systems which integrate strips of short rotation coppices into conventional agricultural fields are receiving increasing attention. These systems can be used for crops and woody biomass production at the same time, enabling farmers to diversify the provision of market goods (Tsonkova *et al*., 2012).

2.2.6. Trees in groups and field copses

Title:	Trees in groups and field copses
Description:	There are trees in group, where trees are connected by overlapping crown cover, following the dimension limits below. They can be limited to features that are protected by GAEC 7, SMR 2 or SMR 3 depending on the Member State.
No. of MS activated:	18
Dimension limits:	Maximum area specified, varies with MS: 0.2 to 0.5ha. In Wallonia, the width must be greater than 10m. In Germany, areas less than 50m² are excluded. In Croatia, areas less than 100m² are excluded.
Implementation rules:	None

Field copses can be described as areas largely overgrown with groups of trees and / or woody shrubs and plants which are not used for agricultural production. These tree and shrubbery arrangements offer many of the same types of biodiversity and ecosystem services benefits that hedgerows (see Section 2.2.3), woodlands and trees in a line (see Section 2.2.5) offer. Indeed, very little research specific to groups of trees and field copses exist, it being generally accepted that the benefits of these areas will be akin to that of a dense hedgerow and woodland. Copses are often integrated into hedgerow length providing a continuity of habitats. When mid-field they are important stepping stones for mammals, birds and pollinators to navigate across the field and provide shelter and habitat for wildlife.

These areas can provide shelter, shade, habitat and food for wildlife. They can also reduce wind-borne soil erosion and help reduce both the amount and rate of runoff into watercourses, thus contributing to flood prevention measures in susceptible areas (see Section 2.2.3).

Well placed wooded areas can also enhance wildlife habitats and collectively form networks of woodland that allow plants and animals to expand their existing habitat. A study by Usher *et al*. (1993) found that there was a relationship between species richness and woodland area, isolation and shape. Small wooded areas could be species rich in both plants and ground-dwelling arthropods. Another study sought to identify the influence of wood area, isolation and management of small mammals (Fitzgibbon, 1993). The study used grey squirrels (*Sciurus carolinensis*) as the indicator species and the focus was mainly on protecting newly planted trees from damage. However, the study found that small mammals were most likely to use large rather than small wooded areas and preferred small areas if they were close to larger woods and/or dense hedgerows. Therefore it further supports the value of habitat connectivity of the farm landscape.

Vanhinsbergh *et al.* (2002) examined the effects of woodland management and structure on the presence, abundance and species richness of birds in 65 farm woodlands of various sizes and shapes created under agri-environment schemes in southern and central England. Over 50 different bird species were recorded in the woodlands in winter and breeding seasons. The geographical location, area, age and conifer content of the woodland, nature of the surrounding farmland and adjoining field boundaries, and the use of herbicides affected the occurrence of individual species at the sites. Species richness was positively associated with woodland area and sites connected to hedgerows with trees had more species than sites connected to treeless hedgerows. Smaller woodlands tended to support a greater overall abundance of birds than larger woodlands. Overall bird abundance and species richness was higher along field boundaries such as hedgerows and walls or ditches with scattered trees than in the farm woodlands. The latter, however, supported a greater overall abundance and number of species of birds than surrounding cropland. The authors suggested that the creation of small farm woodlands provides habitat for several bird species that are currently declining and is a valuable tool for promoting bird diversity. To maximise bird diversity, the planting of small woodlands should coincide with the preservation of existing woodlands, trees, and hedgerows.

Due to the relatively small size of copses and tree groups there is a limit on the diversity of animals and plants that can be supported. For nesting birds and bats suitable tree cavities for nesting and roosting will be limited although on sites where conservation is actively managed opportunities can be enhanced by the appropriate siting of bat and bird boxes (Meddings *et al*., 2011).

2.2.7. Field margins

Title:	Field margins
Description:	These are a margin along a field boundary following the dimension limits below. They can be limited to features that are protected by GAEC 7, SMR 2 or SMR 3 depending on the Member State.
No. of MS activated:	17
Dimension limits:	Maximum and minimum width, varies with MS: 1 to 20m
Implementation rules:	In Germany and Hungary, they must be predominantly covered with grassy and herbaceous plants, be adjacent to arable land and have no agricultural production. In Sweden field margins must be uncultivated on arable land, should be maintained at least until the harvest of the main crop, and cannot be situated on or contiguous to areas with land laying fallow.

Field margins are an integral part of Europe's lowland agriculture. They are best described as the area of land between the crops and the field boundary and are considered to provide a vital habitat for plants, birds, mammals and insects. Many farmland species have declined over recent years due to agricultural intensification, so arable field margins provide vital havens for these species. A considerable amount of research has been undertaken to understand and evaluate the value field margins offer to biodiversity and other ecosystem services.

A study undertaken by Korpela *et al.* (2013) investigated how field margins rich in wild flowers (wild flower strips) could help mitigate biodiversity loss on the farm. The study focused on pollination services (using bumblebee abundance as a surrogate indicator) and species diversity using the total species richness of bumblebees, butterflies and moths was used as an indicator. Results from the study showed that flower-rich margins offered benefits for pollination as bumblebee abundance increased strongly in the first two years following establishment and stabilised from year three. Species diversity followed the same pattern, increasing significantly for first two years, then stabilised from year three. Broader conservation benefits, quantified by using habitat specialist butterflies as surrogate indicator, increased more slowly and the real benefits were not seen until year three. The benefits seen in all areas were independent of experimentally varied strip properties such as shape, wild flower composition, and placement, the same benefits being seen for open field parcel edges, between cropping fields, next to a forest and the middle of a field parcel.

The occurrence of pollinating insects in field margins with different vegetation was studied in field experiments conducted by Lagerlof *et al*. (2003) whereby the communities of pollinating insects in reclaimed field margins were compared with those of a margin with a naturally diverse flora and an adjacent pasture. The study found that sown leguminous plants added to the reclaimed margins were very attractive to most insect groups, especially pollinators. Butterflies were found in all vegetation types. It was concluded that flowering plants with field margins can give highly positive effects. Positive management and conservation of field margins and hedgerows will increase the abundance and diversity of pollinators (Stanley & Stout, 2013).

In a similar study that looked at the plant composition of field margins in terms of their invertebrate biodiversity, Meek *et al*., (2002) compared five types of field margin: cropped; sown with a tussocky grass mix; sown with a grass and wildflower mix; split margin (tussocky grass adjacent to hedge and grass and wildflower next to crop); and natural regeneration. The study found that each margin type had a distinct vegetation profile by their first mid-summer. The cropped margin was the least favoured in invertebrates with the other margin types containing double or more numbers of invertebrates over a similar area. Only one species, the carabid *Nebria brevicollis*, was trapped in higher numbers in the cropped treatment than on any sown margin, and then only in autumn. With respect to the other four margin types preferences depended on the invertebrate type. As would be expect the pollinators and flying insects preferred those margins containing flowers and Harvestmen in autumn rejected the natural regeneration margin in favour of any sown treatment. The study findings clearly demonstrated that sown field margins can rapidly produce substantial biodiversity benefits on arable land, with the resulting fauna influenced by the type of field margin created.

Many bird species also make good use of field margins for foraging. An observational study of bird foraging habitat selection on lowland mixed farmland, in relation to underlying invertebrate and vegetation characteristics was undertaken by Douglas *et al.* (2009). The study used breeding yellowhammers (*Emberiza citronella*) as the indicator species. The study identified a clear seasonal shift in the relative use of field margins and cereal crops. Margins were used less than crops in late summer despite high invertebrate abundance relative to cereals. Vegetation height was much higher in late summer suggesting that the lack of use by the birds at this time was related to height reducing food accessibility. When the margins were cut the use of the cut patches by the birds increased. The authors concluded that the provision of invertebrate rich field margins is important for farmland birds but their value will be reduced if they are not cut.

A review by Vickery *et al*. (2009) considered how field margins can be best managed to provide a rich source of food for farmland birds. The authors made a number of conclusions. Grassy strips tend to be limited in the bird food resources they offer but potentially supply grass seeds and, depending on the complexity of the sward structure, a range of arthropods. If strips are selectively managed and perennial forbs are added to a grass mixture this will provide a more diverse plant and invertebrate food resources for birds. The availability of seeds and invertebrates on uncropped margins is strongly influenced by management, particularly cutting, cultivation and herbicide use. Cropped margins with reduced chemical inputs and wild bird cover crops can provide relatively high food resources compared with a conventionally managed crop. However, resources are only present until harvest, their plant communities are relatively poor and arthropod abundance is usually lower than in uncropped margins. The best winter food supplies for birds will be provided by options that create seed-rich habitats in winter. The best summer food supplies will be provided by options that create a structurally and floristically diverse sward. The least valuable margin in terms of food resources is a grass-only strip. On an area-for-area basis, field margins will potentially produce food resources for birds more cost effectively than whole farm practices such as organic farming, though the value of margins will depend on their management and the diversity of margin types at a farm scale. Because no single margin type can provide the optimum year-round food supply, different types of margins and indeed different types of habitats, such as hedgerows, should be incorporated at the farm level, but appropriate management is needed to deliver their benefits.

Some researchers have investigated the value of field margins for enhancing beneficial insects and so improve natural pest management of crops. For example, a population study investigated if the benefits of field margins established for conservation of northern bobwhite quail (*Colinus virginianus*) extended to the enhancement of biological pest control in adjacent fields (Olson & Wäckers 2007). The densities of a selection of insect species and the predation and parasitism rates of insect pest species were measured in first- and second-year field margins established for bobwhite quail as well as in an adjacent cotton crop. The study demonstrated that field margins designed to specifically benefit one select species may be unsuitable for providing other ecological services. By making small adjustments in the vegetative composition of these field margins to ensure a more diverse structure, such as adding early season nectar-producing plants, it may be feasible to combine biodiversity and pest-control benefits and thereby optimise the overall ecological services to be gained. The findings of this study are similar to those of another conducted by Smith *et al*. (2008) that the greatest biodiversity benefits of field margins were seen if the margin is managed to target certain species groups, such as farmland birds and pollinators. The authors also considered what affect this management approach might have on soil fauna. They found that soil biodiversity was greater in the field margin than in the crop. Within the margins, management had a significant effect on soil macrofauna. Scarified plots had lower populations and less diversity of Isopods. The species composition of scarified plots was similar to crop plots.

Management of field margins helps define the benefits these areas have for biodiversity. Several studies reviewed herein considered the interactions between the field margin and broader agricultural activities and functions. Marshall and Moonen (2002) found that agricultural functions such as the application of fertilisers and pesticides had strong effects on the field margin flora and the broader biodiversity of the margin may influence the other species on the farm especially farmland birds. However, the authors found that the benefits were not all positive. For example, strong populations of some plants may spread into crops becoming field weeds. In addition, margins are also attractive to a variety of insects not all of which are beneficial and this may have implications for the pest management activities.

An early study undertaken by De Snoo (1999) sought to identify the biodiversity benefits of reducing pesticide drift on field margins and found that the presence and abundance of plants associated with arable farming increased substantially in the unsprayed edges, as did the flora value of the vegetation. The impact on epigeic soil invertebrates was relatively minor. However, there was a pronounced effect on phytophage insects. The number of visits to the unsprayed edges by insectivorous birds also increased.

Musters *et al.* (2009) investigated the benefits of taking field margins out of intensive cultivation. The study found that newly established grass margins are less species-rich than field boundaries with a long history, justifying the expectation that field margins, if properly managed and given time and appropriate seed sources, could develop into relatively species-rich vegetation. The study also found that plant species richness of the field margins increased in the years following establishment over a period of four years. Over the four year period shifts in species composition were recorded indicating a decrease in soil nitrogen. The most striking result was the marked increase in the plant species richness of the adjacent ditch banks in the five years following creation of the margins.

2.2.8. Ponds

Title:	Ponds
Description:	These are ponds that meet the dimension limits below. Member States may decide that a strip with riparian vegetation along the water with a width of up to 10 meters is included in the size of the pond. Member States may also establish criteria to ensure that ponds are of natural value, taking into account the role that natural ponds play for the conservation of habitats and species. They can be limited to features that are protected by GAEC 7, SMR 2 or SMR 3 depending on the Member State.
No. of MS activated:	12
Dimension limits:	Maximum and minimum area specified, varies with MS: 0.01 to 0.5ha
Implementation rules:	Reservoirs made of concrete or plastic shall not be considered EFA.

There is no globally recognised definition of precisely what constitutes a pond, although in the UK, for example, ponds are often defined as a permanent or seasonal waterbodies between 1 m^2 and 2 ha in surface area (Freshwater Habitats Trust, n.d.). As a result the term encompasses waterbodies with a wide range of surface areas, depths and origins (natural and manmade) (European Pond Conservation Network, 2008). What is not in doubt however, is that there are a very large number of such bodies across Europe, for example the UK has 400,000 (0.0025-2 ha), France 1 million (<0.5 ha) and Denmark just under 120,000 (0.01- 5 ha) such waterbodies (European Pond Conservation Network, 2008). Consequently, they account for a considerable percentage of the available standing waters, e.g. 97 % of discrete standing waterbodies in the

UK, and therefore have significant environmental potential, despite significant loss of this habitat in some countries over the past century, with 50-90 % not being unusual (European Pond Conservation Network, 2008).

In biodiversity terms, ponds are an extremely important habitat or group of habitats, having been shown to support both a greater number of species and in many cases rare species, including amphibians, macroinvertebrates, macrophytes, etc., than many other aquatic habitats, such as rivers and lakes (Biggs *et al.*, 2005; Nicolet *et al.*, 2007; Biggs, 2007; Davies *et al.*, 2008; Céréghino et *al.*, 2008). Natural pond systems are characterised by the wide range of habitats they provide, including a variety of surface areas, deep open waters, shallow shorelines, open and shaded banks, submerged, floating and emergent vegetation, and so on, meaning that they are both individually and within a geographical area structurally and ecologically varied (Céréghino et *al.*, 2014; Davies *et al.*, 2008). Equally, ponds provide for a range of successional stages, with a life-cycle which naturally encompasses a gradual filling with sediment from the surrounding catchment, shallowing and eventually drying, albeit that the period over which this may occur will vary from site to site, and all stages in this process have their own biodiversity signatures, none of which are intrinsically more valuable than others, although some may be rarer (Biggs *et al.*, 2005). Even ponds which to the untrained eye possess little value may be of importance to biodiversity. Nowhere is this more evident than in the case of temporary ponds, which for a significant part of the year may dry up altogether, such that their importance is easily overlooked making them highly susceptible to damage and/or loss. Nevertheless, they are now recognised as being of considerable importance, particularly, although not exclusively, in Mediterranean regions (Nicolet *at el.*, 2004). The harsh environment they present may be a barrier to many species, and this often results in them possessing lower species richness than permanent waterbodies; however, it also leaves the door open for rare species which would otherwise be outcompeted in a permanently flooded situation (Céréghino *et al.*, 2008; Nicolet *et al.*, 2004). As a result, Mediterranean temporary ponds are a Natura 2000 habitat (Ruiz, 2008), and are included as a Priority Habitat for the EU under the auspices of the Habitats Directive (Oertli *et al.*, 2005).

In addition, and despite having been viewed as such by some past researchers, ponds are far from being isolated habitat 'islands' set in a sea of dry land (Biggs *et al.*, 1994, 2000). Indeed, they interact extensively with the aquatic and terrestrial environments which surround them (Céréghino *et al.*, 2014; Miracle *et al.*, 2010; Biggs *et al.*, 2000). The role of ponds and pond networks is discussed further in Section 2.3.

Ponds also have an important role to play in the delivery of a wide range of other ecosystem services (Céréghino *et al.*, 2014, 2008), including those related to water quality, flood management and climate change mitigation and adaptation. In particular, they can, if correctly managed, reduce the contamination of downstream waterbodies with non-point source pollutants, including some which are of great significance with respect to agriculture, such as sediments and nutrients (Miracle *et al.*, 2010; Céréghino *et al.*, 2014; Ockenden *et al.*, 2014). Some catchment models have suggested that small waterbodies could remove 50-60% of phosphorus and 14-20% of nitrogen, without any additional measures being added (IGER, 2002; Biggs, 2007; Braskerud, 2002a, 2002b), although they are probably best integrated with other measures, such as buffer strips (Ewald *et al.*, 2012; Natural England, 2010; IGER, 2002). In doing so they could have a significant impact on local water quality, although at the scale of very large catchments it may be impossible to provide sufficient ponds to have a significant water quality impact (Passy *et al.*, 2012). The key factors in determining a pond systems suitability for reducing non-point source pollution include vegetation type, water temperature (seasonably variable) and residence time, which is itself dependent on climate and catchment-pond ratio, although recommendations for this in the literature are very variable (IGER, 2002), with a series of ponds being likely to be more effective than a single waterbody (IGER, 2002).

In terms of climate change mitigation, ponds may (due to their vast number) sequester considerable amounts of carbon, with a 500 m^2 pond capable of sequestering 1000 kg-C yr^{-1} (Miracle *et al.*, 2010; Céréghino *et al.*, 2014). However, this benefit may be offset somewhat by emissions of, for example, CH_4, although there is evidence that this can be reduced by ensuring a high level of aquatic plant cover (Thiere *et al.*, 2011). As far as climate change adaptation is concerned, a sufficiently dense network of ponds may provide a means by which aquatic organisms, e.g. amphibians, might move to new habitats in response to changes in climate (Biggs, 2007). In terms of flood management, which climate change may cause to be an increasingly important issue in some parts of Europe, strategically located ponds may be utilised to attenuate run-off events, with significant implications for catchment flood risk (Biggs, 2007). For example, it has been estimated that (in England) the installation of 10,000 m^3 km^{-2} of pond storage would be able to absorb all the runoff resulting from typical heavy rainfall events within that area (Céréghino *et al.*, 2014 and Biggs, 2007).

Clearly not all of these ecosystem services are wholly compatible. For example, the importance of clean water for pond biodiversity is highlighted by a number of authors (e.g. Natural England, 2010) as something which may not always be compatible with the goal of using them to clean up non-point source pollution, although examples do exist of the two being done simultaneously, e.g. using sequences of ponds which become progressively cleaner (Biggs, 2007). Equally, some sources suggest that ponds used to reduce pollution may become nutrient rich, and potentially become a source of pollution in their own right, necessitating dredging of polluted sediments (IGER, 2002), something else which may not be compatible with the needs of biodiversity. Nevertheless, it is clear from the above examples that despite their limited individual size, farm ponds (like many others) have an important role to play in the delivery of a number of desirable environmental outcomes, if they are appropriately managed.

Although pond biodiversity is in part controlled by natural site specific factors beyond the scope of anthropogenic management, including climatic and biogeographic location, and elevation (Céréghino *et al.*, 2014), there is much which can be done to maximise environmental benefits. For example, it has been demonstrated that what is central to their conservation value is the varied nature of the habitats they provide (Davies *et al.*, 2008), and consequently, many management guidelines focus on the provision of as natural as possible structures (e.g. Pond Conservation, n.d.). Although hard and fast quantifiable rules for the creation/management of ponds are difficult to establish, a number of basic principles are evident from the published literature, often based on observed statistical relationships, many of which contradict the established wisdom of decades (Biggs *et al.*, 1994). It is worth noting at this point however, that patterns which hold true in lowland environments may or may not be consistent with those found in alpine locations. Hinden *et al.* (2005) for example found that although some relationships followed the same trend in both altitudinal belts, e.g. there was a positive relationship between pH and Odonata richness, others gained or lost importance with altitude, or indeed had a positive relationship with biodiversity measures at altitude and a negative relationship in lowland areas, e.g. conductivity, or vice versa. Nevertheless, a number of properties have been demonstrated to play a role in determining pond biodiversity, including:

- Hydroperiod
- Size, although there is evidence that this may have little importance for most species (Oertli *et al.*, 2002)
- Vegetated area, which may be a better indicator than size (Gee *et al.*, 1997)
- Water quality
- The level of connectivity between ponds and other ponds/aquatic habitats (Céréghino *et al.*, 2008)

The extent to which these apply will vary between species and groups of species (Oertli *et al.*, 2002). In the case of hydroperiod, for example, it used to be the established wisdom that ponds should not be allowed to dry up and that stable water depth should be maintained wherever possible. However, this ignored the now widely recognised value of temporary ponds, and the fact that the seasonal drawdown zone has been shown to be one of the richest a site may possess, with a number of species, particularly plants, evolved to take advantage of an environment that progressively dries out (Williams *et al.*, 1999). Consequently, this recommendation is no longer prevalent in management guidelines, being replaced by the need to maintain a natural hydroperiod (e.g. Biggs *et al.*, 2001). Similarly, pond management guidelines often suggested that ponds should be dredged to prevent them becoming chocked with vegetation and/or silt, when in discussed above all ponds are to some extent transitory bodies, with a natural life-cycle all parts of which are valuable, and which inevitably includes siltation and gradual shallowing and drying (Biggs et *al.*, 1994). Consequently, unless rates of siltation have become unusually high, it may be better to allow ponds to evolve, and instead focus on area-based management regimes (see below). The same goes to some extent for shading, which is often cited as being detrimental to pond biodiversity (Biggs *et al.*, 1994, 2005), since so long as this is kept to a reasonable level (Gee *et al.*, 1997) it can in fact be beneficial in increasing biodiversity - after all many natural ponds will have existed in afforested areas (Williams *et al.*, 1999). Macrophyte species richness has, for example, been shown to increase with the proportion of the margin shaded, up to a maximum of 22% for emergent plants and 30% for floating/submerged plants (Gee *et al.*, 1997). In addition, stocking of ponds with desirable species is often unnecessary (Ewald *et al.*, 2012) and potentially undesirable. Stocking with fish, for example, may negatively impact on numbers of Odonata due to predation (Gee *et al.*, 1997), if new ponds are sited within the vicinity of suitable natural repopulation sources, indeed new ponds have been shown to be colonised quickly and may contain a greater range of species, including rare species – perhaps favouring those more suited to a less established environment than those established for a greater period of time (Gee *et al.*, 1997; Williams *et al.*, 2008). Clearly then, it may be that the level of management required for any individual pond may not be as intensive as might once have been assumed, instead more holistic catchment-based management may be appropriate (as discussed in Section 2.3).

Many existing ponds in agricultural areas have been installed for reasons other than environmental management, for example to provide year-long irrigation water. Some of these may therefore have been constructed with artificial substrates (plastic or concrete), and such systems tend to have a significantly lower number of zooplankton species than more 'natural' ponds (Miracle *et al.*, 2010), with knock on implications for higher species, and may be structurally simplistic, providing limited habitat suitability for some species. For example, Ferreira and Baja (2013) found that artificial irrigation ponds could offer little scope for amphibian conservation, due to their dissimilarity with the natural temporary waterbodies of the region. More sympathetically designed manmade ponds need not be considered as being fundamentally different to natural ponds (Céréghino *et al.*, 2014; Sebastián-González *et al.*, 2010); indeed there is evidence that pond biodiversity is more strongly controlled by ecological processes which may affect any type of pond. In creating new ponds for biodiversity therefore, care should be taken to replicate in as far as practical natural pond shape and structure, so as to maximise the variety of environmental niches, and ensure suitable habitat for target species. Although it should be stressed that care is needed to ensure that pond creation doesn't destroy valuable pre-existing habitats (Biggs *et al.*, 1994).

Temporary ponds have particular pressures and maintenance needs reflecting their transitory nature (Biggs *et al.*, 2001; Dimitriou *et al.*, 2006, Nicolet *et al.*, 2007). As already noted, temporary ponds are especially vulnerable to damage or loss, by for example, overgrazing which damages the natural plant assemblage, either through livestock eating the vegetation, or through them excessively trampling the ground (Dimitriou *et al.*, 2006). Equally however, intensive agriculture often lowers local water tables, e.g. though deliberate drainage or abstraction of for irrigation, reducing the period for which the pond may be flooded, or the extent of that flooding, and often results in pond sites receiving additions of nutrients and/or pesticides (Dimitriou *et al.*, 2006). Although all management requires site specific emphasis, key to the management of temporary ponds is the maintenance of a natural hydroperiod which allows for winter flooding and summer drying (Dimitriou *et al.*, 2006). Consequently, interfering with pond morphology, for example by altering or deepening the bed should be avoided, particularly in the dry season as this may result in the loss of wild plant seeds and macroinvertebrates (Dimitriou *et al.*, 2006). Equally, it may be necessary to keep some livestock away from the pond area even when dry, so as to minimise the damage they may cause, although if invasive plant species are a problem grazing by appropriately chosen livestock may in fact be beneficial. Indeed, mechanical and/or chemical intervention may be necessary in some cases (Biggs *et al.*, 2001), although it should always be done with considerable care. Other amendments, such as topping up from neighbouring watercourses, which as well as amending the hydroperiod may also allow pollutants on to the site, should be avoided if possible, instead opting for a 'less is more' approach to management (Biggs *et al.*, 2001).

2.2.9. Ditches

Title:	Ditches
Description:	These are ditches, including open watercourses for the purpose of irrigation or drainage, that meet the dimension limits below. They can be limited to features that are protected by GAEC 7, SMR 2 or SMR 3 depending on the Member State.
No. of MS activated:	15
Dimension limits:	Maximum width specified, varies with MS: 2-12m
Implementation rules:	Channels with walls of concrete shall not be considered EFA.

Ditches are manmade or severely altered watercourses, often characterised by marked temporal fluctuations in water depth, sometimes including periods of complete drying (Herzon & Helenius, 2008); beyond that however, they can vary considerably in both their physical scale and other physical properties. Some open field drains for example, may be little more than 20cm wide and dry except during periods of precipitation and/or snow melt, whilst main drains may exceed 10m in width and constantly have at least some water content (Herzon & Helenius, 2008). They can also be structurally quite complex, consisting of an aquatic component which is often relatively shallow, an underlying substrate, a bare earth or vegetated bank and often some form of wider margin, although the size of these components varies considerably both spatially and in some case temporally (Herzon & Helenius, 2008). Nevertheless, despite their artificial characteristics, within intensively farmed landscapes, ditches can replace lost natural aquatic features, and may be one of the few remaining biodiversity resources (Blomqvist *et al.*, 2003), which in some cases at least can support considerable biodiversity, including species of conservation value (Clarke, 2014). This however, is easily threatened by pressures such as the use of herbicides and other pesticides too close to the top of the bank, damage by grazing livestock, nutrient enrichment through fertilizer applications in the local area, and falling water levels as a result of continued land drainage (Armitage *et al.*, 2002).

In terms of aquatic biodiversity, the biological communities associated with ditches can be expected to vary from those of other waterbodies as a result of their being linear features, with high edge ratios, and therefore subject to an intensive exchange of matter and biological organisms between themselves and the surrounding terrestrial environment (Herzon & Helenius, 2008). However, what is equally important is that ditches often have different characteristics to other waterbodies in the area, allowing for the development of different ecological communities (Armitage *et al.*, 2002). Consequently where comparisons with the biodiversity of other aquatic features exist they tend favourable, suggesting that ditches, despite often being manmade features make a valuable contribution to the overall biodiversity of agricultural landscapes (Armitage *et al.*, 2002). In Finland for example, ditches which take the form of canalised natural streams (i.e. generally wet), have nevertheless been found to support spawning grounds for Brown trout (*Salmo trutta*) (Herzon & Helenius, 2008). Whilst frogs and newts have been found to benefit from ditches which periodically dry out, since such systems tend to exclude the predatory fish which can take a heavy toll on juveniles, yet they are still of assistance in facilitating movement across the agricultural landscape (Herzon & Helenius, 2008). Ditches can also be useful habitats for threatened crayfish, particularly if they are associated with overhanging vegetation and there is clean water, although it has to be acknowledged that this is uncommon in many agricultural areas (Herzon & Helenius, 2008). As far as aquatic flora is concerned, ditches are characterised by regular management followed by recolonization and gradual change, leading to spatial and temporal variability in plant community composition and structure (Herzon & Helenius, 2008). Indeed, this is an important property of such environments, since the different stages of hydroseral succession support different communities of invertebrates, and therefore have value in their own right (Herzon & Helenius, 2008), and it is human intervention that ensures the continued presence of such a diversity of habitats.

In addition, ditch systems (which include the bank, etc.) support a considerable diversity of terrestrial flora and fauna. For mammals, such as mice, voles, water vole and otter for example, ditch areas provide cover from predators, corridors for movement and feeding habitat (Herzon & Helenius, 2008). Equally, farmland bird species richness has been shown to relate well to the heterogeneity of farmland habits, something to which ditches and their surrounds contribute significantly (Herzon & Helenius, 2008). They are particularly useful in terms of the provision of damp soil for probing feeders, permanent water for aquatic invertebrate foods, sparsely vegetated areas to allow access to soil invertebrates, rank emergent vegetation for nesting, and bush/tree groups for nesting and/or serving as singing posts (Herzon & Helenius, 2008). On a smaller scale ditch banks/margins support invertebrate communities, the structure of which is dependent on the vegetation present (e.g. the presence or absence of nectar producing plants and successional stage), as well as general site characteristics such as aspect, protection from wind and availability of shade (Herzon & Helenius, 2008). Such properties for example make ditches, hydrologically unsuitable for species such as dragonflies (Herzon & Helenius, 2008).

In terms of terrestrial flora, ditches support a greater diversity of plants than either cropped areas or sown field margins; although most species are relatively common and can also be found elsewhere on the farm (Herzon & Helenius, 2008). In addition, such environments generally favour species tolerant of high nutrient status and common herbicides, which can lead to a reduction in plant biodiversity in favour of those species capable of taking advantage of a nutrient rich environment, and thus outcompeting species better suited to low nutrient status environments, and thereby colonise new areas (Blomqvist *et al.*, 2003). As a result, some of the species present may be considered weeds (Herzon & Helenius, 2008). However, work carried out in the Netherlands has shown that species previously common in wetland areas, grasslands and dry hayfields, but which now have high conservation value, may now only be found in ditch banks (Herzon & Helenius, 2008). In general, a greater diversity of plant species can be found in ditch banks associated with grasslands than croplands (Clarke, 2014), although there are some which are less tolerant of grazing and which may therefore be more commonly associated with cropped areas (Herzon & Helenius, 2008).

As many species (e.g. invertebrates) have limited scope for dispersal, being located close to other ditches and aquatic habitats is important for controlling a waterbodies species composition, as are its water quality and dissolved oxygen status (Herzon & Helenius, 2008). For example, some studies have indicated that the lack of suitably local recolonization sources, can be used to explain the fact that the management of ditch banks to enhance plant species diversity, a popular element in the agri-environment schemes of some countries, has in some cases failed to deliver the expected biodiversity benefits (van Dijk *et al.*, 2014; Geertsema & Sprangers, 2002). However, many ditches are connected to larger (often natural) waterbodies, and as such may themselves serve as important refuges from the impacts associated with high flow and pollution events, and pathways for recolonization dispersal, allowing the wider aquatic environment to recover from those disturbances (Clarke, 2014; van Dijk *et al.*, 2014).

Ditches also play a role in a number of other ecosystem services including water regulation and quality management, and crop pollination and biological forms of pest control through the species communities they support (see above - Herzon & Helenius, 2008). As far as water is concerned, they facilitate the accelerated transfer of water away from agricultural land, and in so doing may inadvertently act as conduits for the movement of pollutants such as nutrients and pesticides, into receiving waters (Herzon & Helenius, 2008). Equally however, they can lead to the retention of flow, and consequently aid in the removal of such pollutants through mechanisms such as re-infiltration in marginal and/or aquatic vegetation and sediment, and enhanced solar degradation (Herzon & Helenius, 2008). Key however, to the water quality characteristics of agricultural ditches, are the mechanisms associated with the movement of the fine sediments (which tend to be more prevalent in ditches than stream environments) to which phosphorus tends to be adsorbed, either because it was carried into the drainage system on that sediment, or because of subsequent adsorption to ditch sediments (Shore *et al.*, 2015). As such, the potential for phosphorus to be transported to receiving waters is a function of the potential for sediment movement, which is in turn controlled by the physical characteristics of the ditch (Shore *et al.*, 2015). Shore *et al.* (2015) in their study of farmland ditches in the Republic of Ireland for example, classified waterbodies based on a combination of their slope (gradient) and catchment area, with those ditches with steeper gradients (high rates of flow) and draining larger areas (having greater levels discharge) being prone to greater sediment and phosphorus transport.

This process can however, be amended by a number of within ditch processes, with implications for the way in which ditches are managed so as to maximise ecosystem benefits and minimise burdens. The development of ditch soils, where a soil is defined as being capable of supporting rooted plants or form horizons as opposed to poorly structured loose sediments, has been identified as a potential mechanism for the removal of aquatic pollutants (Needelman *et al.*, 2007). This includes, but is not limited to, phosphorus, due to its tendency to be sediment bound; however this nutrient can move between particulate and soluble forms, depending on the conditions prevalent at a site (Needelman *et al.*, 2007). For example, periodic oxidation of ditch soils and sediments through drying out, may result in the precipitation of iron minerals with a high phosphorus sorption capacity, whereas processes which increase water retention, may inadvertently lead to a decrease in the phosphorus sorption capacity of bed sediments, through the reduction of iron from its ferric (Fe^{3+}) to its more soluble ferrous (Fe^{2+}) form (Needelman *et al.*, 2007). In addition, the presence of sulphates, which in agricultural systems may come from sources such as poultry manure, may reduce phosphorus retention, since in highly anaerobic ditch soils, they may be microbiologically reduced to produce sulphides which then tend to preferentially bind to iron, resulting in the release of previously bound phosphorus into solution and reducing subsequent phosphorus adsorption capacity (Needelman *et al.*, 2007). However, this may be offset by a reduction in the solubility of ferrous minerals leading to their retention when they would otherwise be lost (Needelman *et al.*, 2007). In contrast, low concentrations of sulphides may however, be beneficial in terms of binding heavy metals, and preventing their downstream movement (Needelman *et al.*, 2007), if preventing their movement into other habitats is seen as beneficial, even if this results in their build up within ditches themselves.

It should be remembered that most ditches have been installed for the purposes of improving drainage, and are therefore managed to maintain that function, including keeping water levels relatively low and the regular clearance of vegetation, something which can be to the detriment to biodiversity, lowering a ditch's conservation value (Twisk *et al.*, 2003; Clarke, 2014). Nevertheless, some approaches to management are liable to be more or less damaging than others. Twisk *et al.* (2003) for example, found that as well as a reduced frequency of ditch management being associated with higher aquatic plant diversity, the removal of vegetation using a mowing drum had a more damaging effect on emergent plants than other forms of mechanical removal, whilst dredging using a suction pipe as opposed to a pull-shovel also led to reduced diversity. This latter case was contrary to expectations, since suction pipes generally remove less vegetation with the sediment and might therefore be expected to be less damaging; however, this is thought to be due to the increased damage associated with the pull-shovel actually favouring pioneer species, which can then take advantage of cleared sites (Twisk *et al.* 2003). Equally, clearing too late in the year was found to be more damaging than doing it in the summer, possibly due to the fact that early clearance allowed for a degree of vegetative recovery prior to the winter period (Twisk *et al.*, 2003). However, in general, the quality of ditch environments is a function of the following (Clarke, 2014; Herzon & Helenius, 2008):

- Geographical context: for example being in former wetland locations where there is an underlying biodiversity pool.
- Physical structure: including the diversity of micro-habitats present, and the cross-sectional form.
- Composition and structure of vegetation: successional stages, submerged/floating/emergent plants.
- Water quality: good quality water improves ecological value.
- Water availability: hydroperiod, depth, flow rate.

These characteristics are of course themselves a function of ditch type and size, as well as the surrounding agricultural and natural environment (Herzon & Helenius, 2008). It is clear from this list however, that there are a number of ways in which these can be managed to the benefit of ditch biodiversity, with sympathetic management aiming to produce a range of water depths, bank profiles, and so on (Clarke, 2014). For biodiversity value to be maximised, good quality management is required, for example by halting the hydroseral succession at a point where there is sufficient open water to allow for a varied macroinvertebrate community structure (Armitage *et al.*, 2002). In peat areas, low ditch water levels favour common plant species, so it has been suggested by some authors, that raising water levels may be an effective means of improving plant biodiversity status (Twisk *et al.*, 2003). Similarly, ditch banks may be managed in such a way as to benefit biodiversity by ensuring that cutting is timed so as to maximise the opportunity for seed setting, which in turn produces a greater available seed resource for dispersal, aiding in ditch bank restoration (Leng *et al.*, 2011).

In terms of actions which may prevent the movement of phosphorus from ditch networks into receiving natural or semi-natural waters, there are a number of management actions which may retard the movement of fine sediments, and therefore the pollutants attached to them (Shore *et al.*, 2015). In ditches with relatively shallow gradients for example, there is a significant opportunity for the retention of sediments, such that their periodic removal may be advisable (Shore *et al.*, 2015; Clarke, 2014). It is a concern with using ditches as a mechanism for sediment/phosphorus removal that, much as in the case of constructed wetlands, nutrient removal may reduce over time (Moore *et al.*, 2010), and the accumulated material may become a source of contamination under high flow conditions. Some ditch sediments have been shown to accumulate concentrations of mobile phosphorus fractions similar to those found in eutrophic lakes, and these may subsequently prove a threat to aquatic biodiversity both within a ditch and its receiving waters (Hill & Robinson, 2012), particularly where material is rapidly mobilised by flood waters. Sediment removal minimises the likelihood of this happening, although removing fine sediments from the channel also means that they are no longer available for adsorbing phosphorus from the water column and as discussed above, there could be negative consequences for biodiversity (Shore *et al.*, 2015; Moore *et al.*, 2010). Such negative impacts could however, be reduced by ensuring that dredging is restricted to the summer, when there is less phosphorus in the water column and fish have finished spawning and incubating eggs (Shore *et al.*, 2015). Ditches in which there is a moderate potential for sediment retention should be managed so as to minimise mobilisation through, for example, the encouragement of vegetative growth (Needelman *et al.*, 2007). It has to be acknowledged however that such actions may not be entirely compatible with drainage (the primary role of most ditches), and steps may need to be taken to minimise any negative impacts in this respect, including the control of woody vegetation (Shore *et al.*, 2015). It may also be possible to amend channel design so as to either reduce flow rates or the likelihood of erosion through overland flow (Shore *et al.*, 2015; Smith, 2009). Where water tables are deep for example, ditch deepening/widening may reduce the velocity of flow and therefore the ability to mobilise sediments, whilst where water tables are high the same actions may lower the water table and reduce overland flow, although it could also increase flow rates (Shore *et al.*, 2015; Smith, 2009). In ditches where there is limited scope for sediment retention however, it may be more appropriate to manage the catchment in such a way as to minimise nutrient entry into the ditch in the first place (Shore *et al.*, 2015), although there is clearly an argument for doing this anyway.

For nitrogen, as well as some of the above actions potentially having an impact, it may be possible to use low-grade weirs or other mechanisms which increase water retention, to provide the conditions suitable for denitrification to occur (Kröger *et al.*, 2014). Such systems increase hydraulic (and therefore chemical) residence times, whilst increasing water holding capacity, such that the anaerobic conditions required for denitrification may be more prevalent (Kröger *et al.*, 2014). However, there is some evidence that the success of such systems decreases with time such that intermittent clearing may be required (Kröger *et al.*, 2014); and as discussed above there may be negative implications for phosphorus retention. Excessive nutrients, including nitrogen, may also be removed through judicious weed cutting, although as in the case of dredging, the material removed must be disposed of in such a way as the nutrient content is not in danger of subsequently re-entering the system. In all cases however, unless the supply of nutrients to ditches is reduced, then water quality is unlikely to be improved in the long-term, and species favoured by high nutrient levels will remain. Indeed, some authors have suggested that once such species have colonised an area, they may persist for some considerable time even if nutrient levels reduce to a point at which their initial colonisation would have been unlikely (Blomqvist *et al.*, 2003; Needelman *et al.*, 2007).

2.2.10. Traditional stone walls

Title:	Traditional stone walls
Description:	These are stone walls that meet the dimension limits below. They can be limited to features that are protected by GAEC 7, SMR 2 or SMR 3 depending on the Member State.
No. of MS activated:	7
Dimension limits:	Maximum and minimum width and height specified, varies with MS: Width: 0.25 to 4m, Height: 0.3 to 5m. In Germany there is a minimum length of 5m.
Implementation rules:	None

Dry stone walls are often dominant field boundaries where rocky outcrops are common, the soil is thin and the climate is too harsh for hedgerows, but some lowland, more fertile regions also have walls, often with an earth bank at the bottom. In some parts of Europe, stone wall field boundaries are common features of agricultural landscapes, yet unlike other linear features (e.g. hedgerows) and despite their prominence there has been very little published peer-reviewed literature relating their impact on biodiversity and ecosystem services.

A review by Collier (2013) described boundary stone walls as novel ecosystems. The review provides good summaries of various studies describing the flora found on old urban walls and old stone buildings and theorises, in the absence of hard data, that field boundary walls must be equally rich. Another review undertaken by Frances (2011) considers the development of urban wall ecology, highlighting the key characteristics of walls that have been found to influence their ability to support species, with a focus on higher plants. The author concludes that such walls can be surprisingly diverse in the ecology they support.

Holland (1972) investigated the vascular plant diversity of stone walls in rural areas of western Ireland. A total of 133 different species were identified in a survey area of approximately 3300 km^2 in which 165 ten metre lengths of wall were examined. A mean of 14.2 plant species per 10m length was determined. The study found the diversity was richest facing north-east and away from water. Walls in exposed coastal area had the least species richness. The research suggested that plant species richness depends on the aspect and degree of exposure (Baur *et al*., 1995).

Often the first plant species to colonise stone walls are lichens. Once established lichens are likely to persist on the wall almost permanently providing the environment is to their liking. Lichens are pollution sensitive and so prefer mild climates and clean air. Lichens provide a food source for a variety of insects and molluscs. A study undertaken by Baur *et al.* (1995) showed a strong correlation between the presence of lichens (i.e. *Aspicilia calcarea*) and the local populations density of a tree snail (*Balea perversa*). Similarly, a study by Baur and Baur (2006) examined habitat preferences of the snail (*Chondrina clienta*) which also showed the preference of stones and walls compared with limestone pavements and the authors proposed the reason for this as the absence of lichens on the limestone.

Survey papers, accumulated by the Dry Stone Walling Association of Great Britain (DSWA, 2007), show that traditional stone walls due provide varied and valuable habitat for a wide range of fauna and flora, in part due to the microclimate that exists close to the wall surface. In harsh climates where trees and hedgerows are scarce, stone walls can act as perches for birds, plucking stations for birds-of-prey and holes and gaps in the wall are attractive roosting places for bats (DSWA, 2007).

In terms of management dry stone walls are best for biodiversity if left relatively undisturbed. However, as walls decay and become totally derelict they lose both their economic and their ecological value. A derelict wall is not stock-proof and does not provide shade or shelter. In addition, derelict walls tend to be overrun by bramble and bracken which will out-compete other plant species. As a consequence, insects, birds and mammal populations which feed on the broad range of fauna in a semi-derelict wall are also driven away.

However, over restored walls will not reach their maximum ecological value until they have had time to weather and mature. Therefore, once established dry stone walls require little in terms of management other than the occasional spot repair (EC, 2012). Over restored walls may lose their biodiversity value until they have been through a process of maturity.

2.2.11. Other landscape features

Title:	Other landscape features under GAEC or SMR
Description:	These are other landscape features that may be protected by GAEC 7, SMR 2 and SMR 3 (see below for details).
No. of MS activated:	10
Dimension limits:	None
Implementation rules:	None

This EFA element covers other landscape features, that are covered by GAEC 7, SMR 2 and SMR 3, but which do not necessarily fall into the features above. Table 2.1 shows the other landscape features (GAEC and SMR) that have been selected by Member States who have activated this EFA element.

Table 2.1: Other landscape features selected by Member States

Member State	Other landscape features description
Denmark	Protected ancient monuments (GAEC7)
Finland	Protected trees, natural monuments (GAEC7)
Germany	Wetlands, ponds, biotopes (GAEC7)
Hungary	Protected ancient monuments (cumanian mounds - shadoofs) (GAEC7)
Ireland	Protected archaeological sites (GAEC7)
Italy	Activated, but no description on other landscape features
Latvia	Protected stones, trees and tree alleys (GAEC7)
Malta	Vegetated slopes - Garrigue (GAEC7, SMR3)
Portugal	Landscape features linked to rice cultivation (GAEC7, SMR2, SMR3)
UK Northern Ireland	Protected archaeological sites (GAEC7)

The evidence for the impact of ponds, wetlands, trees and tree alleys have been collated in previous sections (Sections 2.2.3-9). Biotopes, listed for Germany in Table 2.1, have been interpreted generically as habitats (i.e. based on the CORINE biotopes (EEA, 2014) and the EUNIS habitat classification (EEA, 2015a)), and therefore are not being considered a specific feature or EFA element for review within this project. Landscape features linked to rice cultivation in Portugal relate to linear elements associated with rice cultivation plots, including drainage and irrigation ditches and bunds (as translated from Portuguese in the data supplied by JRC). The evidence for these has been collated in a previous section (Section 2.2.9).

Consequently, there are only two main features that are not covered in the other sections: ancient monuments and archaeological sites (in a number of Member States); and Garrigue (in Malta). These are reviewed below.

Ancient monuments and archaeological sites

Ancient monuments and archaeological sites can cover a broad range of features from the 'find spot' of a single object to the upstanding remains of internationally important monuments. They can be both above and below ground and can include prehistoric standing stones, burial mounds, earthworks, through to the many types of medieval site such as castles, monasteries, abandoned farmsteads and villages. Many sites can be quite fragile and can be damaged by any significant ground disturbance, because this displaces vulnerable features (such as ditches and walls) and finds (such as pottery and bone), and once lost these sites are irreplaceable.

The inclusion of ancient monuments and archaeological sites as EFA elements has a clear impact with respect cultural ecosystem services, for example cultural heritage, educational, aesthetic or spiritual value (Acreman *et al*., 2011; Hernández-Morcillo *et al*., 2013; Tengberg *et al*., 2012). There may also be other benefits associated with management activities or restrictions to protect archaeological sites. For example, archaeological sites under arable land may be subject to reduced-depth or non-inversion cultivation. As well as protecting the site, this may also reduce energy/fuel used for cultivation and thus reduce greenhouse gas emissions (CALU, 2007). For sites under grass, livestock management to reduce poaching, compaction and soil erosion will protect archaeological sites and have benefits for soil protection, greenhouse gas emissions and nitrate leaching (Machefert *et al*., 2002).

Garrigue in Malta

Garrigue (sometimes spelt garigue) is typical of karstic rocky areas of limestone (Schembri, 1993) populated by resilient low lying shrubs and aromatic plants which grow in the shallow soil pockets. Agricultural land is commonly surrounded by this type of habitat and garrigue outcrops often appear within cultivated areas.

Figure 2.1a: Garrigue with Euphorbia
(Source: MEPA, 2015)

Figure 2.1b: Garrigue in Malta
(Source: Portelli, 2010)

There are many sub-types of garrigue, including the Mediterranean Thyme (*Thymus capitatus*), the Mediterranean Heath (*Erica mutliflora*), the Maltese Spurge (*Euphorbia melitensis*), the Maltese Fleabane (*Chiliadenus bocconei*) and many others. Maritime garigue, present on gently sloping rocky areas, is characterised by the Golden Samphire (*Inula crithmoides*), the Sea Samphire (*Crithmum maritimum*) and the Maltese Sea Lavender (*Limonium melitensis*) (MEPA, 2015). Figure 2.1 shows examples of Garrigue. There are also structural differences between high and low garrigues. Low garrigues are characterised by low-growing bushes (less than 0.5m high), while large bushes of up to 1m in height dominate in high garrigues. *Anthyllis* garrigue (dominated by the Shrubby Kidney Vetch - *Anthyllis hermanniae*) can occur as both low and high varieties, while an important type of high garrigue is that dominated by the Tree spurge (*Euphorbia dendroides*), which normally occurs on steep rocky ground (MEPA, 2015). It is believed that these shrubs produce aromatic oils and other chemicals which leach into the soil and prevent the growth of other plants in the vicinity, especially annuals. This results in characteristic open spaces of garigue areas (Portelli, 2010).

Many endemic and rare species thrive in garrigue habitat, such as the Maltese Spider Orchid (*Ophrys melitensis*) and the Maltese Shrew (*Crocidura sicula calypso*) (MEPA, 2015), and it provides food and habitat for other species such as bats (Baron, 2007); snails (Filfla Door Snail - *Lampedusa imitatrix*; Maltese Door

Snail - *Lampedusa melitensis*; and the Għar Lapsi Top Snail - *Trochoidea gharlapsi*) (NBSAP, 2012); and a multitude of insect species and various indigenous wall lizards, the most common one being the Maltese Wall Lizard (*Podarcis filfolensis maltensis*). The flowers of garigue shrubs are an important source of nectar which is collected by bees to form honey. Malta has been well known for its thyme honey and it is believed that the name Melita is derived from the Greek word for honey (Portelli, 2010). Much of the garigue has disappeared, with significant areas built upon, covered with soil and converted into fields, or planted with trees. There are now fewer thyme bushes for bees to visit with a consequential loss in the production of thyme honey (Portelli, 2010). It can also be easily damaged through agricultural practices such as land reclamation, overgrazing and the use of PPPs.

Clearly garrigue has an important role for biodiversity conservation, as illustrated by the species it is known to support. The benefit of garrigue for ecosystem services (beyond biodiversity) is less clear, with little if any literature of the topic, other than the inherent link between biodiversity conservation and cultural ecosystem services such as landscape, aesthetic and tourism benefits, and possibly pollination with respect to the population of bees and production honey mentioned above.

2.2.12. Buffer strips

Title:	Buffer strips
Description:	These are strips of land and vegetation between production areas and the feature to be buffered, such as a watercourse. They include the buffer strips along watercourses required under GAEC 1, SMR 1 or SMR 10 as well as other buffer strips, and meet the dimension limits below. There shall be no agricultural production on buffer strips. By way of derogation from the no production requirement, Member States may allow grazing or cutting, provided that the buffer strip remains distinguishable from adjacent agricultural land.
No. of MS activated:	20
Dimension limits:	Maximum and minimum widths are specified, which vary with MS, and in some instances vary with whether the buffer strip is implemented under GAEC1, SMR1 or SMR10 or not (other buffer strips).
Implementation rules:	In some instances the following may be specified: whether a strip of riparian vegetation is required; whether grazing, cutting or cultivation is allowed; whether non-harvestable wild-bird seed mixes and nectar sources can be sown; and whether the use of pesticides and fertilisers is allowed.

In agricultural terms, buffer strips are zones of uncropped vegetation at the boundary between farmland and surface waters (Barling & Moore, 1994; Blackwell *et al.*, 1999), and such areas have been associated with the delivery of a number of environmental benefits, including bank stabilisation, habitat provision and the improvement of water quality (Barling & Moore, 1994; Blackwell *et al.*, 1999). Nevertheless, it is in the latter case, a role in which they have been deliberately employed since at least the 1960s (Barling & Moore, 1994), that most emphasis has been placed, with other benefits generally being viewed as an added bonus (Barling & Moore, 1994). In this context, buffer strips have been attributed with benefits in relation to the protection of waterbodies from a number of pollutants, both dissolved and particulate (i.e. sediment and sediment bound).

As far as sediment transport is concerned, this is in part reduced as a result of the extensive root systems which may be associated with buffer strips, since these hold soils together and increase infiltration, i.e. they reduce overland flow (Lovell & Sullivan, 2006), thereby reducing erosion. However, the key process is that associated with the trapping of sediments being carried in overland flow, so as to prevent their subsequent entry into a waterbody (Barling & Moore, 1994; Uusi-Kämppä & Jauhiainen, 2010). This occurs most efficiently when flow rates are sufficiently low as to ensure that the vegetation in the buffer strip doesn't become submerged, and where it enters the buffer strip approximately uniformly across its length - focused flow will often lead to buffers being breached, and effectively ignored (Barling & Moore, 1994). However, buffer strip performance declines significantly as sediment particle size reduces, such that there is an inverse relationship between the length of a grass filter required and particle size (Barling & Moore, 1994). Barling & Moore (1994), for example, identified the optimal trapping distances for sands, silts and clays to be 3m, 15m and 122m respectively (for an overland flow rate of 1.02 litres sec^{-1} m^{-1}). This has potentially serious implications for the trapping of those pollutants most often associated with fine sediment particles, including most notably phosphorus, which tends to be preferentially attached to fine particles (i.e. clays), since buffer strips may be better traps (in percentage terms) of sediment in general than sediment bound nutrients (Barling & Moore, 1994; Kay *et al.*, 2009). It is also unfortunate that the period of maximum delivery of sediment, and therefore sediment associated pollutants, corresponds to the period of minimum efficacy of buffer strip performance (winter), when there is reduced vegetation growth, reduced infiltration and high water tables (Kay *et al.*, 2009).

Buffer strips (both grassed and vegetated) can also be effective in removing dissolved nutrients, with some studies suggesting that removal rates for nitrogen, phosphorus and potassium, can all be over 90% within 3-4 m of a buffer strip (Barling & Moore, 1994). In general however, it is in terms of nitrogen that most work has been done, and the effectiveness of buffers strips in dealing with this nutrient has been found to be extremely variable, with both considerable benefits and dis-benefits being reported in the literature (Kay *et al.*, 2009; Leeds-Harrison *et al.*, 1999; Lovell & Sullivan, 2006). The reasons for this would appear to be that performance is highly dependent on site specific properties such as those related to soil, climate, vegetation cover, physical dimensions, sediment properties and local land management practices (Kay *et al.*, 2009; Leeds-Harrison *et al.*, 1999; Blackwell *et al.*, 1999). Work carried out in the UK for example, revealed that in the studied catchments, buffer strips did not substantially reduce watercourse NO_3-N levels, something which was thought to be as a result of the presence of bypass flow paths (e.g. field drains) rendering the buffers ineffective (Leeds-Harrison *et al.*, 1999; Blackwell *et al.*, 1999; Kay *et al.*, 2009). Consequently, it is clear that for such buffers to be effective, the hydrology of the strip must be conducive to denitrification and/or plant uptake (the two main processes by which nitrogen is removed - Leeds-Harrison *et al.*, 1999); something which requires long percolation times so as to lead to saturation, and therefore the anaerobic conditions in which denitrification can take place; a suitable energy source for anaerobic bacteria (the presence of plants may achieve this); and long retention times within the buffer so as to allow time for denitrification to occur (Leeds-Harrison *et al.*, 1999). It may also be beneficial if there is an impermeable layer close to the surface, so as to ensure that subsurface flow is within reach of the root system (Hill, 1996), although some authors have found that within the riparian buffer strip zone, evapotranspiration (when sufficiently high) can be effective in inducing draw up of water from depth, allowing a greater level of flow interception, and therefore nitrogen removal, than might otherwise be possible (Balestrini *et al.*, 2011). Clearly however, these properties are unlikely to occur everywhere, so the merits of each potential buffer strip location must be considered on a site by site basis (Leeds-Harrison *et al.*, 1999), but there is sufficient evidence to suggest that under suitable conditions, such as in flat catchments where the rate of water flow between the field and watercourse is relatively slow (Balestrini *et al.*, 2011), nitrogen removal can be significant, at least on a local scale, although catchment scale effectiveness is much less clear (Kay *et al.*, 2009). Given that ideal conditions cannot be guaranteed to exist at all times however, it is clear that buffer strips for pollutant control should only be considered as a secondary measure, after the minimisation of source generation (Barling & Moore, 1994).

Other pollutants for which buffer strip may prove beneficial include pesticides and microbiological contaminants such as faecal coliforms (e.g. *E.coli*). In the latter case, buffers have been shown to be an effective barrier to the contamination of surface waters adjacent to grazed land and/or that receiving applications manure or slurry, although effectiveness reduces significantly as overland flow increases (Tate *et al.*, 2006). In relation to pesticides, there are a number of studies suggesting that buffer strips can have a significant impact on the fate of such chemicals in the environment, principally by immobilising them for long enough for degradation to occur, although the empirical evidence as to their precise effectiveness is limited (Kay *et al.*, 2009). Nevertheless, that which is available suggests that strongly sorbed chemicals (i.e. those attached to sediment particles) may be immobilised within the first few metres of a buffer (such that additional width is of no particular benefit), whilst more hydrophilic substances display a linear relationship between buffer width and chemical immobilisation, such that buffer width becomes much more important and the effectiveness of buffer strips in their removal more limited (Lovell & Sullivan, 2006; Kay *et al.*, 2009).

Beyond their potential water quality benefits, the main environmental property attributed to buffer strips relates to their ability to improve biodiversity within the agricultural landscape. It is clear that the amount of uncropped land present in intensively farmed areas has declined significantly in recent decades, and it has been suggested that this has been a factor in the observed declines in farmland biodiversity (Josefsson *et al.*, 2013; Cole *et al.*, 2012). Consequently, buffer strips have been put forward as part of the solution to this problem, on the basis that they result in an increase in the availability of uncropped habitat and in the diversity of that habitat across the landscape, although there are limited studies available to provide empirical evidence for this (Josefsson *et al.*, 2013; Cole *et al.*, 2012). Nevertheless, a number of the studies which are available, do lend support to the biodiversity benefits offered by buffer strips, with, for example, Josefsson *et al.* (2013) demonstrating their impact on skylark (*Alauda arvensis*) numbers, and the invertebrates they feed on, in arable landscapes, and Maisonneuve and Rioux (2001) demonstrating their benefit for small mammals and herpetofaunal diversity. As well as providing uncropped habitat, buffer strips can benefit terrestrial biodiversity by, for example, providing a sanctuary from predation (e.g. on small mammals) and/or in-field operations, or by providing vital corridors for movement between otherwise unlinked habitat areas, reducing levels of habitat fragmentation (Lovell & Sullivan, 2006; Cole *et al.*, 2012). Additionally, they can be of benefit to aquatic biodiversity through mechanisms such as the provision of shading, reducing water temperatures, increasing dissolved oxygen concentrations and limiting primary production, and supplementing available food sources through the vegetative matter which may fall in (Barling & Moore, 1994; Lovell & Sullivan, 2006). However, features such as buffer strips are not universally beneficial for biodiversity, and perhaps it should not be expected that they would be, with Fuentes-Montemayor *et al*. (2011) for example, demonstrating that they, along with field margins, hedgerows and species-rich grasslands, did not benefit pipistrelle bats (*Pipistrellus pipistrellus*) in the area they studied in Scotland.

Recommended buffer strip widths for nutrient removal vary considerably, being anything between 3 and 200m, no doubt at least in part as a result of their impact being highly nutrient and site specific, although most are for something in the range of 5-15 m (Kay *et al.*, 2009). Research suggests that the majority of nitrogen capture for example, occurs in the first 5-8m (Kay *et al.*, 2009). Similar widths are reported in the literature for pesticide removal, generally being in the range of 5-20m, and it has been demonstrated by some authors that buffers with relatively large catchment area to buffer area ratios (e.g. 30:1) are just as effective as those with smaller ratios (e.g. 15:1). In terms of biodiversity, the ideal size is likely to be dependent on the species which they are intended to benefit, albeit that taking additional land out of intensive agricultural production might be expected to be beneficial, although in reality there has been a lack of research into the widths required for biodiversity purposes (Cole *et al.*, 2012). In practice therefore, the optimum width of a buffer strip should be a compromise between the width required for the reduction of diffuse pollution, the ability of the buffer to serve as a habitat in its own right and the costs incurred in installing and managing the buffer and through taking land out of production (Cole *et al.*, 2012). As a result however, it is likely that many buffer strip schemes may fall short of the ideal suggested by some academic sources. It has been suggested for example, that for water quality protection, buffer strips should be at least 25m and perhaps 100-200m (or more) wide, which is well in excess of those promoted by agri-environment schemes, such that at the catchment scale, they may in theory have to encompass an impractically large proportion of the catchment to be of significant benefit (Davies *et al.*, 2009). Indeed, this has led some authors to question the wisdom of focusing on buffer strips, at least in relation to aquatic biodiversity, with

Davies *et al.* (2008, 2009) pointing to the fact that in their studies they found that water quality was unlikely to be of good quality if intensive agriculture exceeded 30-50% of the catchment.

However, there are things that can be done in terms of buffer management which may improve their ability to deliver the ecosystem services and biodiversity provision we desire of them. In general, the biodiversity benefits of buffers strips can be increased if they are planned with biodiversity in mind, despite this often being viewed as an indirect benefit (Lovell & Sullivan, 2006). This includes planting a mixture of plant species, and including woody plants is likely to be more beneficial than installing a purely grassed buffer strip (Lovell & Sullivan, 2006). Equally, the usefulness of buffer strips as corridors for the movement of fauna is dependent on their length and width being appropriate for the relevant species, although there is little quantitative data as to what that should be (Lovell & Sullivan, 2006). Buffer management may also be essential if the maximum pollutant removal performance is to be achieved, since where strips become compacted due to the effects of vehicle movement (buffer strips, much like other field margins, are often viewed as a convenient routes for movement around the farm) and/or livestock, levels of infiltration can be reduced (Lovell & Sullivan, 2006) leading to excessive levels of overland flow. Equally, the occasional removal of excess sediment may be necessary, particularly if pollutants such as phosphorus build up, to prevent buffers themselves becoming subsequent sources of both sediments and their associated pollutants (Lovell & Sullivan, 2006). This has been highlighted in the literature as a potential weakness with the potential to threaten the sustainability of buffer strip efficacy, i.e. they may end up becoming sources of sediment and/or soluble phosphorus (Lovell & Sullivan, 2006; Kay *et al.*, 2009; Uusi-Kämppä & Jauhiainen, 2010). In addition, work in Finland, for example, has suggested that in unmowed vegetated buffer strips, the build-up of plant residues enhances the phosphorus status of surface soils, enhancing losses of dissolved P, particularly in the spring (Uusi-Kämppä & Jauhiainen, 2010). As a consequence the removal of vegetation may be necessary, albeit that this may not be wholly compatible with the needs of biodiversity.

2.2.13. Agroforestry

Title:	Hectares of agroforestry
Description:	This is arable land (that is eligible for the basic payment scheme or the single area payment scheme) that combines production from trees and crops and/or livestock at the same time, e.g. intercropping.
No. of MS activated:	12
Dimension limits:	None
Implementation rules:	None

Some of the benefits of agroforestry are also covered under other EFA elements, such as hedges, tree alleys, trees in a line, forest edges and short rotation coppice (Sections 2.3.3-6 and 2.2.14-15). This section focuses more of the integration of trees and agricultural production on the same unit of land.

Burgess (1999) reported a mixed impact on crop pest populations associated with agroforestry. Grain aphids (*Sitobion avenae*) in barley, and pea and bean weevil (*Sitona spp*) and pea midge (*Contarinia pisi*) in pea crops declined. Slug populations and thrips (*Thysanoptera*) increased. The decline in certain pests was attributed to the presence of permanent areas within the cultivated crop offering potential to enhance beneficial naturally occurring predators, reducing overall pest pressure, although this is reported by Holland *et al*. (1999; 2005) as being dependent on sufficient ground cover being established and maintained on the soil surface. This is illustrated by the implementation of, for example, 'beetle banks' in the UK under Entry Level Stewardship (Natural England, 2013). Dix *et al*. (1995) report that although beneficial insects are enhanced by the presence of trees within cultivated areas, suitable hibernation areas (tussocky grass and herbaceous vegetation) need to be present at the base of the tree lines. Further, because such species need to utilise both the crop and the tree planted area in order to exert an impact on crop pest populations, they are essentially ecotone species and benefit most from a high edge to area ratio i.e. thin tree lines.

The introduction of perennial crops, decreased tillage frequency and the establishment of a permanent root system is reported to reduce the risk of soil erosion (Langeveld *et al*., 2012). The deposition of leaf litter and the decay of root material benefits C sequestration (Falloon *et al*., 2004) and potentially improves soil water infiltration rates which reduce surface water run-off (Dimitriou *et al*. 2012; Kahle *et al*., 2007). Reduced surface run-off and deeper rooting systems decrease the risk of nitrate and phosphorous entering groundwater (Langeveld, 2012). Removal of nitrate leached beyond the rooting zone of many arable crops by the deeper roots of tree species permits recycling via assimilation and eventual deposition via leaf litter (Nair, 2011). Particular benefit may be realised on sandy soils, where nitrate retention ability is limited (Nair and Graetz, 2004) or adjacent to riparian areas to intercept run-off (Schultz *et al*., 2009). Erosion mitigation is maximised where a surface cover of grass, for example, is maintained at the base of the trees and bare soil is avoided (Phillips, 1989), conducive with the enhancement of beneficial species (Holland *et al*., 1999, 2005). Ideally, a species adapted to partial shade, reflecting conditions beneath the tree canopy, should be established (Dix *et al*., 1995). There is also potential for the mixture to be manipulated to enhance pollinators for example (e.g. see Section 2.2.18). Schroth and McNeely (2011) highlight the need to consider appropriate tree mixtures, with different rooting strategies and temporal nutrient requirements that maximise the complementarity effect (coexistence of species exploiting different resources) of the species present. Where planted as a line of trees perpendicular to prevailing winds, agroforestry areas may function as shelterbelts (Brandle & Kort, 1991) that reduce the risk of wind erosion, especially during stages in the cropping cycle when there is limited ground cover (López *et al*., 2002). Pesticide drift may also be intercepted in more mature stands with a higher canopy. Le Houérou (1993) discuss the potential benefits of agroforestry at broader spatial scales, with their introduction as low input extensively grazed systems to prevent land degradation in the Mediterranean region.

A key benefit to the presence of trees on biodiversity within areas dominated by cultivation, according to Langeveld *et al*. (2012), Nair (2011) and Smith and Watson (2011), is the increase in structural diversity at the field scale, and the creation of a habitat mosaic and improved connectivity of habitat fragments at the landscape scale. The implementation of agroforestry areas as the linear features preferred by Dix *et al*. (1995) offers potential for them to act as a wildlife corridors, allowing the movement of populations between what would otherwise be isolated habitats (Hilty *et al*., 2006). A review by Burgess (1999) identifies that both silvoarable and silvopastural systems improve arthropod and bird diversity, and silvoarable systems also improve small mammal diversity. This has potential benefits for insectivorous and predatory bird species (Sage, 1996). A number of species are known to utilise corridors within agricultural landscapes, some of which, such as the Red Data Book listed great crested newt (*Triturus crestatus*) exist as meta-populations, and require dispersal between multiple ponds and habitat fragments within a given area to ensure overall population survival (Oldham *et al*. 2000). The use of agroforestry areas as buffer strips adjacent to wetland areas reduces the risk of nutrient run-off (Dimitriou *et al*. 2012; Kahle *et al*., 2007) and eutrophication (Johnston and Dawson, 2005; Smith *et al*., 1999; Withers and Lord, 2002), and any associated loss of biodiversity within water bodies (Dudgeon *et al*., 2006).

2.2.14. Strips along forest edges

This section covers two EFA elements: strips along forest edges with (i) no production and (ii) with production. Given the similarity of these two EFA elements, the literature for these two elements has been reviewed as a single element.

Title:	Strips of eligible hectares along forest edges - NO PRODUCTION
Description:	These are strips along forest edges where there is no agricultural production and which meet the dimension limits below. Member States may allow grazing or cutting, provided the strip remains distinguishable from adjacent agricultural land.
No. of MS activated:	11

Dimension limits:	1 to 10m
Implementation rules:	None
Title:	Strips of eligible hectares along forest edges - WITH PRODUCTION
Description:	These are strips along forest edges where there is agricultural production and which meet the dimension limits below.
No. of MS activated:	8
Dimension limits:	1 to 10m
Implementation rules:	In some instances the following may be specified: whether pesticides and fertiliser are allowed to be used; and whether grazing or cutting is allowed.

In an agricultural context, the forest or woodland edge is the transition zone, or ecotone, between the woodland interior and cropped or grazed land (Fry & Sarlöv-Herlin, 1997). Within modern intensive farming systems, even though there may have been significant planting of farm woodland, the boundary between woodland and agricultural land has generally become sharper and more defined, with a clear demarcation line often existing between the two land use types, and true edge habitat almost disappearing (Fry & Sarlöv-Herlin, 1997). However, some European countries have been promoting woodland/forest edge management, with a view to improving biodiversity and/or recreational (aesthetic) value (Sarlöv Herlin, 2001).

In biodiversity terms, ecotones (including woodland edges) are generally considered to be more species rich than either of the habitat types they separate, as a result of containing members from the habitats on either side of them, as well as some ecotone specialists (Fry & Sarlöv-Herlin, 1997). In part this 'edge effect' is a result of the fact that woodland edges are often associated with characteristics which, despite being related to the habitats on either side, are sufficiently different to support unique communities of plants and animals, for example by receiving greater sunlight and being drier, warmer and windier than the forest proper, yet more humid, shaded and protected from the wind than agricultural fields (Fry & Sarlöv-Herlin, 1997). Equally however, the conditions found in forest edges, lead to a greater number of micro-habitats than can be found within the body of the forest itself. Ouin *et al.* (2015) for example, found that the number of tree microhabitats (patches of bark loss, cracks, sap runs and epiphytes) can be significantly greater in such locations, due to a combination of factors including, a higher tree density and trees having a larger diameter than in the forest proper as a result of taking advantage of the increased light and nutrient levels available at woodland edges (Ouin *et al.*, 2015).

Good quality, structurally diverse, woodland edges, fulfil a number of roles which benefit biodiversity, many of which are similar to those performed by good quality hedgerows, including their obvious role in the provision of sites for breeding and foraging, shelter and dispersal corridors for a range of wildlife (Fry & Sarlöv-Herlin, 1997). A number of studies have concluded that for farmland birds for example, the more structurally diverse a woodland edge is, the greater the diversity, richness and abundance of species present is likely to be (Dyda *et al.*, 2009; Fry & Sarlöv-Herlin, 1997), with the same applying specifically to breeding birds, despite the increased likelihood of predation (Sarlöv Herlin, 2001). Similarly, several invertebrate groups, including butterflies, bumblebees and beetles, utilise the tall herbaceous vegetation on the field-ward side of the edge zone, as a source of either nectar or overwintering habitat, whilst a complex architecture favours web producing spiders (Defra, n.d.; Fry & Sarlöv-Herlin, 1997).

In addition however, modern farms are highly mechanised, chemically enhanced environments, which may threaten both plant and animal species sensitive to such activities. Woodland edges therefore, can serve as either short or long-term refuges from this potentially damaging activity (Fry & Sarlöv-Herlin, 1997). The former may be the case in relation to birds and mammals seeking a refuge from mechanical activities such as harvesting, whilst the latter may be better applied to plant species sensitive to fertilisers and/or herbicides, including some which provide a vital food source for local fauna (Fry & Sarlöv-Herlin, 1997). Therefore, such habitats may serve as refuges for species which would otherwise have become locally extinct, but which as a result are available to recolonize other areas once suitable conditions are available (Fry & Sarlöv-Herlin, 1997).

As essentially linear features between two other habitats, one role attributed to woodland edges, albeit that evidence is limited (Fry & Sarlöv-Herlin, 1997), is in the provision of corridors for the movement of species around the rural landscape, and in that sense their spatial linkages are important, with habitats such as woodland edges and hedges having a combined role to play (Fry & Sarlöv-Herlin, 1997). Sarlöv-Herlin and Fry (2000) for example found such connectedness was important in the patterns of dispersal of woody plants from forest woodland edges, if their seeds were animal distributed. Whilst other authors have pointed to the fact that hedgerow species are more similar to those found in woodland edges than those in the woodland centre (McCollin *et al.*, 2000), meaning that a good quality woodland edge zone is important in terms of the overall connectedness of habitats, with woodlands without such edges being less beneficial.

Finally, woodland edges act as a buffer, protecting the woodland proper from the damaging effects associated with modern agricultural practices, such as pesticide and nutrient drift, as well as more natural processes such as those associated with wind and light penetration, ensuring the essential characteristics of woodland are preserved (DARD, n.d.; Fry & Sarlöv-Herlin, 1997). In this respect, they may prove valuable, since some authors (e.g. Willi *et al.*, 2005) have suggested that arable agriculture can lead to elevated nitrogen levels penetrating 100m or more into areas of ancient woodland, resulting in inadvertent changes to ground flora (Willi *et al.*, 2005). Similarly other authors have pointed to the possible damage caused by ammonia deposition close to intensive livestock units (Pitcairn *et al.*, 1998, 2002), and by pesticide drift (Jobin *et al.*, 1997).

As well as being important for biodiversity, woodland edges traditionally perform a number of other ecosystem services, although some are beyond the immediate focus of this project. These include, for example, a direct role in the provision of human foods such as blackberries and other fruit, the small scale provision of wood, as well as an aesthetic role in relation to the provision of amenity resources (Fry & Sarlöv-Herlin, 1997). They also benefit agricultural production through the provision of three key services. Firstly, as a result of providing habitat for a wide range of invertebrate species, they can maintain a significant pool of natural predators of agricultural pests, with a number of species being found in high densities in woodland edges in the spring, allowing for their movement out into the field, with benefits in terms of both crop damage and pesticide usage (Fry & Sarlöv-Herlin, 1997). In addition, many invertebrates found in woodland edges serve as pollinators, and are therefore essential for both the health of agricultural/horticultural production and the functioning of wider ecological systems (Defra, n.d.). Finally, being more densely vegetated than woodland proper, they are a key component in the use of woodland as windbreaks (Fry & Sarlöv-Herlin, 1997).

Through the appropriate management of woodland edges, it is possible to maximise the ecological benefits afforded by both new and existing woodland edge (Fry & Sarlöv-Herlin, 1997). In general, it is considered important in woodland edge management to ensure a structurally diverse habitat, with multiple layers of dense vegetation moving gradually, over some metres, from woodland to open farmland, including zones of shrub and herbaceous vegetation (Dyda *et al.*, 2009; Fry & Sarlöv-Herlin, 1997). Similarly, structural diversity at the scale of the local landscape will also serve to maximise overall biodiversity value (Fry & Sarlöv-Herlin, 1997). However, guidelines for woodland edges contain few hard and fast management rules, although there are some clear rules of thumb. These include having sloped edges, i.e. where vegetation becomes shorter as you move from woodland to farmland (Fry & Sarlöv-Herlin, 1997), indeed woodland edges can be combined with a field margin/buffer strip, effectively extending the woodland edge ecotone further out into the field, and providing even greater diversity of species and habitats (Clarke *et al.*, 2011; Defra, n.d.) (Also see Sections 2.2.7 and 2.2.12). It is also recommended that a woodland edge should have a curvilinear form, although this isn't always compatible with agricultural practices, and all edge forms should be appropriate for the region in which the feature is being developed (Fry & Sarlöv-Herlin, 1997). Indeed there is no consensus as to how wide the edge zone should be, in part because this needs to be regionally appropriate, with most sources suggesting it should be as wide as possible (Fry & Sarlöv-Herlin, 1997).

As far as the vegetation itself is concerned, as well as ideally being quite dense and multi-layered, species can be selected with biodiversity in mind, for example by ensuring the presence of pollen baring species such as (in the UK) willows like the goat willow and blackthorn, as well as wild cherries, crab apples, hawthorn and rowan (Defra, n.d.), although the choice should reflect local conditions and native species. It may also be necessary to control some plant types including brackens and bramble, although before doing so it has to be borne in mind that these species too may have considerable conservation value, despite often being viewed as a problem (Blakesley & Buckley, 2010). There may however, be circumstances in which the maintenance of dense vegetation within the woodland edge may not be appropriate, due to the need to deliver a regionally appropriate form, since open woodland is common in some areas, and may be a requirement of some valuable species of, for example, birds (Clarke *et al.*, 2011; Blakesley & Buckley, 2010). One way of achieving this is through the use of grazing or browsing livestock to clear some vegetation, but this must be done with great care, since livestock can supress the development of saplings, and remove excessive ground vegetation (Clarke *et al.*, 2011; Blakesley & Buckley, 2010). Through preferential grazing, they may also remove some palatable species more than other less palatable such as gorse, changing the makeup of the plant community (Clarke *et al.*, 2011).

2.2.15. Short rotation coppice

Title:	Areas with short rotation coppice
Description:	These are areas used for the production of biomass in the form of short-rotation coppice. Member States shall establish a list of species that can be used for this purpose, to enable selection of species that are most suitable from an ecological perspective (thereby excluding species that are clearly not indigenous). The use of mineral fertiliser and plant protection products will vary with Member State.
No. of MS activated:	23
Dimension limits:	None
Implementation rules:	Species specified, varies with MS. Restrictions on the use of mineral fertiliser and plant protection productions, varies with MS. In Flanders there is a maximum harvest cycle of 8 years.

A number of studies that assess the overall impact of SRC on biodiversity make reference to pollinators but provide limited detail. Willow SRCs are stated by Langeveld *et al*. (2012) to have a positive impact on honeybees although they do not provide an explanation. Smith and Watson (2011) highlight that many flowering plants are unable to grow in the understorey of the more mature phases of SRC due to shading. Despite this, they conclude that there is no notable impact on bees, or other potential pollinators such as butterflies. They do however note a potential negative impact on species beneficial for pest control in agricultural land, namely carabid beetles, due in part to the lack of vegetation cover on the soil surface.

The lack of vegetation present on the soil surface may increase surface run-off and the movement of soil particles, a potential indicator of soil erosion risk and nutrient (nitrate and phosphorous) loss to adjacent water bodies (Dimitriou *et al*., 2009; Busch, 2009). Where SRC is introduced onto existing cultivated arable land, an increase in soil bulk density may be observed due to the topsoil no longer being cultivated. There is also potential for enhanced C sequestration from the deposition of leaf litter and the decay of root material (Falloon *et al*., 2004). This may improve soil infiltration (Dimitriou *et al*. 2012), coupled with reduced risk of surface run-off (Kahle *et al*., 2007). Langeveld *et al*. (2012) and Kort *et al*. (1998) conclude that in SRC overall, soil erosion is reduced. The perennial cropping system decreases tillage frequency, the permanent root system physically binds the soil particles, and increased water consumption by the crop maintains soils below water field capacity for longer. The authors note that the bare ground beneath SRC stands has a limited sediment trapping capacity, although this may be mitigated by the addition of grass buffer strips to the perimeter (Phillips, 1989). Greatest soil erosion risk in SRC is immediately post-harvest but before establishment of the following crop, where bare soil exists in combination with limited ground or canopy cover. There is also potential damage to soil structure from harvesting operations (Armstrong, 1999), particularly on heavier fine particulate soils with poor drainage. This risk is increased further by harvesting during winter periods in order to maximise crop yield and avoid negative impacts on breeding birds. Surface and subsurface soil compaction risk may be greatly increased, coupled with the risk of damage to existing field drains.

Short rotation coppice is reported to improve water quality, with decreased nitrate and pesticides in groundwater, along with a decline in flood risk (Langeveld, 2012; Nisbet *et al*., 2011). The impact of SRC on phosphate in the groundwater is less conclusive, with disagreement among authors (for example Langeveld, 2012; Nisbet *et al*., 2011). Inputs of pesticide tend to be limited to the need for weed control during early phases of establishment (Nisbet *et al*., 2011). As such, the deterioration of water quality in SRC due to pesticide use is considered to be reduced relative to arable cropped agricultural land. Lowrance *et al*. (1984) cite the additional benefit of intercepting both aerial pesticide drift and that bound to sediment.

Supplementary inorganic fertiliser applied to SRC is less than to arable crops (Nisbet *et al*., 2011). Nitrogen fertiliser application in the first year of establishment does not benefit crop growth but may increase surface run-off of nitrate (Heilman & Norby, 1998). As such, it is not typically applied to the first or second rotation crops, with N contained within atmospheric ammonia deposition and nutrient runoff from neighbouring agricultural land being deemed sufficient (Nisbet *et al*., 2011). Where adherence to 'good practice' is followed, nitrate concentrations in the groundwater are estimated to be reduced by a factor 20 compared to arable cropping (Dimitriou *et al*., 2012; Schmidt-Walter & Lamersdorf, 2012). Aronsson *et al*., 2000) provide an example of supplementary N applied at 153 kg N ha^{-1} but nitrate loss from below the root zone in SRC continuing to remain low. Lord *et al*. (2007) conclude that the risk of nitrate leaching from SRC was likely to be minimal. An analysis of mean annual leaching losses from agricultural fields over 60 site-years by Langeveld *et al*. (2012) found leaching from different crops as follows: winter cereals (40 kg ha^{-1}), oilseed rape (48 kg N ha^{-1}), potatoes (66 kg N ha^{-1}) and woodland (17 kg N ha^{-1}). Woodland was reported to vary between 0 and 24 kg N ha^{-1} yr^{-1} and that levels from SRC crops would be comparable. Heilman and Norby (1998) and Nyakatawa *et al*. (2006) suggest that the rapid assimilation and potential depletion of nutrients from soils might be exploited to target planting of SRC on areas on sloping fields at risk to erosion or run-off and the protection of riparian zones i.e. form 'biogeochemical barriers'. Long-term studies by (Ryszkowski *et al*., 1999) found that woodland strips reduced N run-off from adjacent agricultural fields and removed surplus nutrients from the run-off in a filtering capacity (Cooper *et al*., 1987; Schultz *et al*., 1995). Willow (*Salix* spp.), poplar (*Populus* spp.) and eucalyptus (*Eucalyptus* spp.) are named specifically by Sugiura *et al*. (2008) as being highly efficient at removing nitrate, phosphorus and potassium. Langeveld *et al*. (2012) reach rather contradictory conclusions regarding phosphorous, stating that concentrations of phosphate increase slightly with a small deterioration of water quality.

A number of authors consider that there is a lowering of the groundwater table associated with SRC crops, due to a decline in water percolation from increased rainfall interception and assimilation by the crop, increased transpiration rates (500 mm per year for SRC poplar, compared to 350-390 mm for ash and beech woodland), resulting in a decline in groundwater recharge (Schmidt-Walter & Lamersdorf, 2012). Recharge was estimated to be reduced an average 50% in the final year before cutting relative to grass, although losses declined when averaged over the entire three or four year cutting cycle (Hall *et al*., 1996). This has two potential impacts on water quality. A potential detrimental impact of SRC on nitrate levels in groundwater may arise not from leaching but where annual rainfall is low which, coupled with increased water consumption by the crop, can result in a concentration effect (Calder *et al*., 2002). Nitrate concentrations in groundwater under SRC crops in low rainfall areas were found to be similar to those from arable land. Recommendations to avoid growing SRC in Nitrate Vulnerable Zones where annual rainfall is below 650mm are given by The Forests & Water Guidelines (Forestry Commission, 2003). A second potential detrimental effect is increased localised deposition of atmospheric N as ammonia relative to arable land, due to the presence of an elevated canopy, although this may be more of an issue in short rotation forestry where the canopy may be higher and consists of evergreen tree species (Forestry Commission, 2003). Where localised atmospheric deposition occurs, it may increase the risk of nutrient enrichment of local surface waters. The rapid growth of SRC and assimilation of soil N however, renders it of limited vulnerability to N loss (Heilman & Norby, 1998; Nyakatawa *et al*., 2006).

A review of impacts on biodiversity by Lavelle *et al*. (2012) note a general overall positive impact on what they consider to be two main categories of assessment: plant species (phytodiversity) and breeding bird species (zoodiversity), though they acknowledge that there is limited information on the length of time taken for the benefits to be realised. They attribute the improvement to an increase in the structural diversity of the landscape relative to arable crops through the creation of a habitat mosaic effect. Other reviews, for example Smith and Watson (2011), extend their analysis beyond plants and birds to include other groups such as bryophytes, invertebrates and mammals.

Plant species are categorised by Lavelle *et al*. (2012) into indicator communities comprised of species representative of woodland, ruderal habitat, grassland and arable land. They note an increase in the diversity of all plant species from the representative habitat types, especially grassland species (a factor of 17 increase), but no impact on the abundance of endangered species. The increase in the mean number of species (described as 'common') associated with particular habitats was grassland species (0.6 to 10.1), woodland species (0 to 5.2), ruderal species (2.7 to 8.1) and arable (2.4 to 3.8). The increase noted for arable species is contradictory to the conclusions of Persson *et al*. (1989) and Kirby (1993) who cite the reduction in light penetrating the canopy and shading the soil as having a negative impact on species of open arable habitats. Their distribution was restricted to gaps in the canopy, or the boundary of the SRC crop in the ecotone, where two contrasting habitats and species that utilise both habitat types may be present (Baum *et al*., 2009). The extent of the ecotone is dependent on edge effect and surface to perimeter ratio. Persson *et al*. (1989) and Kirby (1993) also document an increase in rare species, citing the examples of *Adonis annua*, *Centaurea cyanus*, *Euphorbia platyphyllos* and *Scandix pecten-veneris.*

Püttsepp (2004) noted a beneficial impact on soil microorganisms and soil fauna due to the potential separation of the soil into distinct zones or horizons under SRC associated with the removal of tillage and deposition of leaf litter, compared to the more uniform upper soil layers of arable land. Species such as willow (*Salix* spp.), alder (*Alnus* spp.), poplar (*Populus* spp.) and eucalyptus (*Eucalyptus* spp.) are able to form symbiotic mycorrhizal associations of two types (ectomycorrhizas and endomycorrhizas) simultaneously, increasing the diversity of fungi within the soil beneath SRC crops (Püttsepp, 2004). Other soil dwelling groups, namely worms, are also reported to benefit from SRC, due to the decreased mechanical damage from tillage, the increased soil moisture associated with no tillage and shading of the canopy, and the increase in deposition of organic material as leaf litter (Hubbard *et al*., 1999; Whalen, 2004).

Compared to arable land in isolation, SRC supports a greater diversity of invertebrate species, with diptera and arachnids named specifically by Sage *et al*. (2006). Specialist species, such as the waved carpet moth (*Hydrelia sylvata*) of alder (*Alnus* spp.), are also added to the overall species richness of an area where SRC is present. This increase is attributed to the greater vertical diversity, the longer cropping cycle, and increased habitat stability and continuity. At the early stages of cropping cycle a greater variety of herbivores and phytophage invertebrate species are supported, and this increases species diversity at the higher trophic levels (Oxbrough, 2010). Further, SRC does not typically receive applications of insecticide, although it may be applied occasionally to treat willow beetle outbreaks. Compared to mature woodland however, it supports fewer species (Oxbrough, 2010) due to the lack of older mature trees, the associated reduction in microhabitat diversity (dead wood, gaps in the canopy) and the duration of time for which they have been available for colonisation by different species. Oxbrough (2010) cites species with limited dispersal capabilities that are likely to be absent from newly established crops, they also mention a decline in diversity and the potential loss and subsequent absence of such species at the end of each cropping cycle. A number of arachnid species were recorded during the first cropping cycle but were removed during harvest then failed to recolonize during the second and following crop cycles. Species diversity is considered lower than woodlands. Where gaps exist in the woodland canopy and sunlight is able to penetrate (largely absent in SRC crops), thermophilous (warmth liking) species can coexist within a relatively small area with species that prefer cooler, shaded conditions. The absence of deadwood in SRC means they are also unsuitable for saproxylic invertebrate species.

An assessment of changes in breeding bird populations associated with SRC by Langeveld *et al*. (2012) found an overall increase in the number of species from 10 to 37, although the precise impact depended on feeding requirements (seed or insectivore) (Berg, 2002; Hanowski, 1997), and habitat (whether species of open areas, shrub, forest, tall ruderal or reed areas and ecotones) (Hanowski, 1997). A further variable was the age and structure of the SRC crop, since height may vary from below 1m when recently harvested up to 8m when fully grown. In summary:

- Woodland and shrub species were found to benefit the most from the introduction of SRC into areas dominated by arable cropping (Lavelle *et al*. 2012), however Coates and Say (1999) and Anderson *et al*. (2004) found that this was subject to feeding strategy. Granivorous birds may not benefit due to the decline of understorey plant species and their seed production capacity. Woodland birds that require mature trees or dead wood (e.g. nuthatch) are unlikely to benefit due to the relative immaturity of the SRC when it is harvested (Sage, 1998). The species that tend to benefit are the insectivores that forage within leaf litter (e.g. blackbirds and thrushes).
- Hedgerow species or those that prefer early development phases of woodland and coppice are likely to benefit from SRC (Anderson *et al*., 2004).
- Ecotone species and those associated with ruderal habitats and reeds were found by Lavelle *et al*. (2012) to increase from three to five species when SRC was introduced to arable dominated areas. This was attributed to the enhancement of vertical structure.

Lavelle *et al*. (2012) concluded that SRC will have a negligible impact on the number of vulnerable (Red Data Book) species, with those that increase in abundance being mainly common and widespread species. Anderson *et al*. (2004) concur in part with this conclusion, and refer to widespread species such as wren (*Troglodytes troglodytes*), blackbird (*Turdus merula*), robin (*Erithacus rubecula*) and chaffinch (*Fringilla coelebs*). They do however, also note the positive impacts on species regarded as 'higher conservation concern' including the reed bunting (*Emberiza schoeniclus*) and song thrush (*Turdus philomelos*). They also cite the value of the ecotone habitat for vulnerable species such as the yellowhammer (*Emberiza citronella*), cirl bunting (*Emberiza cirlus*) and corn bunting (*Emberiza calandra*). The linear edge effect provided by the SRC - arable transition provides, according to Sage (1996) ideal habitat for small mammals and hunting areas for birds of prey, making specific reference to owls. The impact on rare specialist bird species of open agricultural land, for example the skylark (*Alauda arvensis*) and corn bunting is unlikely to be favourable, with the area only being potentially suitable during the first year of the rotation (Sage, 1996). The positive impact on small mammals is noted as beneficial to birds of prey by Sage (1996). Larger mammals such as deer are considered by Lavelle *et al*. (2012) to also have potential to benefit from the enhanced structural diversity of the area.

2.2.16. Afforested areas

Title:	Afforested areas
Description:	Afforested areas (planted woodland) that were previously supported under rural development schemes (Regulation 1307/2013).
No. of MS activated:	15
Dimension limits:	None
Implementation rules:	None

Within the context of this work, afforestation refers to planted woodland that was previously supported under rural development schemes. Generally, the term afforestation is applied to human-induced conversion of land to forest that has not been forested for a period of at least 50 years, with the term reforestation being applied when the un-forested period is of less than 50 years (Bredemeier & Dohrenbusch, 2004). Many European countries have ambitious plans for the amount of afforestation which will occur over the next few decades, with the aim of meeting a number of environmental goals, but particularly those related to biodiversity and climate change mitigation. The Republic of Ireland for example, has set a target of bringing the total level of forest cover up from 10% to 17% by 2030 (O'Driscoll, 2013), which at the time of setting required planting at a rate of 20,000 ha yr^{-1} (Buscardo *et al.*, 2008), although so far they are lagging behind that target (O'Driscoll, 2013).

Despite the artificial nature of planted forests and woodlands, some studies have found there to be evidence that such environments can be of considerable benefit to a number of species of flora and fauna, including some of conservation value (Brockerhoff *et al.*, 2008). Consequently, the afforestation of abandoned or marginal agricultural land is seen as an important tool for the recreation and/or restoration of forest ecosystems in a number of countries (Lazdinis *et al.*, 2005). Their value is in part thought to be a consequence of the varied structure, and therefore range of ecological niches, found within forested areas, allowing them to support a diverse ecology (Bredemeier & Dohrenbusch, 2004). In general, older stands of trees provide a better habitat for forest species than younger stands, because of the greater horizontal and vertical diversity in structure which develops with age, the increased availability of dead wood, light levels becoming more appropriate for forest vegetation, soils that are enriched with organic matter and nutrients, and the fact that as a greater number of forest species colonise an area the scope for inter-species facilitation increases (Bredemeier & Dohrenbusch, 2004; Brockerhoff *et al.*, 2008). However, although, in many parts of Europe the natural vegetative cover would be that of some form of forest, it may take a long time to get to that point through natural succession alone, with plenty of scope for the development of less desirable environments in the meantime, and with the potential for anthropogenic barriers to prevent natural succession from reaching its ultimate conclusion (Brockerhoff *et al.*, 2008). Fortunately however, there is evidence that the judicious establishment of plantation forests can expedite this process (Brockerhoff *et al.*, 2008), giving natural processes a head start.

In addition, as is the case with a number of the ecological features discussed in this report, the biodiversity benefits of afforestation are determined not only by the characteristics of individual areas of planted forest and/or woodland, but also by landscape scale issues, and consequently the full scope for biodiversity benefit is likely to be achieved only if changes are made in light of a knowledge of the context within which planted forests will be set. Plantation forests have, for example, the ability either to supplement the existing provision of this type of habitat within an area or to complement that provision by providing something which would otherwise be missing from the landscape (Brockerhoff *et al.*, 2008). They can serve to connect previously fragmented habitats, or when planted alongside natural woodland to provide a buffer for that habitat from external influences, such as pesticide and/or nutrient drift (Brockerhoff *et al.*, 2008).

However, afforestation is far from universally considered to be the biodiversity benefit that the above sources would seem to suggest (Brockerhoff *et al.*, 2008), although this is in part due to the way in which some studies assess success or failure. It is widely accepted that the biodiversity value of planted forests is unlikely to be as great as that of natural forests (although the magnitude of the differences can vary considerably), since they have lower levels of structural diversity (Brockerhoff *et al.*, 2008). Nevertheless, it is against this natural benchmark that some studies choose to judge the success or failure of afforestation programmes, even though it is probably unsound to do so within a context in which afforestation is occurring on land which had previously been in agricultural production, rather than as a result of the felling of natural forest (Brockerhoff *et al.*, 2008). A more reasonable evaluation can perhaps be made through a comparison with the biodiversity of the land in its pre-afforestation state (i.e. as agricultural land), and against this planted forests compare more favourably (Brockerhoff *et al.*, 2008), although there are still plenty of studies which conclude that the overall changes brought about by afforestation may not be beneficial (at least for some species groups), even when assessed against this less stringent baseline.

The doubts over the ecological value of afforestation are in part down to the fact that even in agricultural areas, pre-existing habitats may have biodiversity value in their own right. Matthews *et al.* (2002) for example, suggest that the gains in terms of forest bird species may not be as great as the losses of farmland species, something they put down to the farmland areas likely to be of most benefit to birds (i.e. marginal areas) also being those most likely to be converted to forest (Matthews *et al.*, 2002). Similarly, Alrababah *et al.* (2007) found that the afforestation of grassland in semi-arid environments resulted in reduced plant diversity. The same authors also noted the importance of a marked change in species composition (Alrababah *et al.*, 2007), something which is probably to be expected, and may well be desired. Similarly, Elmarsdottir *et al.* (2008) found composition change to be the main characteristic of change for birds, surface invertebrates and vascular plants, with little or no reduction in species richness, whilst fungi and soil invertebrates actually increased in species richness. Clearly then, the biodiversity benefits or otherwise of programmes of afforestation, are likely to be a function of a number of spatially variable and species variable factors, and care needs to be taken to avoid damaging valuable pre-existing biotypes through afforestation process (Bredemeier & Dohrenbusch, 2004). Key questions to be answered in determining the biodiversity benefits or otherwise of a particular afforestation scheme relate to (Brockerhoff *et al.*, 2008):

- The previous land use: intensively managed farmland is likely to present a lower baseline state than extensive forms of agriculture.
- Any other land uses which could be implemented: even if afforestation proves to be of benefit, there may be more beneficial changes which could have been made.
- The tree species are planted.
- The age of the stand.
- How and for what the land is being managed: see below for the conflicts between biodiversity management, climate change mitigation and wood product production.
- The impact on other forest areas: at a broader scale (and probably beyond the scope of the current project) planted forest could reduce the pressure on natural forest for the provision of resources such timber.

In addition to the possible benefits for biodiversity, forests are planted to fulfil a number of other ecosystem services, or indeed in attempt to achieve multiple benefits. Chief amongst these (other than the provision of wood products itself) is carbon sequestration. Photosynthesis is a major form of carbon removal from the atmosphere, such that on a global scale sequestration may account for up to twice as much carbon transfer each year as deforestation (Broadmeadow & Matthews, 2003). It is perhaps unsurprising then, that the important role which forest-based carbon sequestration may play in climate change mitigation has been recognised (Broadmeadow & Matthews, 2003), and there is considerable interest in the use of afforestation as a means of achieving this goal (Matthews *et al.*, 2002; Plantinga & Wu, 2003). Estimates based on bottom-up studies (obtaining global estimates by working up from regional studies) have suggested that at a cost of up to \$100 tCO_2eq^{-1} (generally considered to be economically viable) forestry-based mitigation could sequester 1.3-4.2 $GtCO_2eq\ yr^{-1}$ by 2030, indeed, around half this could be achieved at a cost of under \$20 tCO_2eq^{-1} (Nabuurs *et al.*, 2007). Global (top-down) models suggest that at the same cost by 2030 sequestration rates could be as high as 13.8 $GtCO_2eq\ yr^{-1}$, although there is reason to suggest that this may be an overestimate (Nabuurs *et al.*, 2007). However it is clear that forestry has significantly potential role in climate change mitigation.

Considerable carbon storage is achieved through the above ground biomass store associated with forest environments, but the importance of other stores, such as leaf litter, brash and soils, many of which can themselves be considerable in size, should not be overlooked (Broadmeadow & Matthews, 2003). Forest soils in particular, can contain more carbon than the vegetation growing in them, although this may be skewed a little by the fact that some of the studies on which this assessment is based, examined forests which had been planted on upland peat soils, which therefore had pre-existing high organic matter contents (Broadmeadow & Matthews, 2003). Nevertheless, forest vegetation leads to a build-up of soil organic matter to a point which is dependent on the balance between the rates of accumulation and loss (through decay and respiration), such that forest soils do generally have higher organic matter contents than those under other, more intensive forms of land use, and managing them may be essential for maximising overall carbon storage (Broadmeadow & Matthews, 2003). It should also be noted however, that the planting of trees on peat soils, may have negative impacts on carbon storage, since when such soils are drained either for or by forestry, considerable oxidation may occur, resulting in significant losses to the atmosphere (Broadmeadow & Matthews, 2003), although this is complicated somewhat by, for example, the fact that although emissions of methane may increase when peat lands are drained, N_2O emissions may decrease (Broadmeadow & Matthews, 2003).

Forest management is characterised by long periods (often decades) of gradual carbon sequestration followed by relatively brief periods of rapid carbon release (Read *et al.*, 2009), this latter period being driven mainly by disturbance of the land during harvesting and/or re-planting (Nabuurs *et al.*, 2007). Mature stands tend to reach an approximate equilibrium between carbon sequestration and loss, and it is at this stage that the size of the forest carbon store is maximised (Broadmeadow & Matthews, 2003); however, in commercially managed forests, the cycles of tree development and harvest, have the effect of keeping an area in a constant state of carbon accretion, since equilibrium is never reached (Bredemeier & Dohrenbusch, 2004). For the maximum benefit to be achieved therefore, it is necessary to carefully balance the overall size of the forest store, and the rate of carbon accumulation.

Afforestation also has implications for those ecosystem services related to water resources, runoff and erosion. It has been estimated that through a combination of increased interception and greater uptake from the soil by vegetation, forest planting can have a significant impact on both surface runoff and infiltration to groundwaters, with both positive and negative implications (Allen and Chapman, 2001). Benefits include a reduction in the erosive potential of surface flows and reduced peak discharges and flood risk in surface waters. However, there is evidence that the overall impact on the surface hydrology of a catchment is unlikely to be significant unless the level of afforestation is high, although localised impacts may be considerable (van Dijk & Keenan, 2007; Trabucco *et al.*, 2008). Drawbacks meanwhile, include reduced surface water low-flow levels with implications for aquatic biodiversity, reduced input to reservoirs used for water supply and/or hydropower, and a reduction in the availability of groundwater resources (Farley *et al.*, 2005; Allen and Chapman, 2001; Wattenbach *et al.*, 2007). This is exacerbated by the fact that levels of interception are higher in the sort of fast growing coniferous forest likely to be planted for commercial exploitation, than in broadleaved forests (Allen and Chapman, 2001). Nevertheless, there are examples in the literature in which afforestation increased groundwater recharge as a result of the improvements that are induced in infiltration (Allen and Chapman, 2001; van Dijk & Keenan, 2007). As far as water quality is concerned, forest planting can result in both acidification and nitrification, in part due to the fact that trees are efficient scavengers of atmospheric pollutants (e.g. SO_2, NO_2 and/or NH_4), but the addition of considerable quantities of acidic, nitrogen rich organic matter in the form of leaf litter is also an important factor (Allen and Chapman, 2001). There are however, some cases of well-designed afforestation being shown to result in the reduced transport of pollutants such as sediment and nutrients to surface waters (van Dijk & Keenan, 2007; Plantinga & Wu, 2003).

Achieving multiple goals through afforestation, is far from straightforward, since there may be conflicts between the management procedures required to maximise the various benefits. Some authors, for example, have pointed to the fact that although the management of existing forests for carbon sequestration is unlikely to have a negative impact on biodiversity, the sort of incentives offered for afforestation for carbon sequestration, are likely to result in the over planting of fast growing alien species (i.e. those with a greater production potential), and that this could be detrimental for biodiversity (Caparrós & Jacquemont, 2003). It is also true, that simply implementing a programme of afforestation might not have the desired results in terms of target biodiversity, with Lazdinis *et al.* (2005), for example, identifying that the availability of key habitats may not increase in proportion to the overall increase in forested area. This led them to suggest that where there is a desire to improve the habitat for target species (in their case of birds) then a proactive approach to management for specific sub-habitats may be beneficial, and that to do this the expertise of ecological specialists should be included in the planning of afforestation programmes (Lazdinis *et al.*, 2005).

In terms of practical management therefore, the primary goal of a forest or woodland must be kept in mind, and not all objectives will be wholly compatible. Although within the context of this work this may be environmental benefits, in many other cases it may be timber or fuel production, which will impact on the extent to which biodiversity and other environmental goals can be catered for within management protocols (Brockerhoff *et al.*, 2008). For example, intensively managed forests, in which the use of monocultures, drainage, nutrient application and mechanical operations are common, are likely to be of lower biodiversity value than more natural stands (Brockerhoff *et al.*, 2008). However, if the assessment is made that afforestation could prove beneficial to biodiversity, there a number of management principles which should be borne in mind, since the general aim should be to achieve a diversity of structure, habitat and food plants (for fauna), together with landscape scale connectivity and continuity of management (Clarke *et al.*, 2011).

The first, and perhaps most obvious thing to consider, is the tree species to be planted, as these must be regionally appropriate; but in addition, it has been identified that the planting of a diverse mixture of species increases the range of available habitats, for other plants and animals (Brockerhoff *et al.*, 2008). However, this may have implications for commercial management if a very diverse mixture is adopted, and both commercial timber production and climate change mitigation may require the growth of relatively fast growing species, which may limit choice. Intensive land management practices should also be avoided if possible, particularly during the establishment phase, since these can cause considerable damage to herbaceous vegetation and/or woody debris, both of which are valuable biodiversity resources in their own right (Brockerhoff *et al.*, 2008). Wider planting of trees and/or heavy thinning can also be beneficial through the provision of a better light environment for herbaceous and other ground vegetation (Brockerhoff *et al.*, 2008). It is also necessary to consider the age at which trees will be harvested (if at all), since as noted above older stands (i.e. those with a longer rotation length) tend to be of greater biodiversity value (Brockerhoff *et al.*, 2008), although their ability to sequester carbon may diminish as a stand reaches maturity and a state of equilibrium is approached (Broadmeadow & Matthews, 2003). Finally, since the landscape scale context in which forests/woodlands exists is important for their overall biodiversity value, this should be considered at the planning stage, the aim being to provide a structural diversity at this scale too, as well as connectedness between habitat areas (Brockerhoff *et al.*, 2008).

2.2.17. Catch crops or green cover

Title:	Areas with catch crops or green cover
Description:	These are areas of crops grown with the objective of preventing the loss of nutrients from the soil and/or providing ground/green cover. Member States shall set up the list of mixtures of crop species to be used and the period for the sowing of catch crops or green cover, and may establish additional conditions notably with regard to production methods. The period to be set by Member States shall not extend after 1 October. Areas under catch crops or green cover shall not include areas under winter crops which are sown in autumn normally for harvesting or for grazing.
No. of MS activated:	21
Dimension limits:	None
Implementation rules:	Species and species mixtures, undersowing, preceding crops; period for sowing, presence in field, input restrictions and other conditions are specified, varies with MS.

Catch crops offer potential to remove surplus nitrogen (N) from within the soil during fallow periods (e.g. preceding a spring sown crop) and decrease nitrate (NO_3^-) loss via leaching or surface run-off (Silgram & Harrison, 1998). In addition, phosphorous (P) loss via surface run-off and soil erosion may also be mitigated, due to the interception of rainfall and dissipation of kinetic energy, which reduces the velocity of surface run-off, and decreases sedimentation (Dabney *et al*., 2001). The prevention of entry of NO_3^- and P_2O_5 into watercourses has a positive impact on water quality through prevention of eutrophication (Johnston & Dawson, 2005; Smith *et al*., 1999; Withers & Lord, 2002). The overall benefit depends on a number of variables. At the broad spatial scale, Dabney *et al*. (2001) conclude that catch crops function optimally in warmer climates with high precipitation, highlighting that in drier climates, for example the Mediterranean region, there may be competition with the crop for water. In cooler climates such as those in northern Europe where the crop may be at the edge of its optimal geographic range with respect to temperature, they may suppress early crop growth.

At smaller spatial scales, soil type is a key driver that determines the pathway that nutrients may enter watercourse, and the impact of cover crops. Freely draining sandy soils are most vulnerable to loss via leaching (Smith *et al*., 1996). According to Silgram and Harrison (1998), the inclusion of a winter cover crop on sandy soils in northern Europe preceding a spring sown cereal potentially decreases NO_3^- leaching by 25 – 50 kg N $ha^{-1}yr^{-1}$. Similarly, Shepherd (1999) assessed the impact of three types of catch crop, forage rape (*Brassica napus*), winter rye (*Secal cereale*) and Dutch white turnip (*Brassica rapa*), over an 8 year period on N leaching report that N loss was reduced by a mean 25 kg NO_3-N ha^{-1} per growing season in sugar beet and potato crops. Staver and Brinsfield (1998) found that a catch crop of rye sown immediately post-harvest of zero tilled corn decreased N loss by 80% compared to bare soil during the winter. Groundwater nitrate concentrations declined from 10-20 mg N L^{-1} to <5 mg N L^{-1} after 7 years continuous use of cover crops. Nitrate leaching from a crop rotation with grass-clover green manure without catch crops was, according to Askegaard (2005) 104 kg N ha^{-1} yr^{-1} on coarse sand, 54 kg N ha^{-1} yr^{-1} on loamy sand and 35 kg N ha^{-1} yr^{-1} on sandy loam. This was reduced by between 30 and 38%, equivalent to 31-34 kg N ha^{-1} yr^{-1} on sandy soil in the presence of a catch crop with lower reductions on the other soil types. In a continuous 19 year trial in a coastal temperate climate on coarse sand soil and sandy loam comparing spring barley preceded by a perennial ryegrass (*Lolium perenne*) catch crop, ploughed during either the autumn or spring, Moller-Hansen and Djurhuus (1997) found that the presence of a catch crop decreased leaching on both soils, and conventional or minimum tillage, by a mean 12-39 kg NO_3-N ha^{-1} per growing season. It was most effective when removed in the spring while autumn tillage increased leaching on sandy loam but not coarse sand. The precise amount is subject to further variables such as annual precipitation and seasonal variation in, for example, excess winter rainfall (the quantity of water intercepted by the soil after it has reached field capacity), determined by the geographic location and year under analysis. Nutrient loss and erosion events peak during the winter and early spring in response to a combination of high precipitation and limited crop cover to assimilate mobilised nutrients (Chambers & Garwood, 2000). To be effective, rapid establishment and coverage of the soil surface to ensure presence by the catch crop during this period of vulnerability is necessary. This is influenced by the type of catch crop, and the sowing date.

A number of crop species and their potential for use as catch crops have been evaluated. Dabney *et al*. (2001) report that grass or brassica cover crops when grown as a single species mix are more effective at removing N than legume crops, however both are more effective when grown in a mixture with legumes. McLenaghen *et al*. (1996) found that a ryegrass catch crop reduced N leaching from 33 kg N ha^{-1} on bare soil (control) to 2.5 kg N ha^{-1}. Both ryegrass and ryecorn (*Secale cereale* var. Rapaki) were more effective than winter field beans (*Vicia faba*) and lupins (*Lupinus augus-tifolius*). The use of field (or faba) beans as a catch crop has been subject to criticism by a number of authors, mainly due to its limited ability to establish ground cover and the N rich residues that increase the risk of N leaching upon removal (see Section 2.2.18). Yeo *et al*. (2014) concur that the most effective species are rye (due to its rapid growth during early growth stages) with 67% and 54% removal of nitrate relative to the baseline for early (September) and late (November) planting respectively. This is followed by barley, a crop that establishes a strong root system during the winter, with a 57% and 38% removal of nitrate, then wheat (41% and 27% nitrate removal). Yeo *et al*. (2014) point out that early planting is essential to maximise the benefit of catch crops, and predict that for every 30 days additional time the cover crop spends growing, nitrate loss is decreased by approximately 2 kg ha^{-1}. Wilson (2012) found that a clover crop sown in September doubles infiltration compared to conventional tillage, reducing the risk of surface run-off and soil erosion but does place emphasis on the benefit of using cover crops in the long term and the time taken for full benefits to be realised i.e. a minimum of 5 years. This concurs with the findings of Staver and Brinsfield (1998) who report significant impacts on groundwater N concentrations after 7 years of continuous cover crops. Askegaard (2011) identified the management of the crop and soil during the autumn as the main factor driving nitrate leaching with nitrate leaching (smallest to largest): catch crop present in autumn and winter (mean 20 kg N ha^{-1}) < cover of weeds/volunteers (mean 30 kg N ha^{-1}) < post stubble cultivation (mean 55 kg N ha^{-1}). Nitrate leaching increase was correlated with the number of autumn soil cultivations.

In southern Europe the impact of cover crops focuses more on the prevention of soil erosion and surface run-off, particularly in vineyards that may often be situated on steeply sloping marginal land (García-Ruiz, 2010). Crop type, as described previously for nitrate leaching, is a significant variable in determining the overall effectiveness. Ruiz-Colmenero (2013) assessed the impact of cover crops on soil erosion in vineyards supplied by rainwater in central Spain. Soil erosion was lower in crops with a permanent cover of purple false brome (*Brachypodium distachyon*) (0.78 t ha^{-1} yr^{-1}) and spring cut winter rye (1.27 t ha^{-1} yr^{-1}) compared to conventional tillage (5.88 t ha^{-1} yr^{-1}). The underlying mechanism attributed to this decrease is a greater abundance of large pore spaces that improve filtration rates by up to 45% in the soil with cover crops relative to tillage. Marques *et al*. (2010) examined the presence of purple false brome (*Brachypodium distachyon*) and winter rye (*Secal cereale*) on soil erosion rates in response to low and high intensity rainfall events in semi-arid Mediterranean systems. The rates of erosion in traditional tilled crops were five times greater compared to a cover crop under low intensity rainfall, however this increased to a magnitude of 30 times greater under high rainfall intensity rainfall. Tilled rows lost an average of 1.1 g m^{-2} yr^{-1} compared with 62 and 70 g m^{-2} yr^{-1} in rows planted with cover crops of winter rye and purple false brome respectively. Both authors agreed that purple false brome was the more effective cover crop, an observation further supported by Ruiz-Colmenero *et al*. (2011) who assessed the impact of four cover crops on soil erosion in Sicilian vineyards. All four cover crops reduced run-off and erosion in comparison to tillage, but by different rates in the following sequence (most to least effective): permanent cover consisting of purple false brome (*Brachypodium distachyon*) (58-93% reduction in soil loss compared to conventional tillage); barley (*Hordeum vulgare*) (mean 82% reduction), winter rye (*Secal cereale*) (mean 57% reduction) and natural regeneration (34% reduction). Ruiz-Colmenero *et al*. (2011) highlight the compromise between maximising the decrease in run-off while minimising the impact on crop yield. Each treatment was also compared with or without a cut in the spring to determine optimal scenarios to maximise run-off reduction but minimise impact on yield. They devised average runoff coefficients (a lower run-off coefficient represents lower run-off) as follows: 5% for tilled soil, 0.9% for permanent covers and 1.4% for cut cover. Under permanent cover there was a 40% associated yield reduction, under natural regeneration a 44% yield reduction, but when barley or rye was cut in the spring, there was a negligible yield reduction. An investigation of the impact of six cover crop treatments on soil erosion in an irrigated vineyard by Novara *et al*. (2011) also found that each cover crop reduced run-off and erosion in comparison to tillage, but again the quantity was dependent on crop type and, more critically, a combination or mixture of species. They established the following sequence (most to least effective): *V. faba* / *Vicia sativa* (-75%), *T. durum* / *V. sativa* (-70%), *Trifolium subterraneum*, *Festuca rubra* / *Lolium perenne* (-66%), *T. subterraneum* / *F. rubra* / *Festuca ovina* and *Triticum durum* (-56%), *Vicia faba* (-40% soil loss compared to tillage). A single species mix of faba bean was deemed least effective of the species examined, similar to the findings of (McLenaghen *et al*., 1996). The efficiency is increased however, at least in this example, when present as a mixture with other species.

Most studies evaluate catch crops as a means of reducing nutrient loss to the environment. Riddle and Bergstrőm (2013) evaluated the impact of catch crops on phosphorous loss and the catch crop as a source of phosphorous in response to plant destruction, albeit as simulated freeze-thaw cycles under glasshouse conditions. This aimed to be representative of potential environmental variables in the most northerly European climates. The leaching of P from plant material grown in clay soil was, as identified for preventing nitrate leaching and soil erosion, dependent on the species used, with greatest quantities measured from chicory (*Cichorium intybus*) (2.6 kg ha^{-1}) > ryegrass (*Lolium perenne*) (2.3 kg ha^{-1}) > oilseed radish (*Raphanus sativus* L.) (2.2 kg ha^{-1}) > honey herb (*Phacelia tanacetifolia* Benth) (1.3 kg ha^{-1}). The authors concluded that there is the potential for a proportion of P to be released from catch crop residues that will be vulnerable to loss to the environment and that soil texture and type of catch crop has a potential impact on the quantity of P entering watercourses in the cooler regions of Europe, although a significant proportion will be retained by the soil itself.

The benefits of cover crops to biodiversity are included in Thomson's (2014) review of cover crops most suitable for the enhancement of avian biodiversity. It also comments on the advantages and disadvantages associated with crop management and the practicalities of their cultivation. The crops, their benefit to resident farmland birds and their management are summarised as follows:

- Sorghum /dwarf grain sorghum (family *Poaceae, Sorghum bicolor*): allows control of broadleaved weeds but no livestock feed value; susceptible to cold, wet summers
- Millet (family *Poaceae, Setaria spp*): suitable for game and small birds; red millet early seed shed, white millet later (Jan); not suitable for heavy, wet soils
- Kale (family *Brassicaceae, Brassica oleracea*): suitable for game and small birds; lasts 2 years; may be hard to establish and is susceptible to flea beetle attack
- Triticale (family *Poaceae, Triticosecale*): suitable for a wide range bird species through to late winter; grows well in poor soils, requires limited supplementary nutrients, good as part of mixture
- Quinoa (family *Amaranthaceae, Chenopodium quinoa*) : easily grown, suitable as a mixture but provides limited cover and does not last beyond December
- Sunflower (family *Asteraceae, Helianthus annuus*): suitable for game and small birds; ideal as a mixture; disadvantage provides limited cover
- Fodder radish (family *Brassicaceae, Raphanus sativus*): suitable for a wide range bird species, rapid growth, ideal in a mixture, seeds slow to ripen so availability late in year; potential competitive dominance over other species in the mixture

Wilson (2012) and Kaspar *et al*. (2008) discuss the benefits of pest and weed control associated with cover crops. Weed control may be instigated by the cover crop, depending on species, via the release of chemicals that supress the growth of other plants, a process known as allelopathy. Species cited specifically to offer potential to supress autumn germinating annual weed species include the Brassicas oilseed radish (*Raphanus sativus* L.), oriental mustard (*Brassica juncea*), and forage radish (*Raphanus sativus*). Pest control may be achieved indirectly through the augmentation of beneficial naturally occurring pest predators. Cover crops may provide winter refugia for predatory beetles such as Carabids which allows the beetles to enter the crop early in the year before the pest has the opportunity to increase in number (Holland *et al*., 1999; 2005). The provision of a nectar source in the spring and summer encourages adult hoverflies (Syriphids) to enter the crop and lay their eggs. These then develop into predatory larvae which again, offer potential to supress pest numbers. Certain cover crops of the mustard family are cited to have potential nematicidal properties (Kaspar *et al*., 2008). A further reference to the crop disease reduction potential of brassicas is also made by Kaspar *et al*. (2008) although the study does not identify which diseases specifically. An improvement to soil conditions and enhancement of soil macro and micro-organisms, through the return of additional biomass upon destruction of the cover crop is cited by Dabney *et al*. (2001) to increase crop vigour and health, and reduce crop susceptibility to pests and diseases.

The inclusion of a cover crop requires an additional sowing operation and an operation to remove it again during the late winter or early spring, a potential issue where machinery needs to access heavier soils while wet (Moller-Hansen & Djurhuus, 1997), although such soils tend not to be at risk to nitrate leaching. A delay in autumn harvest also renders a cover crop impractical due to the requirement to sow it as early as possible to be effective (Wilson , 2012; Yeo *et al*., 2014). Establishment may also require an initial intensive seedbed preparation e.g. de-stoning (Wilson, 2012). Cover crop mixtures with different rooting profiles (e.g. tap roots to break up the soil, others to add organic matter or fix N) are deemed to be more beneficial than a single species mix. Kaspar *et al*. (2008) recommends the use of oat, winter wheat, barley, triticale, and winter rye since they grow rapidly in cool weather, are frost hardy and low cost. The authors also suggest the potential use of non-frost hardy varieties as an alternative to removal by shallow tillage or herbicide in the spring where they assimilate a proportion of the surplus N during the autumn, and are then destroyed by cold weather during the winter. This option would eliminate the risk posed by entering problematic soils.

2.2.18. Nitrogen fixing crops

Title:	Areas with nitrogen fixing crops
Description:	These are areas of crops, such as legumes, that fix nitrogen from the atmosphere into the soil. Members states will specify a list of species that can be grown (considered as contributing to the objective of improving biodiversity). Those crops shall be present during the growing season. Member States may establish additional conditions notably with regard to production methods. Member States shall establish rules on where nitrogen-fixing crops qualifying as ecological focus area may be grown. These rules shall take into account the need to meet the objectives of Directive 91/676/EEC and Directive 2000/60/EC, given the potential of nitrogen-fixing crops to increase the risk of nitrogen leaching in the autumn.
No. of MS activated:	31
Dimension limits:	None
Implementation rules:	Species specified, varies with MS. Other conditions include: mandatory sowing and/or cultivation period, mandatory follow-up crop/fallow, conditions for ploughing, cutting, grazing, conditions/prohibition of fertilisers or pesticides, threshold for NFC as EFA, neighbouring elements (e.g. field margins are required in Scotland), and varies with MS.

Nitrogen fixing crops listed for use in EFAs include faba bean (*Vicia faba*), pea (*Pisum spp*), alfalfa (*Medicago*), lupin (*Lupinus*) and clover (*Trifolium*) (faba bean and clover are also reviewed in Section 2.2.17). The value of a particular plant species to pollinators depends in part, on the morphology of the flower combined with size of the pollinating insect and morphological adaptations to, for example, the mouthparts (Goulson *et al*., 2005). A review by Kirk and Howes (2012) summarises the value of individual flowering plant species to bees, including bumblebees (as a function of morphological adaptations to tongue length), honeybees and solitary bees. The value of potential species for selection within EFAs are summarised as follows:

- Red clover (*Trifolium pratense*) is especially suitable for long tongued bumblebee species, although they are also suitable for short tongued species. It will be utilised by honeybees but is not as valuable a resource as white clover (*Trifolium repens*).
- White clover is suitable for a range of bumblebee species, both short and long tongued, and honeybees.
- Both clover species are acknowledged as having potential value to solitary bees although there is greater uncertainty due to lack of data.
- Field or faba bean (*Vicia fabia*) is suitable for both short and long tongued bumblebee species, honeybees and solitary bees. Köpke and Nemecek (2010) acknowledge the potential for faba beans to provide nectar for bumble bees with specific reference to long tongued species (*Bombus pascuorum* and *B. hortorum*) able to reach the nectar directly from the corolla but that they may be subject to nectar removal without pollination by short tongued bumblebee species that pierce the base of the flower to feed. This also allows honeybees to gain access.
- Pea (*Pisum spp*) with specific reference to garden pea (*Pisium sativum*) considered to be of negligible value to bees, with only occasional visits to flowers observed.
- Alfalfa (*Medicago*) also known as Lucerne (*Medicago sativa*) is attractive to long tongued bumblebees, especially the common carder bee (*Bombus pascuorum*) and solitary bees such as the blue mason bee (*Osmia caerulescens*), although less so to honeybees and short tongued bumblebee species.
- Lupin (*Lupinus*) with reference to three species: white lupin (*Lupinus albus*), blue lupin (*Lupinus angustifolius*) and yellow lupin (*Lupinus luteus*); attractive to honeybees and short tongued bumblebee species, less so to long tongued bumblebees and solitary bees. The long flowering period of 4 to 6 weeks is beneficial however there is some uncertainty regarding the quantity of nectar produced.

Within the EFA element guidelines clover is grouped as a single entity, no differentiation is made between individual species (red or white), where a potential difference in value may exist to different pollinator groups.

The impact of N fixing crops on water quality is influenced by the species grown, with faba bean (*Vicia faba*) in particular subject to a number of analyses in which it has been identified as a potential risk to increasing nitrate leaching within a crop rotation. Entrup and Stemann (1990) found that between 110-140 kg ha^{-1} of nitrate may be leached during a winter wheat crop following faba beans, mainly due to the rapid mineralisation of high N content residues post-harvest (Jensen *et al*., 2010). Faba beans have the highest dependence on N_2 fixation for growth (they fix the greatest quantity of N) compared to other grain legumes from temperate climates (Jensen *et al*., 2010). As such, they do not extract residual nitrate from the soil, increasing the risk of accumulation of soil nitrate. Justus and Köpke (1995) also cite their weak allorhizal tap root system (a root that penetrates the soil vertically and has horizontal secondary roots) coupled with low root density and rooting depth, as features of the crop that increases the risk of nitrate leaching when it is grown as a single species mix. Jensen *et al*. (2010) conclude that preventive measures, e.g. catch crops, intercropping, or minimum or zero tillage, are necessary to minimise potential detrimental impacts on water quality. Jensen *et al*. (2010) present an example of faba bean undersown with cock's-foot grass (*Dactylis glomerata*) or winter ryegrass immediately after sowing or emergence, where soil nitrate is reduced from 144 kg ha^{-1} to 32-72 kg ha^{-1}, coupled with a negligible impact on yield. Contrary to the recommendations of Jensen *et al*. (2010), Köpke and Nemecek (2010) cite faba beans as a potentially problematic option to use with minimal tillage due to its poor competitive ability with weeds. They suggest the use of intercropping, or deep-rooting brassicas in a catch crop capacity instead with spring oats and spring barley found to be effective as intercrops, reducing nitrate leaching by 37-50% and 45-59% respectively. Maize, when positioned so that the maize / faba bean root zones overlap either partially or completely, increased surplus N uptake by 20%. Aufhammer (1992) found that winter rapeseed (*Brassica napus*), barley (*Hordeum vulgare*) and ryegrass (*Lolium perenne*) as catch crops all reduced N loss but that their effectiveness depended on the faba bean growth stage when sown, and the extent of its canopy cover development. Sowing during the flowering period was not recommended due to the spatially variable cover crop establishment.

The impact of clover (*Trifolium* spp.) on nitrate loss while actively growing is derived from a combination of studies on grassland and leys on cultivated land. Cuttle *et al*. (1992) report losses of 2-24 kg N ha^{-1} from ryegrass fertilised with 150-200 kg N ha^{-1} and 6-33 kg N ha^{-1} from an unfertilised ryegrass / white clover pasture respectively after 3 years. Stopes *et al* (2002) found leaching of nitrate to be similar between the grass/clover ley of an organic rotation (45 kg N ha^{-1}), long-term grassland in receipt of <200 kg N ha^{-1} (44 kg N ha^{-1}) and a grass ley under conventional management (50 kg N ha^{-1}). A number of studies focus on nitrate concentrations post-removal by incorporation, when much of the nitrate is released from the mineralisation of organic N derived from the residues (Macdonald *et al*., 1989). This is a common theme running through the impact on water quality of the N-fixing crops permitted within EFAs other than faba bean, and the associated risk to environmental loss via leaching. The timing of the removal of a grass/clover ley and the type of crops that follow are a key factor according to Djurhuus and Olsen (1997). N leaching from a grass/clover ley followed by a winter wheat crop, then either spring barley or winter rye was variable, between 3-84 kg N ha^{-1} yr^{-1} in response to 150-250 kg N ha^{-1} of supplementary N. Leaching was reduced, especially on coarse sand soils when the ley was removed in spring compared to late autumn, and when the second crop after removal of the N-fixing crop was winter rye compared to spring barley. The winter rye crop avoided a fallow period during the winter. Kaspar *et al*. (2008) assessed the use of legumes as cover crops and, although they accumulate less N during the winter, they will assimilate surplus N if present. When N is present, clover does not fix N, rather it assimilates residual N within the soil.

Nitrate leaching may continue from leguminous crops, the quantity while the crop is growing relative to non-legumes grown under 'good practice' varies depending on the crop, its ability to establish ground cover and the rooting system. Alfalfa (*Medicago*), if allowed to grow for more than one year may produce potentially deep rooting systems (Mathers *et al*., 1975) that permits removal of residual soil nitrate to a depth of 1.8m after 1 years growth, increased to 3.6m after 2 years. The inclusion of alfalfa within a rotation of continuous corn reduced nitrate leaching during crop growth from 55-81 kg N ha^{-1} during the previous corn crop, to 9 kg N ha^{-1} (Toth & Fox, 1998). In a similar manner to other N-fixing crops, the release of nitrate from the mineralisation of root and shoot material followed its destruction by glyphosate, when 75 kg N ha^{-1} leachate was measured by Kavdir *et al*. (2005). The timing of the removal of the N-fixing crop and the type of crop that follows is critical in minimising nitrate loss at this stage. The loss of nitrate during the growth of lupin crops (*Lupinus* spp.) was found to be higher, although not significantly, than from ryegrass, mustard and ryecorn in a study in New Zealand (McLenaghen *et al*., 1996). It was however, significantly less than faba bean and an unsown control. Although reported as a possible cause of increased N leaching (Entrup & Stemann, 1990; Jensen *et al*. 2010; Köpke & Nemecek, 2010), faba bean and its tap rooted system may improve soil infiltration however Köpke and Nemecek (2010) consider the evidence at the time of writing as inconclusive due to apparent low percent root penetration on compacted soils compared to safflower, lupins and peas. The use of Austrian winter pea (*P. sativum arvense*) as a green manure in a rotation consisting of winter wheat and spring pea (*Pisium sativum*) was reported by Reganold (1987) to increase soil organic matter levels and decrease topsoil erosion by 16cm over a 38 year period compared to a rotation without. The impact on N loss is not reported by Reganold (1987) although Hauggaard-Nielsen *et al*. (2003) found no significant difference in cumulative NO_3^- leaching between barley, pea and a barley-pea intercrop 18 months after their removal.

Köpke and Nemecek (2010) note the susceptibility of faba bean to weed infestation and the opportunity to reduce this susceptibility through the use of species mixtures. Intercropping with spring barley or wheat reduced weed density and weed biomass compared to faba bean crop alone (also has positive implications for reducing the risk of nitrate leaching). Finn *et al*. (2013) found that weed suppression in clover crops was also more effective when part of a grass mixture. Lupin is reported by Kruidhoff *et al*. (2008) as a poor competitor with weeds, exerting little suppressive effect while growing but some allelopathic impact is observed post incorporation of residues, although this is not as great as lucerne or winter oilseed rape. The allelopathic impact of alfalfa was found by Chung and Miller (1995) to be highly species specific. Both germination and seedling growth of *Abutilon theophrasti* were inhibited, and seedling growth of *Chenopodium album*, *Amaranthus retroflexus* and *Digitaria sanguinalis* suppressed in response to the application of alfalfa extract. Crop pathogens may be affected by N-fixing crops after their incorporation, the precise impact of which is dependent on the species of crop (Conklin *et al*. 2002). Although not directly applicable to the growth phase of the N-fixing crop, it has implications for their potential removal and/or re-establishment. The widespread soil pathogen *Pythium*, responsible for the rot of seeds and roots, and the 'damping off' of seedlings, was found to increase after the incorporation of common vetch (*Vicia sativa*) and crimson clover (*Trifolium incarnatum*) but declined after green pea (*Pisum sativum*) (Conklin *et al*. 2002). Austrian winter pea may supress Verticillium wilt (*Verticillium dahliae*) (Ochiai *et al*. 2008). Another soil borne pathogen (*Sclerotinia minor*) infects both lettuce crops and winter pea (Koike *et al*., 1997) but does not infect faba bean (or oilseed radish or barley).

2.3. Whole landscape perspective

Section 2.2 considered the biodiversity and ecosystem services value of each particular EFA element in isolation. However, it is evident that the value of habitats can only be maximised if there is good connectivity between habitats on the farm and the farm level landscape structure is heterogeneous (Morandin & Kremen, 2013; Benton *et al*., 2003; Wolton *et al*., 2013; Menz *et al*., 2011; Hunter, 2002; Shackleford *et al*., 2013; Bailey *et al*., 2007; Le Coeur *et al*., 2002). These two issues appear to be of equal or greater importance than the value of any single habitat in isolation.

Farmland heterogeneity, meaning where there are different fields connected by a variety of non-cropped habitats (e.g. woodlands, ponds, wetlands etc.) and wildlife corridors (i.e. linear features such as hedges, walls and tree lines), aids species abundance, diversity and persistence as well as helping to manage predatory-prey interactions (Hunter, 2002; Bailey *et al*., 2007). For example a positive relationship between the abundance of butterflies and farmland heterogeneity has been identified particularly at scale of greater than 5 km in diameter (Benton *et al*., 2003). Similarly Hinsley and Belamy (2000) found that hedgerows do not serve bird populations well in isolated patches. Connectivity between patches was vitally important. Wolton *et al.* (2013) reported that there is good evidence for the importance of habitat connectivity to vertebrates, as navigational aids and for commuting between breeding and foraging sites. There is, however, comparatively little evidence that connected linear features such as hedgerows are important corridors for mammal dispersal.

Whilst hedgerows can serve as a valuable corridor facilitating the movement of fauna from one habitat to another and so broadening distribution hedgerows do not always act in this way when it comes to flora. An early paper by Helliwell (1975) reports a study of the distribution of vascular plant species in hedgerows and concluded that woodland plant species did not spread easily throughout the hedgerow network.

As mentioned in Section 2.2.8, ponds also interact extensively with the aquatic and terrestrial environments which surround them (Céréghino *et al.*, 2014; Miracle *et al.*, 2010; Biggs *et al.*, 2000). Emerging insects for example, may go on to utilise the surrounding geographical area during their adulthood, despite being aquatic whilst immature, are therefore both influenced by the properties of that area, and in providing a valuable food source (e.g. for birds, bats, etc. - Céréghino *et al.*, 2014; Kalda, 2015) have a significant impact on non-aquatic biodiversity. Equally, other groups (such as amphibians) may use ponds as both habitats per se (i.e. for breeding), and as vital stepping-stones for movement around the landscape and/or as refuges for the recolonization of the wider environment, particularly within in areas where other suitable habitat may be limited (i.e. intensively farmed landscapes - Nicolet *et al*., 2007). This connectivity to their surroundings however, means that the ecological value of ponds is prone to damage through processes occurring within their catchments, including those specifically related to intensive agricultural production, such as nutrient enrichment, pesticide contamination, sedimentation (as a result of elevated rates of erosion), water abstraction and/or direct damage by livestock (Biggs *et al.*, 2005; Nicolet *et al.*, 2007; Céréghino *et al.*, 2008; Miracle *et al.*, 2010). Indeed, the small size of ponds makes them particularly vulnerable to damage, since the scope for impact buffering through, for example, dilution of pollutants, is extremely limited.

It has also now become clear that pond networks (i.e. ponds sufficiently close together to be linked such that organisms may move between them) are extremely important (Miracle *et al.*, 2010), allowing as they do for the movement of species between them, and for the provision of a range of habitats to the overall benefit of species diversity (Ribeiro *et al.*, 2011). It has, for example, been noted that although large ponds generally contain a greater number of species than equivalent small ponds, a network of varying small ponds may contain more (and a greater variety) than a large pond with the same surface area (Oertli *et al.*, 2002). A fundamental characteristic of natural pond systems, is a variety of pond types and sizes, providing a wide range of habitats, and species moving between ponds at different points in their life-cycle or in response to environmental (e.g. climatic) pressures (Jeffries, 2005). In so doing, their capacity for adaptation is increased, which given the scope for damage (short or long term) to pond environments posed by natural and anthropogenic processes, increases their long-term chances of survival. Ensuring that species have the environments they require (particularly in light of relative unknowns such as climate change impacts) is difficult, so it has been suggested that we should concentrate on ensuring that a network of ponds (albeit not physically linked) with different properties exists, thereby providing species with the opportunity to take care of themselves (Jeffries, 2005).

Equal consideration should also be given to the surrounding terrestrial habitats, since the importance of water quality is now widely recognised (e.g. Natural England, 2010); indeed some sources suggest that a waterbody may only remain in good condition until agricultural land exceeds 30-50% of its catchment, something which is likely to be very common in many parts of the EU (Davies *et al.*, 2008, 2009). Where particular species are to be targeted (e.g. Great crested newt - *Triturus crestatus*) then a holistic, landscape scale, approach becomes even more important, as it is necessary to ensure that all the required habitats (both aquatic and terrestrial) are present, and that they are sufficiently 'connected' to allow for species needs, preferably targeting areas in which there is the maximum chance of success (e.g. close to colonisation sources in clean catchments - Rannap *et al.*, 2009). Even related species however, may have very different needs and be influenced by factors occurring on different scales. Raebel *et al.* (2012) for example, identified that dragonflies (*Anisoptera* spp.) were influenced by landscape variables at a radius of around 1600 m, whereas their less mobile relatives the damselflies were influenced at a smaller 100-400 m radius scale; something they suggested might make current conservation policies (often implemented very locally – i.e. a pond and its immediate surrounds) more beneficial to damselflies than dragonflies. It is fortunate then, that the small scale of many pond catchments (which contrasts markedly with those for many other waterbodies – Davies *et al.*, 2008), means that the potential for the protection of ponds through agricultural de-intensification, may be relatively high (Biggs *et al.*, 2005; Céréghino *et al.*, 2008).

There may also be interactions and connectivity issues to be considered between cropped areas and landscape features. As described in above (Sections 2.2.1 and 2.2.15 to 18) areas of fallow, short-rotation coppice, afforested areas, catch/cover crops, and nitrogen fixing crops, for example, all have a number of potential benefits (and burdens in some instances) for biodiversity and ecosystem services. In some instances there may be synergies or trade-offs with the functional impact of other landscape features. As such a holistic perspective may be necessary to enhance or maximise the synergies and minimise the trade-offs. This may be in respect of the combinations of EFA elements (spatially and temporally on a farm) and their design and management.

3.0. Impact assessment (establishment of criteria and guidelines)

3.1. Introduction

The objective was to define criteria, rules and guidelines that will facilitate the comparison of different EFA elements within the EFA calculator with respect to their performance in relation to positive and negative impacts on ecosystem services, biodiversity and management, in the context of a specific farm and environment. Much of the information and data required to make this assessment was collated and synthesised in the literature review (Section 2). However, this information was unstructured and not harmonised, thus is not in a form that could be directly used to underpin the EFA calculator software. In order to convert the information into a form that can be used in the calculator an impact assessment framework was required, and once the framework was established the information collated and synthesised in the literature review (Section 2) could be processed.

Annex C describes the work that was undertaken to develop the impact assessment framework. This section describes the framework that has been developed to process the information in the literature review (Section 2) and provides an overview of the impact criteria, rules and guidelines that have emerged and which are used to underpin the EFA calculator software.

3.2. The impact assessment framework

3.2.1. Introduction

There are three components to the assessment framework:

- EFA elements and farm features
- Impact categories
- Parameters and parameter classes

Each EFA element has one or more farm features, and each feature has one or more potential positive and negative impacts on ecosystem services, biodiversity and management. Each potential impact is quantified using scoring system (see Section 3.2.5), and parameters and parameter classes are used to determine variations in potential impact.

3.2.2. EFA elements and farm features

In Section 2, each individual EFA element was reviewed. However, during the development of the impact assessment framework it became apparent that some EFA elements consist of two or more farm features, and it is these features that are assessed using the impact assessment framework. For example, in Scotland, the EFA element 'Field margins' can just be a vegetated strip of land, but it can also include a 2m wide ditch and a 3m wide hedge (Scottish Government, 2014). Vegetated strips, hedges and ditches are all features in themselves, and each can have its impact assessed individually (as opposed to assessing the impact of a field margin as whole). Consequently the impact of the EFA element is determined by the selection of the features that make up that element.

The features are (many of which directly correlate with EFA elements):

- Agroforestry
- Ancient monuments
- Land strips (adjacent/parallel to water)
- Land strips (other)

- Ancient stones
- Archaeological sites
- Catch crops or green cover
- Ditches
- Fallow land
- Garrigue
- Hedges or wooded strips
- Isolated trees
- Natural monuments
- Nitrogen fixing crops
- Ponds
- Short rotation coppice
- Terraces
- Traditional stone walls
- Trees in line
- Woodland

Table 3.1 shows how the features relate to EFA elements (note: this can vary between Member States, thus Table 3.1 is a summary for the whole of Europe).

Table 3.1: EFA Element features

EFA Element	Feature
Fallow land	Fallow land
Terraces	Terraces
Hedges or wooded strips	Hedges or wooded strips
Isolated trees	Isolated trees
Trees in line	Trees in line
Trees in groups and field copses	Woodland
Field margins	Land strips (adjacent/parallel to water)
	Land strips (other)
	Hedges or wooded strips
	Ditches
Ponds	Ponds
	Land strips (adjacent/parallel to water)
Ditches	Ditches
Traditional stone walls	Traditional stone walls
Other landscape features	Ancient monuments
	Ancient stones
	Archaeological sites
	Garrigue
	Hedges or wooded strips
	Isolated trees
	Natural monuments
	Ponds
	Terraces
Buffer strips (GAEC1, SMR1 or SMR10)	Land strips (adjacent/parallel to water)
Buffer strips (Other)	Land strips (other)
Agroforestry	Agroforestry
Strips along forest edges (NO PRODUCTION)	Land strips (other)
Strips along forest edges (WITH PRODUCTION)	Land strips (other)
Short rotation coppice	Short rotation coppice
Afforested areas	Woodland
Catch crops or green cover	Catch crops or green cover
Nitrogen fixing crops	Nitrogen fixing crops

3.2.3. Impact categories

There are three 'top level' impact categories (as specified in the project tender specification document):

- Ecosystem services: pollination, pest control, water quality control and soil erosion covered as a minimum, but others have also been added where information exists
- Biodiversity: maintenance and enhancement
- Management: ease of implementation, management and control

As described in Annex C, there is an impact hierarchy for each of these top level impact categories. For ecosystem services, the Common International Classification of Ecosystem Services (CICES) system (Haines-Young & Potschin, 2013) has been used. The CICES structure has been followed, with the addition of 'Nitrate leaching' and 'Phosphate run-off' as sub-classes under 'Chemical condition of freshwaters', to account for the different nature of these effects in relation to this ecosystem service.

For biodiversity, the European Nature Information System (EUNIS) species groups (EEA, 2015b) as a starting point, on the basis that these will aid interpretation in the software. The same hierarchy as ecosystem services (Section > Division > Group > Class) has been used, albeit there are no impact categories at the class level. The classification evolved as the impact assessment proceeded, with species/groups created as they were found in literature (from Section 2).

For management, there is a more simple set of categories, designed to capture the potential burden on farm management. The same hierarchy as ecosystem services (Section > Division > Group > Class) has been used, but as the number of impact categories is limited the hierarchy only goes down to the Section level.

3.2.4. Parameters and parameter classes

For each feature-impact combination the impact is scored (see Section 3.2.5 and Section 3.3 for examples) using a set of parameters and parameter classes. A parameter is an attribute associated with the feature, e.g. soil texture, which when changed can result in a difference in the impact. Classes within each parameter have been determined in order to assign different impact values for different conditions for each parameter. Classes can be qualitative or quantitative, with the latter usually consisting of bands, e.g. class 1 = 0 to 10; class 2 = 11 to 20, etc. These parameters and classes have largely been derived from the literature (Section 2).

There are currently 138 parameters, with a total of 702 classes. Annex E lists all the parameters and parameter classes that have been used. The combination of impacts and parameters for each feature effectively forms an impact matrix. The impact matrices for each feature are shown in Section 3.3.

3.2.5. Scoring impacts

3.2.5.1. Introduction

All the impacts have been scored on a scale of -100 to +100. The negative and positive values are used to reflect whether the impact is positive or negative, and then the score is used to reflect the relative impact of the feature in relation to the impact.

There are two approaches to scoring impacts (see Figure 3.1):

- Approach 1: a quantitative approach, which draws upon meta-modelling. A score is awarded for each possible combination of parameters, e.g. using Figure 3.1: A-F-G = 10; A-F-H = 15; A-F-I = 10.

- Approach 2: a qualitative approach, which is similar a risk factor approach, where by scores are awarded for each class, then the scores for the classes selected are summed and weighted for each parameter, e.g. using Figure 3.1: Impact B would score 5 for Class J and -75 for Class N, and these would then be summed using the weightings (W) for Parameters 7 and 9 (resulting in overall score of -22, due to the greater weight given for Parameter 7).

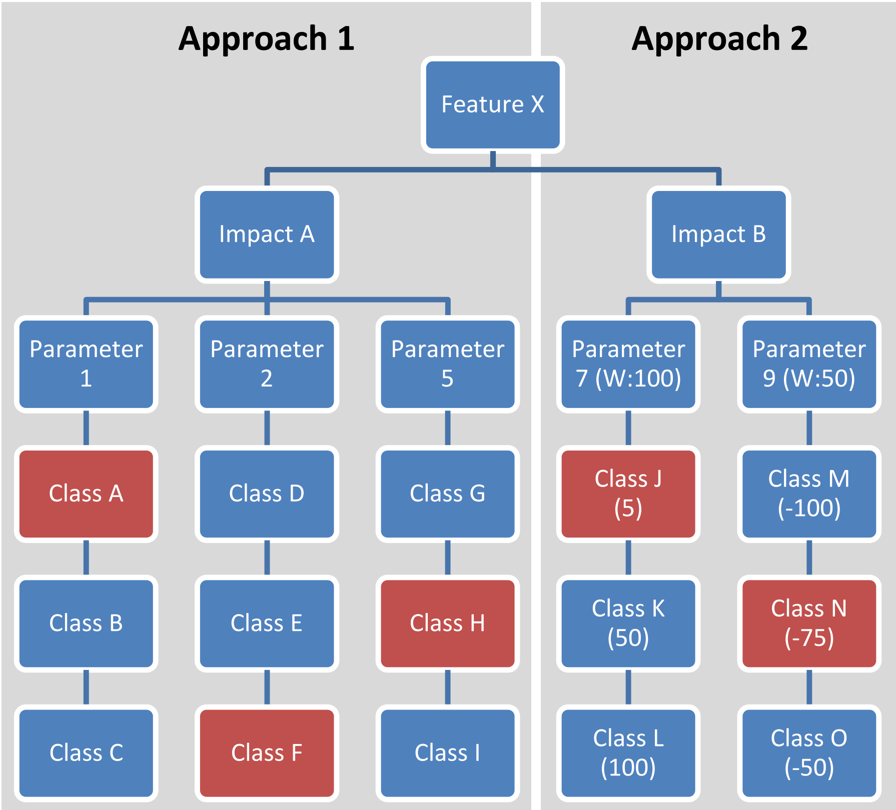


Figure 3.1: Overview of scoring concept

Each approach is described in detail below (Sections 3.2.5.2 & 3.2.5.3). Each feature is scored for an impact at the appropriate level in the impact hierarchy as can be determined from the literature. Thus for very specific impacts this is normally done at the class or group level. For example, ditches have impacts on Aesthetic services; Chemical condition of freshwaters; Flood protection; and Pollination and seed dispersal. The impacts are then aggregated (see Section 3.2.6) to derive the impact for division and section level impact categories, and also the top level impact categories. Table 3.2 shows an example of this aggregation hierarchy for the ditches example mentioned above.

Table 3.2: Example of impact aggregation hierarchy: Ditches-ecosystem services

Section	Division	Group	Class
Regulation & Maintenance	Mediation of flows	Liquid flows	Flood protection
	Maintenance of physical, chemical, biological conditions	Lifecycle maintenance, habitat and gene pool protection	Pollination and seed dispersal
		Water conditions	Chemical condition of freshwaters
Cultural	Physical and intellectual interactions with biota, ecosystems, and land-/seascapes	Intellectual and representative interactions	Aesthetic

3.2.5.2. Quantitative (meta-model) approach

The quantitative approach has been used for a limited number of impact assessments, including:

- Provision of water for as a material
- Provision of water for nutrition
- Flood protection
- Global climate regulation by reduction of greenhouse gas concentrations
- Nitrate leaching
- Phosphate run-off
- Mass stabilisation and control of soil erosion

Models or quantified data were used to derive quantities of water, carbon, nitrate, phosphate and soil for all the possible combinations of the relevant associated parameters. These values are then converted onto the scale of -100 to +100 using a calibration table. Table 3.3 shows an extract of this data (as it is not practical to display all 375 combinations here) for the impact of fallow land on mass stabilisation and control of soil erosion. Table 3.4 shows the calibration data that have been used to covert quantitative data on tonne of soil erosion per year onto -100 to +100 scale (note: all the data are negative as it is a case minimising a negative impact).

Table 3.3: Impact of fallow land on mass stabilisation and control of soil erosion (data extract)

Slope	Soil texture	Annual rainfall	Ground cover (fallow)	Value
Flat	Coarse	Very high (>765 mm)	None (bare soil)	-1.1
Moderate	Coarse	Very high (>765 mm)	None (bare soil)	-6.3
Steep	Coarse	Very high (>765 mm)	None (bare soil)	-26.3
Flat	Medium	Very high (>765 mm)	None (bare soil)	-2.8
Moderate	Medium	Very high (>765 mm)	None (bare soil)	-17
Steep	Medium	Very high (>765 mm)	None (bare soil)	-71
Flat	Medium fine	Very high (>765 mm)	None (bare soil)	-4
Moderate	Medium fine	Very high (>765 mm)	None (bare soil)	-24
Steep	Medium fine	Very high (>765 mm)	None (bare soil)	-100
Flat	Fine	Very high (>765 mm)	None (bare soil)	-3.1
Moderate	Fine	Very high (>765 mm)	None (bare soil)	-18.6
Steep	Fine	Very high (>765 mm)	None (bare soil)	-77.4
Flat	Very fine	Very high (>765 mm)	None (bare soil)	-1.6
Moderate	Very fine	Very high (>765 mm)	None (bare soil)	-9.3
Steep	Very fine	Very high (>765 mm)	None (bare soil)	-38.8

Table 3.4: Calibration data for mass stabilisation and control of soil erosion

Score	t/ha/yr
-100 to -51	>100
-50 to -46	91 to 100
-45 to -41	81 to 90
-40 to -36	71 to 80
-35 to -31	61 to 70
-30 to -26	51 to 60
-25 to -21	41 to 50
-20 to -16	31 to 40
-15 to -11	21 to 30
-10 to -6	11 to 20
-5 to -0.5	1 to 10
-0.4 to 0	0

The same calibration data has been used for all features that have these impacts. As such, the feature with the greatest impact formed the basis for the range in the calibration. By using the same calibration data, the impact of each feature is directly comparable.

3.2.5.3. Qualitative (risk factor) approach

The qualitative approach has been used for the majority of feature-impacts. There are two variations of the approach:

- Automated: Where scores are awarded for each parameter class and each parameter is given a weight to account for the relative significance of that parameter, thus an overall score for any particular combination of parameter classes can be automatically calculated (using Equation 3.1).
- Manual: Where all possible combinations of parameter classes are generated and then each combination is awarded a score. This approach is used when a particular parameter or parameter class changes the impact score in way which cannot be accounted for using class scores and parameter weights, for example if a parameter classes switches the impact from positive to negative, or where a parameter class has an overriding effect such as limiting any potential impact.

The automated approach uses Equation 3.1 to determine the overall impact score. Each parameter is given a weighting between 0 and 100 and each class is given a score between -100 and +100. When the classes have been selected, the score for each class is then weighted using the parameter weight as a proportion of the sum of all the parameter weights, resulting in an overall score between -100 and +100.

$$Impact\ Score = \sum\left(class\ score_n \times \left(\frac{Parameter\ weight_n}{\sum(Parameter\ weights)}\right)\right) \qquad \text{[Equation 3.1]}$$

Table 3.5 shows the parameter weights and class scores that have been assigned for the impact of fallow land on reptiles.

Table 3.5: Parameter weights and class scores for the impact of fallow land on reptiles

Parameter	Weight	Class	Score
Adjacent vegetation structure	100	Large area (>1ha) of rough grassland, scrub, hedges or woodland	100
		Small area (<1ha) of rough grassland, scrub, hedges or woodland	67
		Short closely grazed grassland or arable crops	10
		Large areas of bare ground	0
Adjacent wildlife corridors	100	Diverse and complete linear features	100
		Uniform linear features with gaps	50
		No linear features	0
Ground cover (fallow)	100	None (bare soil)	0
		Natural regeneration	67
		Sown bird seed mix	5
		Sown wildflower	35
		Sown grass only	67
South aspect	100	>75% faces south	100
		50-75% faces south	67
		25-50% faces south	25
		<25% faces south	0
Topography	100	Banks, ridges, hollows or hummocks	100
		Mostly uniform	0

As described above, in some instances the automated approach to calculating the score is not appropriate. In these instances a more manual technique has been taken. The manual technique is similar to the quantitative (meta-model) approach (see Section 3.2.5.2) in that all possible combinations of parameter classes need to be assigned a score. This method has been applied for the following features and impacts:

Hedges or wooded strips and Trees in line

- Pesticide drift
- Filtration/sequestration by flora and fauna

Terraces

- Aesthetic services
- Provision of water for as a material
- Mass stabilisation and control of soil erosion

Traditional stone walls

- Fungi
- Invertebrates: Bees
- Invertebrates: Beetles (carabids)
- Invertebrates: Butterflies and moths
- Invertebrates: Dragonflies and damselflies (Odonata)
- Invertebrates: Hoverflies and hoppers
- Invertebrates: Pollinating invertebrates
- Small mammals (mice, shrews, voles)
- Terrestrial plants: Ferns

- Terrestrial plants: Mosses and liverworts

For example, the impact of terraces on mass stabilisation and control of soil erosion has four parameters: Soil texture; Annual rainfall; Gradient; and Terraces are regularly maintained. The latter has simple Yes/No classes. If Yes is selected, terraces are given a positive impact for mass stabilisation and control of soil erosion. However, if No is selected, then the score is inversed and a negative impact is awarded (on the basis that terraces which are not maintained can result in increased soil erosion, whereas those which are maintained will reduce soil erosion).

Finally, a disadvantage of the qualitative approach is that the scores that emerge from the process for different features for the same impact are not directly comparable – they are only relative for comparing the potential impact of the same feature with different attributes (parameter classes). To overcome this issue an additional level of calibration has been developed, known as Cross Feature Calibration (CFC). The CFC provides a facility to increase/decrease the relative importance of different features for each impact. In many instances this information may not be known, so the CFC is set to 1 for all features, but in other instances it may be known and/or an estimate can be made for the relative importance of one feature compared to another. Table 3.6 shows the CFC for reptiles, where an attempt has been made to differentiate the importance of the features for reptiles.

Table 3.6: Cross feature calibration for reptiles

EFA Element	CFC Weight
Agroforestry	0.5
Ancient stones	0.3
Catch crops or green cover	0.5
Fallow land	0.7
Garrigue	1
Isolated trees	0.7
Land strips (adjacent/parallel to water)	0.7
Land strips (other)	0.7
Nitrogen fixing crops	0.5
Short rotation coppice	0.5
Terraces	0.8
Traditional stone walls	1

3.2.6. Aggregation techniques

In order to facilitate the communication of impacts within the software, a means of aggregation is required. The aim is to simplify data and information to aid decision making whilst not losing important detail or transparency. In this instance it is about aggregating information up the 'Section > Division > Group > Class' hierarchy.

Two approaches were explored: (i) all impacts for each top level impact are summed regardless of level; (ii) impacts are averaged up the hierarchy. The second approach was favoured, as the first results in bias, with higher scores for those impact categories which have a larger number of sub-divisions, groups and classes.

With respect to the selected methodology, firstly, positive and negative impacts are averaged and aggregated separately. This is to avoid potential negative impacts becoming hidden by being 'cancelled out' by positive scores (and vice versa). Secondly, a weighting can be applied to the averaging/aggregation process. By default they are all set to 100, but the user (within the settings section of the software – see Section 4.8) can adjust these if they wish to increase/decrease the importance of any particular impact category. For example, the user may wish decrease the weight attached to cultural ecosystem services (compared to provisioning and regulation and maintenance services); or they may wish to focus on enhancing biodiversity for birds. Finally, the aggregation process starts at the class level (or sub-class in the case of ecosystem services) and then works up the hierarchy. As impacts have been scored at different levels the averaging process takes account of scores awarded directly to an impact category and any sub-categories (which may themselves have sub-categories). Thus the aggregation process starts at the bottom and then works up the hierarchy transferring the aggregated data at each level to the next level. The average is calculated as the sum of the impact scores on the impact category itself and the scores for the sub-categories, and then divides the total sub-categories plus one (thus accounting for the impact category and its sub-categories). The aggregation process potentially results in 6 values, i.e. positive and negative values for ecosystem services, biodiversity and management.

3.2.7. Additional ranking impact categories

Within the EFA calculator software there is a facility to rank farm features (see Section 4.6), in the context of creating new features for EFA, based on their potential impact. This uses the scoring system described above to rank features that could be created on the farm. The user can accept the default criteria to rank the features, which are the top level impact categories of ecosystem services, biodiversity and management, or they can select custom criteria (a combination of any impact categories). There are also two prototype ranking criteria that user can invoke (using the options and settings). These are:

- Land taken out of production
- Feature diversity index (FDI)

The land taken out of production criterion is relatively simple. If the feature being created removes land from agricultural production then it is awarded a negative score (i.e. -100), and if it does not remove the land from the production then it scores zero. The features that potentially remove land from production are:

- Ditches
- Fallow land
- Garrigue
- Hedges or wooded strips
- Isolated trees
- Land strips (adjacent/parallel to water)
- Land strips (other)
- Ponds
- Traditional stone walls
- Trees in line
- Woodland

The second additional criterion, the feature diversity index (FDI), is a slightly more complex assessment. The basic hypothesis is that the overall benefit of the farm to biodiversity will increase with the diversity of features present on the farm. To account for this the software calculates the FDI for each feature as shown in Equation 3.2:

$$FDI_n = 1 - \left(\frac{area\ of\ all\ features}{area\ of\ feature_n}\right) \qquad \text{[Equation 3.2]}$$

If the feature does not exist on the farm then it scores a maximum FDI of 1. If it already exists, then area of what exists will be taken into account in proportion to all the other features on the farm, i.e. if it is a large area then the FDI will be low and if it a small area then the FDI will be high. The FDI is then used as the basis for the ranking of the feature.

3.3. Overview of feature-impacts (criteria and guidelines)

3.3.1. Agroforestry

Table 3.7: Impact matrix for agroforestry

	Ecosystem services					Biodiversity									
	Mass stabilisation and control of soil erosion	Nitrate leaching	Pest control	Phosphate run-off	Pollination and seed dispersal	Amphibians	Bats	Birds of prey	Flowering plants	Insectivorous birds	Pollinating invertebrates	Reptiles	Seed eating birds	Small mammals (mice, shrews, voles)	Soil surface invertebrates
Adjacent vegetation structure			✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Adjacent water bodies quality						✓									
Adjacent wildlife corridors			✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Agroforestry species	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Annual rainfall	✓	✓		✓											
Distribution density of adjacent water bodies						✓	✓								
Field size			✓												
Old trees or buildings present within 1 km²							✓								
Slope	✓			✓											
Soil texture	✓	✓		✓											
South aspect												✓			
Topography												✓			

Adjacent vegetation structure

Structurally diverse habitat such as rough grassland, scrub, hedgerow or woodland in close proximity provides favourable habitat to many species of fauna. Such habitat provides a favourable habitat to amphibians during the terrestrial phase of their lifecycle (where immediately adjacent to ponds) (ARG, 2010; Baker *et al*., 2011; Oldham *et al*., 2000); a favourable foraging habitat to reptiles (with the exception of woodland), especially where small patches of bare ground are also present (Brady and Phillips, 2012; Edgar *et al*., 2010; HCT, 2007; Wright and Baker, 2011); and will enhance flowering plant species diversity (Langeveld *et al*., 2012). This habitat declines in suitability with a decrease in structure, for example frequently cut vegetation maintained at a low height; where large areas of bare or frequently disturbed ground are present; or, in the case of reptiles, where succession has proceeded to establish mature woodland with cooler microclimates (Brady and Phillips, 2012).

Adjacent water bodies quality

Clear water, with abundant aquatic invertebrate communities and submerged aquatic plants indicates water conditions favourable to amphibians (ARG, 2010; Baker *et al*., 2011; Oldham *et al*., 2000). A decline in quality is indicated by increasing discolouration and a decline in aquatic invertebrate diversity and aquatic plant presence.

Adjacent wildlife corridors

Diverse, quality hedgerow or linear features with dense structurally diverse vegetation provide: hibernation sites for small mammals and insects (thus supporting their predators) (Holland and Luff, 2000; Pfiffner and Luka, 2000; Thomas and Marshall, 1999); perches; sources of seed; increased flowering plant species diversity and resources for pollinating insects (Hannon & Sisk, 2009; Hunter, 2002); potential habitat for night flying insects (a source of food for bats) (BCT, 2013; JNCC, 2001); and enhanced dispersal and connectivity of habitat fragments (Hilty *et al*., 2006). Those adjacent to ponds, optimise the potential for amphibian dispersal between (ARG, 2010; Baker *et al*., 2011; Oldham *et al*., 2000) and may also be utilised by reptiles (Wright and Baker, 2011). Many species of bats demonstrate a preference to fly along linear features such as hedgerows where they function as 'commuting habitats' (JNCC, 2001). These qualities are reduced with a decrease in hedge structure and the presence of gaps.

Agroforestry species

The flowers of deciduous trees may provide a source of nectar and pollen for insects, especially *Salix spp*. (willow) and *Tilia spp*. (lime) (Kirk and Howes, 2012). Natural regeneration of wildflowers in the understory of deciduous plantations may increase wildflower diversity (Langeveld *et al*., 2012) and also favour pollinating invertebrates (Hannon & Sisk, 2009; Hunter, 2002). Where the development of tussocky grasses occurs, it will provide potential nest sites for some species of bumblebee, or potentially increase the presence of small mammal nests that may also be utilised by bumblebees (Fussell and Corbet, 1992; Kells and Goulson, 2003; Lye *et al*., 2009); and good winter cover and hibernation sites are provided for surface active insect predators of crop pests (Holland and Luff, 2000; Pfiffner and Luka, 2000; Thomas and Marshall, 1999). The limited cultivation and re-establishment frequency also favours predatory insect populations.

Agroforestry species enhance the structural diversity of the habitat. This, coupled with a decrease in tillage frequency and the potential for the development of tussocky grasses in the understory, enhances the suitability of the habitat to amphibians during the terrestrial phase of their lifecycle (ARG, 2010; Baker *et al*., 2011; Oldham *et al*., 2000). The enhanced numbers of surface active invertebrates (Holland and Luff, 2000; Pfiffner and Luka, 2000; Thomas and Marshall, 1999) increases insectivorous bird numbers and insectivorous and grass eating small mammal species (Kells and Goulson, 2003; Lye *et al*., 2009).. The fruit of species such as holly (*Ilex spp*), crab apple (*Malus spp*), wild cherry (*Prunus spp*) and yew (*Taxus spp*) are a potential food source for seed eating birds. The flowers of deciduous trees, especially *Salix spp*. (willow) and *Tilia spp*. (lime) provide a source of nectar and pollen for flying insects (Kirk and Howes, 2012), that are a source of food for bats (JNCC, 2001; BCT, 2013) and insectivorous birds. The enhanced structural diversity of the habitat may be of benefit to reptiles during the early phases of establishment (Brady and Phillips, 2012). The shading produced by mature plantations, especially in coniferous species, does not provide a favourable habitat for reptiles.

Nitrate leaching is reduced compared to arable cropping (Langeveld *et al*., 2012). Supplementary nitrogen is not applied and tillage frequency is reduced. This decreases the rate of mineralisation and release of nitrogen from organic matter. A permanent and deeper rooting system utilises the nitrogen within nitrate more effectively than that of an arable crop, rendering it unavailable to leaching (Nair, 2011; Nair and Graetz, 2004).

Both coniferous and deciduous woodland significantly reduce the risk of soil erosion and surface run-off of phosphate (Dimitriou *et al*. 2012; Kahle *et al*., 2007; Langeveld *et al*., 2012). This increases with increased maturity and ground cover.

Annual rainfall

An increase in annual rainfall generally corresponds to an increased risk of nitrate leaching (Smith *et al*., 1996), surface run-off and surface erosion (Dimitriou *et al*. 2012; Kahle *et al*., 2007; Langeveld *et al*., 2012).

Distribution density of adjacent water bodies

The presence of other suitable water bodies in close proximity, not isolated by, for example, roads enhances the potential for movement of amphibians between them and decreases the risk of localised extinction should loss of an individual water body occur (ARG, 2010; Oldham *et al*., 2000). The potential benefit increases with increased water body density within the surrounding area.

Ponds provide an additional source of insects active in the evening and at night, such as mosquitos, a source of food for bats (JNCC, 2001).

Field size

Several predatory insect species hibernate in field margins (Holland and Luff, 2000; Pfiffner and Luka, 2000; Thomas and Marshall, 1999). A small field size favours movement of these species from the boundaries into more central cropped areas.

Old trees or buildings present within 1 km²

Trees with crevices, holes or loose bark provide day roosts for bats (Forestry Commission, 2005; JNCC, 2001). Old buildings may also contain potential points of entry and suitable roost sites (JNCC, 2001).

Slope

An increase in slope gradient increases the risk of surface run-off and soil erosion (Bienes *et al*., 1996; García-Ruiz *et al*., 1995).

Soil texture

Course soil textures, for example those with a high proportion of sand, are vulnerable to nitrate leaching (Smith *et al*., 1996). The risk is lower for soils with an increasingly greater proportion of smaller particle sizes such as clays.

Soils with a high proportion of silt are more vulnerable to surface erosion and phosphate run-off than clay soils whose particles are more tightly bound, or the coarser sand soils that drain more freely (van der Knijff *et al*., 2000).

South aspect

A southern aspect favours reptiles as it allows basking for longer periods throughout the day, including when air temperatures are lower (Brady and Phillips, 2012; Edgar *et al*., 2010).

Topography

Complex topography provides areas exposed to sun and shade at different times of the day, important for effective thermoregulation in reptiles (Brady and Phillips, 2012; Edgar *et al*., 2010).

3.3.2. Ancient monuments

Table 3.8: Impact matrix for ancient monuments

	Ecosystem services		Management
	Aesthetic services	Heritage and cultural services	Labour
Feature has infrastructure for visitors		✓	✓
Feature is a significant component in the local landscape	✓		
Number of visitors		✓	

Feature is a significant component in the local landscape

Where ancient monuments are a significant feature of a local area their aesthetic significance can increase and this will add to the areas cultural heritage.

Number of visitors

High numbers of visitors to ancient monuments can be viewed as indicator of their cultural value.

Feature has infrastructure for visitors

Infrastructure for visitors to ancient monuments may enhance their cultural value. Ancient monuments on agricultural land require careful management and this can add to labour requirements. Such areas are best left in permanent pasture or wide margins left around the area to prevent cultivation damage.

3.3.3. Ancient stones

Table 3.9: Impact matrix for ancient stones

	Ecosystem services		Biodiversity				Mgt.
	Aesthetic services	Heritage and cultural services	Fungi	Mosses and liverworts	Reptiles	Snails	Labour
Adjacent vegetation structure					✓		
Adjacent wildlife corridors					✓		
Annual rainfall			✓	✓			
Feature has infrastructure for visitors		✓					✓
Feature is a significant component in the local landscape	✓						
Lichens present						✓	
Number of visitors		✓					
South aspect					✓		

Adjacent vegetation structure

Structurally diverse successional habitat such as rough grassland and scrub provides favourable habitat to reptiles. This habitat declines in suitability with a decrease in structure, for example frequently cut vegetation maintained at a low height, or where succession has proceeded to establish mature woodland with cooler microclimates.

Adjacent wildlife corridors

Diverse, quality hedgerow or linear features with dense structurally diverse vegetation facilitates the potential for reptile dispersal. Movement between and into ponds is reduced with a decrease in hedge structure, and the presence of gaps.

Annual rainfall

Ancient stones which have higher levels of moisture, e.g. from higher rainfall, are more favourable for fungi and mosses and liverworts.

Feature has infrastructure for visitors

Infrastructure for visitors to ancient stones may enhance their cultural value. Ancient stones on agricultural land require careful management and this can add to labour requirements. Such areas are best left in permanent pasture or wide margins left around the area to prevent cultivation damage.

Feature is a significant component in the local landscape

Where ancient stones are a significant feature of a local area their aesthetic significance can increase and also add to the areas cultural heritage.

Lichens present

Snail populations tend to increase when lichens are present.

Number of visitors

High numbers of visitors to ancient stones can be viewed as indicator of their cultural value.

South aspect

A southern aspect favours reptiles as it allows basking for longer periods throughout the day, including when air temperatures are lower.

3.3.4. Archaeological sites

Table 3.10: Impact matrix for archaeological sites

	Ecosystem services		Management
	Aesthetic services	Heritage and cultural services	Labour
Feature has infrastructure for visitors		✓	✓
Feature is a significant component in the local landscape	✓		
Number of visitors		✓	

Feature is a significant component in the local landscape

Where archaeological sites are a significant feature of a local area their aesthetic significance can increase and this will add to the areas cultural heritage.

Number of visitors

High numbers of visitors to archaeological sites can be viewed as indicator of their cultural value.

Feature has infrastructure for visitors

Infrastructure for visitors to archaeological sites may enhance their cultural value. Archaeological sites on agricultural land require careful management and this can add to labour requirements. Such areas are best left in permanent pasture or wide margins left around the area to prevent cultivation damage.

3.3.5. Catch crops or green cover

Table 3.11: Impact matrix for catch crops or green cover

	Ecosystem services				Biodiversity							
	Mass stabilisation and control of soil erosion	Nitrate leaching	Pest control	Phosphate run-off	Amphibians	Birds of prey	Flowering plants	Insectivorous birds	Reptiles	Seed eating birds	Small mammals (mice, shrews, voles)	Soil surface invertebrates
Adjacent vegetation structure			✓		✓	✓	✓	✓	✓	✓	✓	✓
Adjacent water bodies quality					✓							
Adjacent wildlife corridors			✓		✓	✓	✓	✓	✓	✓	✓	✓
Annual rainfall	✓	✓		✓								
CC species groups 1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
CC species groups 2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Distribution density of adjacent water bodies					✓							
Field size			✓									
Old trees or buildings present within 1 km²												
Slope	✓			✓								
Soil texture	✓	✓		✓								
South aspect									✓			
Topography									✓			

Adjacent vegetation structure

Structurally diverse habitat such as rough grassland, scrub, hedgerow or woodland in close proximity provides favourable habitat to many species of fauna. Such habitat provides a favourable habitat to amphibians during the terrestrial phase of their lifecycle (where immediately adjacent to ponds) (ARG, 2010; Baker *et al*., 2011; Oldham *et al*., 2000); a favourable foraging habitat to reptiles (with the exception of woodland), especially where small patches of bare ground are also present (Brady and Phillips, 2012; Edgar *et al*., 2010; HCT, 2007; Wright and Baker, 2011); and will enhance flowering plant species diversity (Langeveld *et al*., 2012). This habitat declines in suitability with a decrease in structure, for example frequently cut vegetation maintained at a low height; where large areas of bare or frequently disturbed ground are present; or, in the case of reptiles, where succession has proceeded to establish mature woodland with cooler microclimates (Brady and Phillips, 2012).

Adjacent water bodies quality

Clear water, with abundant aquatic invertebrate communities and submerged aquatic plants indicates water conditions favourable to amphibians (ARG, 2010; Baker *et al*., 2011; Oldham *et al*., 2000). A decline in quality is indicated by increasing discolouration, and a decline in aquatic invertebrate diversity and plant presence.

Adjacent wildlife corridors

Diverse, quality hedgerow or linear features with dense structurally diverse vegetation provide: hibernation sites for small mammals and insects (thus supporting their predators) (Holland and Luff, 2000; Pfiffner and Luka, 2000; Thomas and Marshall, 1999); perches; sources of seed; increased flowering plant species diversity and resources for pollinating insects (Hannon & Sisk, 2009; Hunter, 2002); potential habitat for night flying insects (a source of food for bats) (BCT, 2013; JNCC, 2001); and enhanced dispersal and connectivity of habitat fragments (Hilty *et al*., 2006). Those adjacent to ponds, optimise the potential for amphibian dispersal between ponds (ARG, 2010; Baker *et al*., 2011; Oldham *et al*., 2000) and may also be utilised by reptiles (Wright and Baker, 2011). Many species of bats demonstrate a preference to fly along linear features such as hedgerows where they function as 'commuting habitats' (JNCC, 2001). These qualities are reduced with a decrease in hedge structure and the presence of gaps.

Annual rainfall

An increase in annual rainfall generally corresponds to an increased risk of nitrate leaching (Smith *et al*., 1996), surface run-off and surface erosion (Dimitriou *et al*. 2012; Kahle *et al*., 2007; Langeveld *et al*., 2012).

CC species groups 1

Species that utilise more nitrogen during the autumn, for example winter oilseed or forage rape (*Brassica napus*) (Defra, 2010), or species that rapidly establish extensive roots, such as winter cereals of which winter rye (*Secal cereale*) is a good example (Shepherd, 1999), are effective at removing nitrogen from the soil and reducing the risk of leaching during the winter, especially on soils with a high percent sand content. Maintenance of ground surface cover during the winter reduces the risk of soil erosion, phosphate run-off and sedimentation (Dabney *et al*., 2001).

All species may provide some shelter during the winter to soil surface active predatory beetles (Holland *et al*., 1999; 2005) compared to bare soil although the impact is likely to be small. All species have a limited effect on amphibians, birds of prey, insectivorous birds, seed eating birds, small mammals, reptiles, and flowering plants when present as winter cover crops.

CC species groups 2

Two species groups with different nutrient requirements and rooting systems are likely to utilise more soil nitrogen during the autumn and winter due to differences in plant functional type and nutrient resource exploitation (Finn *et al*., 2013). Maintenance of ground surface cover during the winter reduces the risk of soil erosion, phosphate run-off and sedimentation (Dabney *et al*., 2001).

All species may provide some shelter during the winter to soil surface active predatory beetles (Holland *et al*., 1999; 2005) compared to bare soil although the impact is likely to be small. All species have a limited effect on amphibians, birds of prey, insectivorous birds, seed eating birds, small mammals, reptiles, and flowering plants when present as winter cover crops.

Distribution density of adjacent water bodies

The presence of other suitable water bodies in close proximity, not isolated by, for example, roads enhances the potential for movement of amphibians between them and decreases the risk of localised extinction should loss of an individual water body occur (ARG, 2010; Oldham *et al*., 2000). The potential benefit increases with increased water body density within the surrounding area.

Ponds provide an additional source of insects active in the evening and at night, such as mosquitos, a source of food for bats (JNCC, 2001).

Field size

Several predatory insect species hibernate in field margins (Holland and Luff, 2000; Pfiffner and Luka, 2000; Thomas and Marshall, 1999). A small field size favours movement of these species from the boundaries into more central cropped areas.

Old trees or buildings present within 1 km²

Trees with crevices, holes or loose bark provide day roosts for bats (Forestry Commission, 2005; JNCC, 2001). Old buildings may also contain potential points of entry and suitable roost sites (JNCC, 2001).

Slope

An increase in slope gradient increases the risk of surface run-off and soil erosion (Bienes *et al*., 1996; García-Ruiz *et al*., 1995).

Soil texture

Course soil textures, for example those with a high proportion of sand, are vulnerable to nitrate leaching (Smith *et al*., 1996). The risk is lower for soils with an increasingly greater proportion of smaller particle sizes such as clays.

Soils with a high proportion of silt are more vulnerable to surface erosion and phosphate run-off than clay soils whose particles are more tightly bound, or the coarser sand soils that drain more freely (van der Knijff *et al*., 2000).

South aspect

A southern aspect favours reptiles as it allows basking for longer periods throughout the day, including when air temperatures are lower (Brady and Phillips, 2012; Edgar *et al*., 2010).

Topography

Complex topography provides areas exposed to sun and shade at different times of the day, important for effective thermoregulation in reptiles (Brady and Phillips, 2012; Edgar *et al*., 2010).

3.3.6. Ditches

Table 3.12: Impact matrix for ditches

	Ecosystem services				Biodiversity												Mgt.
	Aesthetic services	Chemical condition of freshwaters	Flood protection	Pollination and seed dispersal	Amphibians	Aquatic invertebrates	Aquatic plants	Biodiversity (general)	Birds	Crustaceans	Emergent aquatic plants	Fish	Mammals	Molluscs	Submerged and floating aquatic plants	Terrestrial plants	Labour
Areas of open water						✓											
Bank vegetation cutting period																✓	
Clearing ditch vegetation frequency			✓				✓	✓									✓
Disposal of cut weeds	✓	✓															✓
Disposal of dredged sediment	✓	✓															✓
Distance to closest source of wild plants							✓									✓	
Ditch vegetation clearance equipment											✓						
Ditches are a traditional feature of local area	✓																
Dredging machine															✓		
Dredging of ditch sediments		✓	✓														✓
Form of the bank									✓		✓		✓			✓	
General flow rate in ditch		✓															
General nutrient status							✓	✓									
High sulphate soil additions		✓															
Intermittent periods of ditch drying		✓															
Livestock access to ditch bank		✓														✓	
Low-grade weirs/small dams in ditch		✓															
Number of connected aquatic habitats	✓				✓	✓	✓			✓		✓					
Number of connected terrestrial linear habitats	✓												✓				
Overhanging vegetation on the bank										✓							
Presence of in-ditch vegetation		✓															
Time of dredging		✓															

	Ecosystem services				Biodiversity												Mgt.
	Aesthetic services	Chemical condition of freshwaters	Flood protection	Pollination and seed dispersal	Amphibians	Aquatic invertebrates	Aquatic plants	Biodiversity (general)	Birds	Crustaceans	Emergent aquatic plants	Fish	Mammals	Molluscs	Submerged and floating aquatic plants	Terrestrial plants	Labour
Vegetation clearance period											✓						
Water status					✓							✓					
Waterbody depth				✓													
Years since dredging															✓		

Areas of open water

Halting hydroseral succession at a point where there is still sufficient open water to allow or a varied macroinvertebtate community can be beneficial in supporting a varied aquatic invertebrate community (Armitage *et al.*, 2003).

Bank vegetation cutting period

Cutting should be timed so as to allow for seed setting in bank plants (Leng *et al.*, 2011).

Clearing ditch vegetation frequency

Surface water drainage systems such as ditches and culverts aim to drain excess surface water away from the land, before water levels put property, roads, land, people and the environment at risk of flooding. If the system of ditches and culverts is maintained to a good standard, any flooding is only likely to affect the floodplain. Surface water drainage systems can provide storage in addition to allowing the flow of water, so maintenance is vital to ensure this storage capacity is maintained. Less frequent clearance is associated with better aquatic plant diversity (Twisk *et al.*, 2003); however, although clearance can be detrimental to biodiversity (Twisk *et al.*, 2003; Clarke, 2014) regular management can be beneficial for plant biodiversity by maintaining a variety of successional stages in the landscape (Herzon & Helenius, 2008; Armitage *et al.*, 2003). The above is therefore a balance. More frequent clearing ditch vegetation will increase labour costs.

Disposal of cut weeds

Removing cut vegetation can improve the aesthetic value of ditches. Where weed cutting occurs, the vegetative material contains nutrients; therefore, safe removal from the area may also remove those nutrients. Removing ditch cuttings will increase labour costs.

Disposal of dredged sediment

Removing dredged sediment can improve the aesthetic value of ditches. Where periodic dredging occurs to remove sediments, that sediment may contain nutrients (i.e. P); therefore safe removal from the area may also remove those nutrients. Removing ditch dredgings will increase labour costs.

Distance to closest source of wild plants

A seed source within 25m may be beneficial in supporting colonisation (Geertsema & Sprangers, 2002; van Dijk *et al.*, 2014).

Ditch vegetation clearance equipment

The type of cleaning machine used (mowing-drum, mowing-basket or ditch-scoop), has been shown to be significantly related to the species number/value of emergent vegetation (Twisk *et al.*, 2003). The mowing-drum is worst (species number = 18.8, species value = 43.3) than the mowing-basket or ditch-scoop (species number = 21, species value = 46.4). Value is used here, and the ditch scoop value should be the default where no further information is provided (Twisk *et al.*, 2003).

Ditches are a traditional feature of local area

Where ditches are a traditional feature of a local area their aesthetic significance can increase.

Dredging machine

Dredging machinery has an impact on plant diversity, with the Pull-shovel being the best and the Suction pipe the worst (Twisk *et al.*, 2003).

Dredging of ditch sediments

Surface water drainage systems such as ditches and culverts aim to drain excess surface water away from the land, before water levels put property, roads, land, people and the environment at risk of flooding. If the system of ditches and culverts is maintained to a good standard, any flooding is only likely to affect the floodplain. Surface water drainage systems can provide storage in addition to allowing the flow of water, so maintenance is vital to ensure this storage capacity is maintained. Periodic dredging removes polluted sediments (i.e. P) (Shore *et al.*, 2015, Clarke, 2014), which if left may become a pollutant source (Hill & Robinson, 2012; Moore *et al.*, 2010). However, excessive dredging removes the fine sediments available for P adsorption (Smith, 2009). More frequent ditch dredging will increase labour costs.

Form of the bank

Banks should have a gentle gradient to maximise biodiversity benefits.

General flow rate in ditch

Lower flow rates reduce the ability to mobilise polluted sediments (Shore *et al*., 2015; Smith, 2009).

General nutrient status

High nutrient status reduces plant diversity (Blomqvist *et al.*, 2003), and faunal diversity is strongly related to floral diversity (Armitage *et al.*, 2003).

High sulphate soil additions

The presence of sulphates (e.g. from poultry manure) may decrease P sorption (thus mobilising it) (Needelman *et al.*, 2007).

Intermittent periods of ditch drying

Processes which result in periodic drying out may precipitate minerals with a high P sorption capacity (i.e. reduce downstream contamination) (Needelman *et al.*, 2007).

Livestock access to ditch bank

Grazing too close to the banks edge may damage biodiversity (Armitage *et al.*, 2003), and may lead to water contamination.

Low-grade weirs/small dams in ditch

Low grade weirs in ditches can increase water retention, and provide conditions suitable for denitrification (Smith, 2009; Kröger *et al*., 2014); however, intermittent clearing may be required (Kröger *et al*., 2014).

Number of connected aquatic habitats

The more connections there are to other aquatic habitats the greater the scope for re-colonisation. Generally the more connected aquatic habitats are the greater their aesthetic value.

Number of connected terrestrial linear habitats

The greater the number of connected terrestrial linear habitats the greater the benefit for small mammals. Generally the more connected terrestrial habitats are the greater their aesthetic value.

Overhanging vegetation on the bank

Overhanging vegetation can be good for crayfish (Herzon & Helenius, 2008).

Presence of in-ditch vegetation

In-ditch vegetation can increase sediment (and Phosphorus) retention (Needelman *et al.*, 2007).

Time of dredging

Dredging in the summer may reduce the negative impacts associated with fine sediments no longer being available for P adsorption, as at this time there is less P in the water column (Shore *et al.*, 2015).

Vegetation clearance period

In northern Europe the cleaning period was shown to be related to emergent vegetation diversity, where July-mid-September (46.4), mid-September-October (44.3) (both nature value for emergent veg – difference = -2.1) (Twisk *et al.*, 2003). September-October is the default (Twisk *et al.*, 2003). However this has been amended a little as exact months may vary around Europe, based on the statement that Autumn clearance is worse than summer clearance as this leaves less time for recovery prior to winter (Twisk *et al.*, 2003).

Water status

Periodic drying reduces pressures on amphibians from predatory fish and conversely permanently wet ditches are better for fish (Herzon & Helenius, 2008).

Waterbody depth

In addition to food, honey bees and other pollinators gather water for use in cooling the inside of the nest on hot days. Honeybees also use water to dilute the honey when they feed it to the larvae. The presence of a water supply on the farm close to habitat will be beneficial as bees will spend less time collecting water and more time gathering nectar. However, where water is deep they have a habit of drowning so the provision of shallow water is valuable.

Years since dredging

Less frequent dredging may be beneficial for plants (Twisk *et al.*, 2003).

3.3.7. Fallow land

Table 3.13: Impact matrix for fallow land

	Ecosystem services					Biodiversity									
	Mass stabilisation and control of soil erosion	Nitrate leaching	Pest control	Phosphate run-off	Pollination and seed dispersal	Amphibians	Bats	Birds of prey	Flowering plants	Insectivorous birds	Pollinating invertebrates	Reptiles	Seed eating birds	Small mammals (mice, shrews, voles)	Soil surface invertebrates
Adjacent vegetation structure			✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Adjacent water bodies quality						✓									
Adjacent wildlife corridors			✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Annual rainfall	✓	✓		✓											
Distribution density of adjacent water bodies						✓	✓								
Field size			✓												
Ground cover (fallow)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Old trees or buildings present within 1 km²							✓								
Slope	✓			✓											
Soil texture	✓	✓		✓											
South aspect												✓			
Topography												✓			

Adjacent vegetation structure

Structurally diverse habitat such as rough grassland, scrub, hedgerow or woodland in close proximity provides favourable habitat. Such habitat provides a favourable habitat to amphibians during the terrestrial phase of their lifecycle (where immediately adjacent to ponds); a favourable habitat to reptiles; and will enhance flowering plant species diversity. This habitat declines in suitability with a decrease in structure, for example frequently cut vegetation maintained at a low height; where large areas of bare or frequently disturbed ground are present; or where succession has proceeded to establish mature woodland with cooler microclimates.

Adjacent water bodies quality

Clear water, with abundant aquatic invertebrate communities and submerged aquatic plants indicates water conditions favourable to amphibians. A decline in quality is indicated by increasing discolouration, and a decline in aquatic invertebrate diversity and plant presence.

Adjacent wildlife corridors

Diverse, quality hedgerow or linear features with dense structurally diverse vegetation provide: hibernation sites for small mammals and insects (thus supporting their predators); perches; sources of seed; increase flowering plant species diversity; potential habitat for night flying insects (a source of food for bats); and enhance dispersal and connect habitat fragments. Those adjacent to ponds, optimise the potential for amphibian dispersal between. Many species of bats demonstrate a preference to fly along linear features such as hedgerows. These qualities are reduced with a decrease in hedge structure and the presence of gaps.

Annual rainfall

An increase in annual rainfall generally corresponds to an increased risk of nitrate leaching, surface run-off and surface erosion.

Distribution density of adjacent water bodies

The presence of other suitable water bodies in close proximity, not isolated by, for example, roads enhances the potential for movement of amphibians between them and decreases the risk of localised extinction should loss of an individual water body occur. The potential benefit increases with increased water body density within the surrounding area.

Ponds provide an additional source of insects active in the evening and at night, such as mosquitos, a source of food for bats.

Ground cover

Tussocky grasses within sown grass mixtures and mixtures with flowering plants provide: potential nest sites for some species of bumblebee, or the presence of small mammal nests that may also be utilised by bumblebees; favourable habitat for insects, and insectivorous birds and small mammals (a potential food source for birds of prey); good winter cover and hibernation sites for a number of insect species (source of food for insectivorous birds) and surface active insect predators of crop pests; suitable foraging areas; and nest sites, and a source of food for grass eating and insectivorous species. The limited cultivation and re-establishment frequency favours predator populations. Mixtures that require more frequent tillage, or areas where bare ground persists are not as favourable to predators although they will be present. Frequent tillage decreases habitat favourability.

Mixtures that contain appropriate flowering plants potentially attract pollinating insects (source of food for insectivorous birds). Wild bird seed mixtures are designed specifically to provide a source of food for seed eating birds. Sown grass or wildflower mixtures, or natural regeneration may contain small seeded plant species that are also suitable. Wildflower mixtures that contain species with a long corolla and light flower colour are favourable to moths, moths provide a source of food to bats that feed at night. A greater frequency of tillage, for example the annual establishment of wild bird seed mixture, decreases habitat favourability.

Bare soil does not represent quality habitat for amphibians. Habitat quality is enhanced by the presence of vegetation that enhances structural diversity, such as tussocky grasses in a sown grass mixture with minimal cutting, or natural regeneration once the vegetation has become established. Bare soil provides potential basking areas for reptiles but must be located in close proximity to vegetated areas that provide shelter and shade, large areas of purely bare ground do not provide favourable habitat.

Natural regeneration may offer potential for the growth of arable flora that will also favour pollinating invertebrates. Natural regeneration favours the development of rare arable flora from the local seedbank. Sown wildflower mixtures also provide a source of flowering plants, determined by the mixture content.

Old trees or buildings present within 1 km²

Trees with crevices, holes or loose bark provide day roosts for bats. Old buildings may also contain potential points of entry and suitable roost sites.

Slope

An increase in slope gradient increases the risk of surface run-off and soil erosion.

Soil texture

Coarser soils have greater capacity for infiltration and sediment trapping.

South aspect

A southern aspect favours reptiles as it allows basking for longer periods throughout the day, including when air temperatures are lower.

Topography

Complex topography provides areas exposed to sun and shade at different times of the day.

3.3.8. Garrigue

Table 3.14: Impact matrix for garrigue

	Ecosystem services	Biodiversity			
	Pollination and seed dispersal	Flowering plants	Invertebrates	Mammals	Reptiles
Buffer strip adjacent	✓	✓	✓	✓	✓

Buffer strip adjacent

Where garrigue is adjacent to agricultural land it would benefit from being protected with buffer strips.

3.3.9. Hedges or wooded strips

Table 3.15: Impact matrix for hedges or wooded strips

	Ecosystem services						Biodiversity											Mgt.
	Aesthetic services	Filtration/sequestration by flora and	Mediation of smell/noise/visual	Pest control	Pesticide drift	Pollination and seed dispersal	Bats	Bees	Birds	Butterflies and moths	Farmland birds	Flowering plants	Invertebrates	Mammals	Mosses and liverworts	Scrubland birds	Woodland birds	Labour
Adjacent trees and woodland							✓											
Deadwood present						✓		✓	✓				✓		✓			
Density of hedgerow trees	✓						✓		✓	✓								✓
Distribution density of adjacent water bodies							✓											
Floral diversity						✓		✓	✓				✓	✓				
Ground cover at base of hedge									✓									
Hedge height		✓	✓	✓	✓						✓					✓	✓	
Hedgerow cutting frequency						✓			✓			✓						✓
Hedgerow cutting season									✓			✓						
Hedgerow is part of a green lane	✓								✓	✓		✓						
Hedges are a traditional feature of local area	✓																	
Mature trees with basal hollows															✓			
Number of other habitats connected to hedge	✓					✓		✓										
Pesticides sprayed on adjacent field		✓			✓													
Porosity		✓	✓	✓	✓													
Sensitive features downwind		✓																
Water bodies downwind					✓													

Adjacent trees and woodland

The incidence of bats is significantly increased by the proximity of woodland.

Deadwood present

The presence of well-grown, dead and decaying trees is beneficial to many species including pollinators, and provides nest holes, foraging and perches. Invertebrates such as spiders, ground beetles and hoverflies are often found in large quantities in hedge bottoms where deadwood residue accumulates. Deadwood provides nesting opportunities for bees. The presence of deadwood can enhance the habitat for mosses and liverworts.

Density of hedgerow trees

The abundance and diversity of birds will be affected by density of hedgerow trees. The presence of hedgerow trees has a large positive impact on the abundance and diversity of moths. Hedges without trees support significantly smaller moth populations. 60% of species (including butterflies) visiting the hedge are dependent on the tree layer. The abundance and diversity of larger moth species will be affected by density of hedgerow trees. Bats visiting hedges are dependent on the tree layer. The incidence of bats is significantly affected by tree density - the more trees present the greater the population and diversity of bats visiting. A moderate number of hedgerow trees can increase the aesthetic value. The number of hedgerows trees can increase labour costs for the management of the trees and also by slowing hedge cutting.

Distribution density of adjacent water bodies

Ponds provide an additional source of insects active in the evening and at night, such as mosquitos, a source of food for bats.

Floral diversity

Floral diversity is one of the most important factors for pollination. Diverse hedgerows will attract a greater diversity of pollinators. Flora-richness in the hedgerow, in terms of both total-richness and insect-pollinated plant richness, is important for birds, insects and mammals.

Ground cover at base of hedge

Good ground cover at the base of the hedge will increase bird species richness.

Hedge height

Tall hedgerows offer the greatest benefit for trapping pests, and most effective in reducing pesticide drift and protecting non-target areas, including water bodies. Tall hedgerows offer the greatest benefit for mediating smell, noise and visual impacts. Farmland bird species tend to prefer shorter trees and hedgerows/grassy or scrub type boundaries. Scrubland bird species tend to prefer trees and hedgerows of intermediate height. Woodland bird species tend to prefer taller trees and hedgerows.

Hedgerow cutting frequency

Uncut hedges provide more flowers and berries than cut hedges. Typically, large wide, bushy hedges support twice as many species of birds than tidy, frequently mechanically cut hedges. Hedgerow cutting reduces the number of flowers and the biomass of berries available over winter. More frequent cutting of hedgerows will increase labour costs.

Hedgerow cutting season

Cutting should be undertaken in the winter, and avoided during the spring and summer. Cutting in winter can increase in biomass of berries.

Hedgerow is part of a green lane

Bird abundance and species richness is greater in green lanes compared to standard hedgerows. Significantly more birds and a greater diversity are found in the inner area than on the outside of the lane. Bird species are found to occur in greater numbers in green lanes rather than in single hedgerows. There tends to be greater number of butterflies in green lanes. Hedgerows that form part of a green land have added ecological benefits, including greater abundance of flowers and more diverse flora. Where hedges are part of a green lane their aesthetic significance can increase.

Hedges are a traditional feature of local area

Where hedges are a traditional feature of a local area their aesthetic significance can increase.

Mature trees with basal hollows

Older trees with basal hollows provide a more suitable habitat for mosses and liverworts.

Number of other habitats connected to hedge

Hedgerow connectivity in a landscape is important to bumblebee movement and therefore to plants that require pollinator bumblebee services. Hedgerow connectivity in a landscape is important to bumblebee movement and therefore to plants that require pollinator bumblebee services. Generally the more connected habitats the greater the aesthetic value.

Pesticides sprayed on adjacent field

If pesticides are not sprayed on the adjacent field, then there is no role for the hedge for reducing pesticide drift.

Porosity

Hedgerows with low porosity offer the greatest benefit for trapping pests. Hedgerows with moderate porosity are the most effective in reducing pesticide drift and protecting non-target areas, including water bodies. Hedgerows with low porosity offer the greatest benefit for mediating smell, noise and visual impacts.

Sensitive features downwind

If there are no sensitive features downwind from the hedge, then its benefit with respect to minimising the effects of pesticide drift are minimal.

Water bodies downwind

If there are no water bodies downwind from the hedge then its benefit, with respect to minimising the effects of pesticide drift and consequent impact on water quality, are minimal.

3.3.10. Isolated trees

Table 3.16: Impact matrix for isolated trees

	Ecosystem services		Biodiversity						
	Aesthetic services	Heritage and cultural services	Amphibians	Bats	Birds	Flowering plants	Invertebrates	Mosses and liverworts	Reptiles
Adjacent trees and woodland					✓				
Adjacent vegetation structure			✓				✓		✓
Adjacent water bodies quality			✓						
Adjacent wildlife corridors			✓				✓		✓
Deadwood present							✓	✓	
Distribution density of adjacent water bodies			✓	✓					
Ground under canopy is cultivated						✓	✓	✓	
Mature trees with basal hollows			✓	✓	✓		✓	✓	✓
South aspect									✓
Tree maintenance period				✓	✓	✓			
Veteran/ancient trees	✓	✓				✓			

Adjacent trees and woodland

The local and landscape effects of isolated trees on birds are more pronounced when they are not part of a consolidated patch of trees and woodland.

Adjacent vegetation structure

Structurally diverse habitat such as rough grassland, scrub, hedgerow or woodland in close proximity provides favourable habitat. Such habitat provides a favourable habitat to amphibians during the terrestrial phase of their lifecycle (where immediately adjacent to ponds); a favourable habitat to reptiles; and will enhance flowering plant species diversity. This habitat declines in suitability with a decrease in structure, for example frequently cut vegetation maintained at a low height; where large areas of bare or frequently disturbed ground are present; or where succession has proceeded to establish mature woodland with cooler microclimates.

Adjacent water bodies quality

Clear water, with abundant aquatic invertebrate communities and submerged aquatic plants indicates water conditions favourable to amphibians. A decline in quality is indicated by increasing discolouration, and a decline in aquatic invertebrate diversity and plant presence.

Adjacent wildlife corridors

Diverse, quality hedgerow or linear features with dense structurally diverse vegetation provide: hibernation sites for small mammals and insects (thus supporting their predators); perches; sources of seed; increase flowering plant species diversity; potential habitat for night flying insects (a source of food for bats); and enhance dispersal and connect habitat fragments. Those adjacent to ponds, optimise the potential for amphibian dispersal between. Many species of bats demonstrate a preference to fly along linear features such as hedgerows. These qualities are reduced with a decrease in hedge structure and the presence of gaps.

Deadwood present

Invertebrates such as spiders, ground beetles and hoverflies are often found in large quantities where deadwood residue accumulates. The presence of deadwood can enhance the habitat for mosses and liverworts.

Distribution density of adjacent water bodies

The presence of other suitable water bodies in close proximity, not isolated by, for example, roads enhances the potential for movement of amphibians between them and decreases the risk of localised extinction should loss of an individual water body occur. The potential benefit increases with increased water body density within the surrounding area.

Ponds provide an additional source of insects active in the evening and at night, such as mosquitos, a source of food for bats.

Ground under canopy is cultivated

The ground under the canopy of trees is best for invertebrates, flowering plants and mosses and liverworts if left uncultivated.

Mature trees with basal hollows

Older trees with basal hollows provide a more suitable habitat for amphibians, birds, invertebrates, bats, reptiles and mosses and liverworts.

South aspect

A southern aspect favours reptiles as it allows basking for longer periods throughout the day, including when air temperatures are lower.

Tree maintenance period

Maintenance of trees is best avoided in the first half of the year, especially January to March for bats and plants, and April to June for birds.

Veteran/ancient trees

Veteran or ancient trees can have historical value, aesthetic value and add to the cultural heritage of the area. Veteran or ancient trees provide a more valuable habitat for flowering plants.

3.3.11. Land strips (adjacent/parallel to water)

Table 3.17: Impact matrix for land strips (adjacent/parallel to water)

	Ecosystem services									Biodiversity									
	Filtration/sequestration by flora and fauna	Mass stabilisation and control of soil	Microbial/pathogen run-off	Nitrogen run-off	Pesticide drift	Phosphate run-off	Pollination and seed dispersal	Sediment bound pesticides	Soluble pesticide run-off	Amphibians	Bats	Birds of prey	Flowering plants	Insectivorous birds	Pollinating invertebrates	Reptiles	Seed eating birds	Small mammals (mice, shrews,	Soil surface invertebrates
Adjacent vegetation structure							✓			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Adjacent water bodies quality										✓									
Adjacent wildlife corridors							✓			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Buffer width	✓	✓	✓	✓	✓	✓		✓	✓										
Depth of impermeable layer beneath buffer strip				✓															
Distribution density of adjacent water bodies										✓	✓								
Erosion risk in catchment		✓	✓			✓		✓											
Field managed to reduce erosion		✓	✓			✓		✓											
Ground cover							✓			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Hydraulic conductivity of the soil		✓	✓	✓		✓		✓	✓										
Mean annual precipitation		✓	✓			✓		✓	✓										
Old trees or buildings present within 1 km²											✓								
Removal of accumulated pollutants				✓		✓													
Risk of overland flow becoming concentrated		✓	✓	✓		✓		✓	✓										
Slope		✓	✓			✓		✓											
Soil texture		✓	✓			✓		✓											
South aspect																✓			
Sub-surface drains under buffer strip				✓					✓										
Topography																✓			
Vegetation density		✓	✓			✓		✓											
Vegetation height	✓				✓														

Adjacent vegetation structure

Structurally diverse habitat such as rough grassland, scrub, hedgerow or woodland in close proximity provides a favourable habitat for amphibians during the terrestrial phase of their lifecycle (where immediately adjacent to ponds); a favourable habitat for reptiles; and will enhance flowering plant species diversity. This habitat declines in suitability with a decrease in structure, for example frequently cut vegetation maintained at a low height; where large areas of bare or frequently disturbed ground are present; or where succession has proceeded to establish mature woodland with cooler microclimates.

Adjacent water bodies quality

Clear water, with abundant aquatic invertebrate communities and submerged aquatic plants indicates water conditions favourable for amphibians. A decline in quality is indicated by increasing discolouration, and a decline in aquatic invertebrate diversity and plant presence.

Adjacent wildlife corridors

Diverse, quality hedgerow or linear features with dense structurally diverse vegetation provide: hibernation sites for small mammals and insects (thus supporting their predators); perches; sources of seed; increased flowering plant species diversity; potential habitat for night flying insects (a source of food for bats); and enhance dispersal and connect habitat fragments. Those adjacent to ponds, optimise the potential for amphibian dispersal between habitats. Many species of bats demonstrate a preference for flying along linear features such as hedgerows. These qualities are reduced with a decrease in hedge structure and the presence of gaps.

Buffer width

The impact on pesticide drift increases with buffer width due to greater opportunities for filtration by vegetation. The impact on surface runoff increases with buffer width due to greater opportunities for infiltration and scope for filtration by vegetation.

Depth of impermeable layer beneath buffer strip

A shallow impermeable layer may provide a confining zone resulting in increased N removal, as this prevents infiltrate from passing below the depth of roots and organic matter (Viddon & Hill, 2004).

Distribution density of adjacent water bodies

The presence of other suitable water bodies in close proximity, not isolated by, for example, roads, enhances the potential for movement of amphibians between them and decreases the risk of localised extinction should loss of an individual water body occur. The potential benefit increases with increased water body density within the surrounding area.

Ponds provide an additional source of insects active in the evening and at night, such as mosquitos, a source of food for bats.

Erosion risk in catchment

Buffer strips may become overwhelmed in the event of excessive sediment delivery, so there is a risk that they may become less effective in locations where soil erosion is high.

Field managed to reduce erosion

Buffer strips may become overwhelmed in the event of excessive sediment delivery, so there is a risk that they may become less effective in locations where soil erosion is high. This can be mitigated if the adjacent field is managed to reduce the risk of soil erosion.

Ground cover

Tussocky grasses within sown grass mixtures and mixtures with flowering plants provide: potential nest sites for some species of bumblebee, or the presence of small mammal nests that may also be utilised by bumblebees; favourable habitat for insects, and insectivorous birds and small mammals (a potential food source for birds of prey); good winter cover and hibernation sites for a number of insect species (source of food for insectivorous birds) and surface active insect predators of crop pests; suitable foraging areas; and nest sites, and a source of food for grass eating and insectivorous species. The limited cultivation and re-establishment frequency favours predator populations. Mixtures that require more frequent tillage, or areas where bare ground persists are not as favourable to predators although they will be present. Frequent tillage decreases habitat favourability.

Mixtures that contain appropriate flowering plants potentially attract pollinating insects (source of food for insectivorous birds). Wild bird seed mixtures are designed specifically to provide a source of food for seed eating birds. Sown grass or wildflower mixtures, or natural regeneration may contain small seeded plant species that are also suitable. Wildflower mixtures that contain species with a long corolla and light flower colour are favourable to moths, moths provide a source of food for bats that feed at night. A greater frequency of tillage, for example the annual establishment of wild bird seed mixture, decreases habitat favourability.

Bare soil does not represent quality habitat for amphibians. Habitat quality is enhanced by the presence of vegetation that enhances structural diversity, such as tussocky grasses in a sown grass mixture with minimal cutting, or natural regeneration once the vegetation has become established. Bare soil provides potential basking areas for reptiles but must be located in close proximity to vegetated areas that provide shelter and shade, large areas of purely bare ground do not provide favourable habitat.

Natural regeneration may offer potential for the growth of arable flora that will also favour pollinating invertebrates. Natural regeneration favours the development of rare arable flora from the local seedbank. Sown wildflower mixtures also provide a source of flowering plants, determined by the mixture content.

Hydraulic conductivity of the soil

One of the most important factors for reducing overland flow is the vertical hydraulic conductivity of the soil, as greater conductivity allows for greater infiltration, reducing pollution by water borne pollutants.

Mean annual precipitation

Buffer strips may be more effective under lower rainfall conditions as antecedent moisture content is important in determining the scope for further infiltration.

Old trees or buildings present within 1 km²

Trees with crevices, holes or loose bark provide day roosts for bats. Old buildings may also contain potential points of entry and suitable roost sites.

Removal of accumulated pollutants

Accumulated pollutants should be removed from the buffer strip to ensure they do not reach a level where they can become a pollutant source, thus negating the effect of the buffer strip. Phosphorus may build up to the point at which it reaches a threshold and, more importantly, biological action makes more of the phosphorus soluble leaving it available for leaching (Stutter *et al.*, 2009; Uusi-Kämppä & Jauhiainen, 2010).

Risk of overland flow becoming concentrated

Overland flow concentration (the concentration of flow into rills or other flow paths) reduces the laminar flow needed for maximum buffer performance.

Slope

On gentler slopes flow rate is reduced and therefore infiltration increased (Muñoz-Carpena *et al.*, 2010).

Soil texture

Coarser soils have greater capacity for infiltration and sediment trapping.

South aspect

A southern aspect favours reptiles as it allows basking for longer periods throughout the day, including when air temperatures are lower.

Sub-surface drains under buffer strip

The presence of sub-surface drains may increase the concentration of N (Bhattarai *et al*., 2009) and pesticides in drainage.

Topography

Complex topography provides areas exposed to sun and shade at different times of the day.

Vegetation density

Dense vegetation provides a greater barrier to overland flow (and the pollutants it carries) than more sparsely populated buffer strips, reducing flow velocity and increasing time for infiltration (Krutz *et al*., 2005).

Vegetation height

Spray drift deposition beyond crop-free no-spray buffers decreases with increasing height of the vegetation in the buffer strip (Reichenberger *et al*., 2007).

3.3.12. Land strips (other)

Table 3.18: Impact matrix for land strips (other)

	Eco. Ser.	Biodiversity									
	Pollination and seed dispersal	Amphibians	Bats	Birds of prey	Flowering plants	Insectivorous birds	Pollinating invertebrates	Reptiles	Seed eating birds	Small mammals (mice, shrews, voles)	Soil surface invertebrates
Adjacent vegetation structure	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Adjacent water bodies quality		✓									
Adjacent wildlife corridors	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Distribution density of adjacent water bodies		✓	✓								
Ground cover	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Old trees or buildings present within 1 km²			✓								
South aspect								✓			
Topography								✓			

Adjacent vegetation structure

Structurally diverse habitat such as rough grassland, scrub, hedgerow or woodland in close proximity provides favourable habitat. Such habitat provides a favourable habitat to amphibians during the terrestrial phase of their lifecycle (where immediately adjacent to ponds); a favourable habitat to reptiles; and will enhance flowering plant species diversity. This habitat declines in suitability with a decrease in structure, for example frequently cut vegetation maintained at a low height; where large areas of bare or frequently disturbed ground are present; or where succession has proceeded to establish mature woodland with cooler microclimates.

Adjacent water bodies quality

Clear water, with abundant aquatic invertebrate communities and submerged aquatic plants indicates water conditions favourable to amphibians. A decline in quality is indicated by increasing discolouration, and a decline in aquatic invertebrate diversity and plant presence.

Adjacent wildlife corridors

Diverse, quality hedgerow or linear features with dense structurally diverse vegetation provide: hibernation sites for small mammals and insects (thus supporting their predators); perches; sources of seed; increase flowering plant species diversity; potential habitat for night flying insects (a source of food for bats); and enhance dispersal and connect habitat fragments. Those adjacent to ponds, optimise the potential for amphibian dispersal between. Many species of bats demonstrate a preference to fly along linear features such as hedgerows. These qualities are reduced with a decrease in hedge structure and the presence of gaps.

Distribution density of adjacent water bodies

The presence of other suitable water bodies in close proximity, not isolated by, for example, roads enhances the potential for movement of amphibians between them and decreases the risk of localised extinction should loss of an individual water body occur. The potential benefit increases with increased water body density within the surrounding area.

Ponds provide an additional source of insects active in the evening and at night, such as mosquitos, a source of food for bats.

Ground cover

Tussocky grasses within sown grass mixtures and mixtures with flowering plants provide: potential nest sites for some species of bumblebee, or the presence of small mammal nests that may also be utilised by bumblebees; favourable habitat for insects, and insectivorous birds and small mammals (a potential food source for birds of prey); good winter cover and hibernation sites for a number of insect species (source of food for insectivorous birds) and surface active insect predators of crop pests; suitable foraging areas; and nest sites, and a source of food for grass eating and insectivorous species. The limited cultivation and re-establishment frequency favours predator populations. Mixtures that require more frequent tillage, or areas where bare ground persists are not as favourable to predators although they will be present. Frequent tillage decreases habitat favourability.

Mixtures that contain appropriate flowering plants potentially attract pollinating insects (source of food for insectivorous birds). Wild bird seed mixtures are designed specifically to provide a source of food for seed eating birds. Sown grass or wildflower mixtures, or natural regeneration may contain small seeded plant species that are also suitable. Wildflower mixtures that contain species with a long corolla and light flower colour are favourable to moths, moths provide a source of food to bats that feed at night. A greater frequency of tillage, for example the annual establishment of wild bird seed mixture, decreases habitat favourability.

Bare soil does not represent quality habitat for amphibians. Habitat quality is enhanced by the presence of vegetation that enhances structural diversity, such as tussocky grasses in a sown grass mixture with minimal cutting, or natural regeneration once the vegetation has become established. Bare soil provides potential basking areas for reptiles but must be located in close proximity to vegetated areas that provide shelter and shade, large areas of purely bare ground do not provide favourable habitat.

Natural regeneration may offer potential for the growth of arable flora that will also favour pollinating invertebrates. Natural regeneration favours the development of rare arable flora from the local seedbank. Sown wildflower mixtures also provide a source of flowering plants, determined by the mixture content.

Old trees or buildings present within 1 km²

Trees with crevices, holes or loose bark provide day roosts for bats. Old buildings may also contain potential points of entry and suitable roost sites.

South aspect

A southern aspect favours reptiles as it allows basking for longer periods throughout the day, including when air temperatures are lower.

Topography

Complex topography provides areas exposed to sun and shade at different times of the day.

3.3.13. Natural monuments

Table 3.19: Impact matrix for natural monuments

	Ecosystem services
	Aesthetic services
Feature is a significant component in the local landscape	✓

Feature is a significant component in the local landscape

Where natural monuments are a significant feature of a local area their aesthetic significance can increase.

3.3.14. Nitrogen fixing crops

Table 3.20: Impact matrix for nitrogen fixing crops

	Ecosystem services					Biodiversity									
	Mass stabilisation and control of soil erosion	Nitrate leaching	Pest control	Phosphate run-off	Pollination and seed dispersal	Amphibians	Bats	Birds of prey	Flowering plants	Insectivorous birds	Pollinating invertebrates	Reptiles	Seed eating birds	Small mammals (mice, shrews, voles)	Soil surface invertebrates
Adjacent vegetation structure			✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Adjacent water bodies quality						✓									
Adjacent wildlife corridors			✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Annual rainfall	✓	✓		✓											
Distribution density of adjacent water bodies						✓	✓								
Field size			✓												
Nitrogen fixing crop species	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

	Ecosystem services					Biodiversity									
	Mass stabilisation and control of soil erosion	Nitrate leaching	Pest control	Phosphate run-off	Pollination and seed dispersal	Amphibians	Bats	Birds of prey	Flowering plants	Insectivorous birds	Pollinating invertebrates	Reptiles	Seed eating birds	Small mammals (mice, shrews, voles)	Soil surface invertebrates
Old trees or buildings present within 1 km²							✓								
Slope	✓			✓											
Soil texture	✓	✓		✓											
South aspect												✓			
Topography												✓			

Adjacent vegetation structure

Structurally diverse habitat such as rough grassland, scrub, hedgerow or woodland in close proximity provides favourable habitat to many species of fauna. Such habitat provides a favourable habitat to amphibians during the terrestrial phase of their lifecycle (where immediately adjacent to ponds) (ARG, 2010; Baker *et al*., 2011; Oldham *et al*., 2000); a favourable foraging habitat to reptiles (with the exception of woodland), especially where small patches of bare ground are also present (Brady and Phillips, 2012; Edgar *et al*., 2010; HCT, 2007; Wright and Baker, 2011); and will enhance flowering plant species diversity (Langeveld *et al*., 2012). This habitat declines in suitability with a decrease in structure, for example frequently cut vegetation maintained at a low height; where large areas of bare or frequently disturbed ground are present; or, in the case of reptiles, where succession has proceeded to establish mature woodland with cooler microclimates (Brady and Phillips, 2012).

Adjacent water bodies quality

Clear water, with abundant aquatic invertebrate communities and submerged aquatic plants indicates water conditions favourable to amphibians (ARG, 2010; Baker *et al*., 2011; Oldham *et al*., 2000). A decline in quality is indicated by increasing discolouration, and a decline in aquatic invertebrate diversity and aquatic plant presence.

Adjacent wildlife corridors

Diverse, quality hedgerow or linear features with dense structurally diverse vegetation provide: hibernation sites for small mammals and insects (thus supporting their predators) (Holland and Luff, 2000; Pfiffner and Luka, 2000; Thomas and Marshall, 1999); perches; sources of seed; increased flowering plant species diversity and resources for pollinating insects (Hannon & Sisk, 2009; Hunter, 2002); potential habitat for night flying insects (a source of food for bats) (BCT, 2013; JNCC, 2001); and enhanced dispersal and connectivity of habitat fragments (Hilty *et al*., 2006). Those adjacent to ponds, optimise the potential for amphibian dispersal between ponds (ARG, 2010; Baker *et al*., 2011; Oldham *et al*., 2000) and may also be utilised by reptiles (Wright and Baker, 2011). Many species of bats demonstrate a preference to fly along linear features such as hedgerows where they function as 'commuting habitats' (JNCC, 2001). These qualities are reduced with a decrease in hedge structure and the presence of gaps.

Annual rainfall

An increase in annual rainfall generally corresponds to an increased risk of nitrate leaching (Smith *et al*., 1996), surface run-off and surface erosion (Dimitriou *et al*. 2012; Kahle *et al*., 2007; Langeveld *et al*., 2012).

Distribution density of adjacent water bodies

The presence of other suitable water bodies in close proximity, not isolated by, for example, roads enhances the potential for movement of amphibians between them and decreases the risk of localised extinction should loss of an individual water body occur (ARG, 2010; Oldham *et al*., 2000). The potential benefit increases with increased water body density within the surrounding area.

Ponds provide an additional source of insects active in the evening and at night, such as mosquitos, a source of food for bats (JNCC, 2001).

Field size

Several predatory insect species hibernate in field margins (Holland and Luff, 2000; Pfiffner and Luka, 2000; Thomas and Marshall, 1999). A small field size favours movement of these species from the boundaries into more central cropped areas.

Nitrogen fixing crop species

A decrease in cultivation frequency reduces the quantity of nitrogen returned to the soil within plant residues via mineralisation (Franzluebbers *et al*., 1999; Silgram and Shepherd, 1999), and reduces the risk of soil erosion (Franzluebbers *et al*., 1999; van der Knijff, 2000) and phosphate loss in surface run-off (Quinton *et al*., 1999). Species that may only require re-establishment and tillage every few years, such as *Lotus spp.* (Birds foot-trefoil) or *Anthyllis* (Kidney vetch), have a lower risk of nitrate leaching, soil erosion and phosphate run-off.

Vicia faba (Faba bean), *Lotus spp.* (Birds foot-trefoil) and *Trifolium spp.* (Clover species) are of value to pollinating insects, for example bees (Kirk and Howe, 2012; Köpke and Nemecek, 2010). They are favoured by solitary bees, short and long tongued bumblebees and honeybees. Species such as *Cicer spp* (Chickpea) and *Glycine spp* (Soybean) may act as a potential food source for seed eating birds (Hanson and Mason, 1985). Species with a long corolla and light flower colour are potentially favourable to moths, and moths provide a source of food to bats that feed at night (BCT, 2013). Suitable foraging areas for amphibians and reptiles are provided by structurally diverse habitats with, for example, tussocky grasses (ARG, 2010; Brady and Phillips, 2012; Oldham *et al*., 2000). Bare soil provides potential basking areas for reptiles but must be located in close proximity to vegetated areas that provide shelter and shade, large areas of purely bare ground do not provide favourable habitat (Brady and Phillips, 2012). A single species sown crop will be of low floral diversity.

A greater frequency of tillage decreases habitat favourability to many soil surface active invertebrates, including predatory beetles. Benefit is provided by species that may only require re-establishment and tillage every few years for example *Lotus spp.* (Birds foot-trefoil), *Anthyllis* (Kidney vetch) and *Trifolium spp.* (Clover species).

Old trees or buildings present within 1 km²

Trees with crevices, holes or loose bark provide day roosts for bats (Forestry Commission, 2005; JNCC, 2001). Old buildings may also contain potential points of entry and suitable roost sites (JNCC, 2001).

Slope

An increase in slope gradient increases the risk of surface run-off and soil erosion (Bienes *et al*., 1996; García-Ruiz *et al*., 1995).

Soil texture

Course soil textures, for example those with a high proportion of sand, are vulnerable to nitrate leaching (Smith *et al*., 1996). The risk is lower for soils with an increasingly greater proportion of smaller particle sizes such as clays.

Soils with a high proportion of silt are more vulnerable to surface erosion and phosphate run-off than clay soils whose particles are more tightly bound, or the coarser sand soils that drain more freely (van der Knijff *et al*., 2000).

South aspect

A southern aspect favours reptiles as it allows basking for longer periods throughout the day, including when air temperatures are lower (Brady and Phillips, 2012; Edgar *et al*., 2010).

Topography

Complex topography provides areas exposed to sun and shade at different times of the day, important for effective thermoregulation in reptiles (Brady and Phillips, 2012; Edgar *et al*., 2010).

3.3.15. Ponds

Table 3.21: Impact matrix for ponds

	Ecosystem services			Biodiversity												
	Aesthetic services	Chemical condition of freshwaters	Pollination and seed dispersal	Amphibians	Aquatic invertebrates	Aquatic plants	Biodiversity (general)	Birds	Dragonflies and damselflies (Odonata)	Emergent aquatic plants	Fish	Hoverflies and hoppers	Mammals	Molluscs	Submerged and floating aquatic plants	Waders
Aquatic vegetation cover				✓	✓	✓		✓	✓		✓		✓			
Are sediments removed by dredging		✓				✓	✓									
Average retention time		✓														
Buffer strip adjacent							✓		✓							
Ducks present						✓			✓							
Feature is a significant component in the local landscape	✓															
Form of the bank					✓					✓			✓			
Level of shading by bank vegetation				✓	✓					✓		✓			✓	✓

	Ecosystem services			Biodiversity												
	Aesthetic services	Chemical condition of freshwaters	Pollination and seed dispersal	Amphibians	Aquatic invertebrates	Aquatic plants	Biodiversity (general)	Birds	Dragonflies and damselflies (Odonata)	Emergent aquatic plants	Fish	Hoverflies and hoppers	Mammals	Molluscs	Submerged and floating aquatic plants	Waders
Mean annual temperature		✓														
Natural water table and hydroperiod maintained							✓									
Number of ponds present	✓			✓	✓			✓								
Pond catchment land use				✓		✓	✓									
Pond catchment proportion agriculture							✓									
Pond is part of a series	✓	✓				✓	✓									
Pond shape	✓				✓					✓						✓
Pond size		✓						✓	✓		✓		✓			
Pond stocked with fish				✓	✓											
Pond substrate	✓						✓									
Pond water source							✓									
Proximity to other aquatic habitats				✓		✓		✓						✓		
Variety of neighbouring ponds	✓			✓	✓			✓								
Waterbody depth			✓			✓					✓					

Aquatic vegetation cover

Generally, the greater the aquatic vegetation cover, the better. The exception is for fish, which often require at least some open water.

Are sediments removed by dredging

Accumulated ponds sediments may act as a pollutant source (e.g. for P) unless intermittently removed; however, dredging also has negative impacts on biodiversity.

Average retention time

Nutrient (and other pollutant) removal is greatest in systems with long retention times, allowing time for biological, chemical and physical processes to occur.

Buffer strip adjacent

Buffer strips benefit biodiversity in a number of ways, through ensuring clean water, and providing habitat. In particular, Odonata may use buffer vegetation to aid emergence and to perch.

Ducks present

The presence of ducks increases pressure on aquatic plants, with negative implications for Odonata species.

Feature is a significant component in the local landscape

Where ponds are a significant feature of a local area their aesthetic significance can increase.

Form of the bank

A number of species benefit from gently sloping banks, including wading birds (which require a muddy shore), some invertebrates (e.g. for breeding), emergent plants and some mammals (e.g. water vole).

Level of shading by bank vegetation

Some shading by bank vegetation may be beneficial for biodiversity, but this may peak between 20% and 30% shading.

Mean annual temperature

The removal on nutrients from surface waters, much of which is driven by the action of aquatic plants, is greater in warmer conditions.

Natural water table and hydroperiod maintained

Maintaining a natural water table and hydroperiod is beneficial for biodiversity. A natural water table and degree of water level fluctuation, is an essential part of maintaining pond habitats, preventing excessive drying, allowing for some drying, and providing an adequate draw down zone.

Number of ponds present

Biodiversity can benefit from the creation of a network of ponds, in some instances, several ponds may contain greater biodiversity than a single pond of equivalent size. A number of ponds together may have more aesthetic value that one or two isolated ponds.

Pond catchment land use

Ponds are heavily influenced by land use in their (usually) small catchments (e.g. there is little scope for dilution of pollutants), such that as intensity of agricultural production goes up, so does the potential impact on biodiversity.

Pond catchment proportion agriculture

Some evidence suggests that biodiversity is unlikely to be good if there is more than 30-50% agriculture in a catchment, and this may be much lower for arable agriculture (Davies *et al.*, 2008), such that the impact on biodiversity can be interpreted as increasing with the amount of agriculture present. With farm ponds with relatively small catchments, it can probably be assumed that urban/industrial development will have a negligible impact in most cases.

Pond is part of a series

Where a series of ponds are used, water quality can be improved to a greater extent than in a single waterbody. Consequently the lower ponds may support a more healthy biodiversity than those early in the chain. A series of ponds may have more aesthetic value than single isolated ponds.

Pond shape

An irregularly shaped bank may result in microtopography, small puddles, and areas of wet mud, to the benefit of some species. Irregular shaped ponds tend to have more aesthetic value as they appear more natural.

Pond size

Larger ponds increase retention time, which aids the removal of pollutants and thus improves water quality. Larger ponds tend to have greater benefits for biodiversity.

Pond stocked with fish

Generally, fish stocking (particularly if with non-native species) increases the pressure on natural biodiversity.

Pond substrate

Evidence suggests that a natural substrate provides a better basis for biodiversity. Un-natural ponds may contain some invertebrates, birds, etc., but are more limited than more natural ponds. Natural ponds tend to have more aesthetic value.

Pond water source

Clean water is essential for high quality pond biodiversity. In general ponds fed by an inflow may be impacted by pollutants and/or invasive species, groundwater is often relatively clean, whilst surface flow can be either clean or polluted depending on the land use in the catchment.

Proximity to other aquatic habitats

Much pond biodiversity also utilises other aquatic habitats (rivers, ditches, lakes, etc.) therefore close proximity to such habitats aids colonisation and movement through the landscape.

Variety of neighbouring ponds

Maximum benefit is usually derived from a network of ponds which represent different successional stages (i.e. depths, sizes, etc.). A number of variable ponds may have more aesthetic value than a group of very similar ponds.

Waterbody depth

A variety of water depths is generally advisable for biodiversity, due to the ability to support a varied community of emergent, submerged and floating vegetation. Fish often require at least some deeper water. In addition to food, honey bees and other pollinators gather water for use in cooling the inside of the nest on hot days. Honeybees also use water to dilute the honey when they feed it to the larvae. The presence of a water supply on the farm close to habitat will be beneficial as bees will spend less time collecting water and more time gathering nectar. However, where water is deep they have a habit of drowning so the provision of shallow water is valuable.

3.3.16. Short rotation coppice

Table 3.22: Impact matrix for short rotation coppice

	Ecosystem services					Biodiversity									
	Mass stabilisation and control of soil erosion	Nitrate leaching	Pest control	Phosphate run-off	Pollination and seed dispersal	Amphibians	Bats	Birds of prey	Flowering plants	Insectivorous birds	Pollinating invertebrates	Reptiles	Seed eating birds	Small mammals (mice, shrews, voles)	Soil surface invertebrates
Adjacent vegetation structure			✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Adjacent water bodies quality						✓									
Adjacent wildlife corridors			✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Annual rainfall	✓	✓		✓											
Distribution density of adjacent water bodies						✓	✓								
Field size			✓												
Old trees or buildings present within 1 km²							✓								
Short rotation coppice species	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Slope	✓			✓											
Soil texture	✓	✓		✓											
South aspect												✓			
Topography												✓			

Adjacent vegetation structure

Structurally diverse habitat such as rough grassland, scrub, hedgerow or woodland in close proximity provides favourable habitat to many species of fauna. Such habitat provides a favourable habitat to amphibians during the terrestrial phase of their lifecycle (where immediately adjacent to ponds) (ARG, 2010; Baker *et al*., 2011; Oldham *et al*., 2000); a favourable foraging habitat to reptiles (with the exception of woodland), especially where small patches of bare ground are also present (Brady and Phillips, 2012; Edgar *et al*., 2010; HCT, 2007; Wright and Baker, 2011); and will enhance flowering plant species diversity (Langeveld *et al*., 2012). This habitat declines in suitability with a decrease in structure, for example frequently cut vegetation maintained at a low height; where large areas of bare or frequently disturbed ground are present; or, in the case of reptiles, where succession has proceeded to establish mature woodland with cooler microclimates (Brady and Phillips, 2012).

Adjacent water bodies quality

Clear water, with abundant aquatic invertebrate communities and submerged aquatic plants indicates water conditions favourable to amphibians (ARG, 2010; Baker *et al*., 2011; Oldham *et al*., 2000). A decline in quality is indicated by increasing discolouration, and a decline in aquatic invertebrate diversity and aquatic plant presence.

Adjacent wildlife corridors

Diverse, quality hedgerow or linear features with dense structurally diverse vegetation provide: hibernation sites for small mammals and insects (thus supporting their predators) (Holland and Luff, 2000; Pfiffner and Luka, 2000; Thomas and Marshall, 1999); perches; sources of seed; increased flowering plant species diversity and resources for pollinating insects (Hannon & Sisk, 2009; Hunter, 2002); potential habitat for night flying insects (a source of food for bats) (BCT, 2013; JNCC, 2001); and enhanced dispersal and connectivity of habitat fragments (Hilty *et al*., 2006). Those adjacent to ponds, optimise the potential for amphibian dispersal between (ARG, 2010; Baker *et al*., 2011; Oldham *et al*., 2000) and may also be utilised by reptiles (Wright and Baker, 2011). Many species of bats demonstrate a preference to fly along linear features such as hedgerows where they function as 'commuting habitats' (JNCC, 2001). These qualities are reduced with a decrease in hedge structure and the presence of gaps.

Annual rainfall

An increase in annual rainfall generally corresponds to an increased risk of nitrate leaching (Smith *et al*., 1996), surface run-off and surface erosion (Dimitriou *et al*. 2012; Kahle *et al*., 2007; Langeveld *et al*., 2012).

Distribution density of adjacent water bodies

The presence of other suitable water bodies in close proximity, not isolated by, for example, roads enhances the potential for movement of amphibians between them and decreases the risk of localised extinction should loss of an individual water body occur (ARG, 2010; Oldham *et al*., 2000). The potential benefit increases with increased water body density within the surrounding area.

Ponds provide an additional source of insects active in the evening and at night, such as mosquitos, a source of food for bats (JNCC, 2001).

Field size

Several predatory insect species hibernate in field margins (Holland and Luff, 2000; Pfiffner and Luka, 2000; Thomas and Marshall, 1999). A small field size favours movement of these species from the boundaries into more central cropped areas.

Old trees or buildings present within 1 km²

Trees with crevices, holes or loose bark provide day roosts for bats (Forestry Commission, 2005; JNCC, 2001). Old buildings may also contain potential points of entry and suitable roost sites (JNCC, 2001).

Short rotation coppice species

The flowers of short rotation coppice species may provide a source of nectar and pollen for insects, especially *Salix spp.* (willow), *Prunus spp.* (wild cherry) and *Tilia spp.* (lime) (Kirk and Howes, 2012). Natural regeneration of wildflowers in the understory of deciduous plantations may increase wildflower diversity (Langeveld *et al*., 2012) and also favour pollinating invertebrates (Hannon & Sisk, 2009; Hunter, 2002). Where the development of tussocky grasses occurs, it will provide potential nest sites for some species of bumblebee, or potentially increase the presence of small mammal nests that may also be utilised by bumblebees (Fussell and Corbet, 1992; Kells and Goulson, 2003; Lye *et al*., 2009); and good winter cover and hibernation sites are provided for surface active insect predators of crop pests (Holland and Luff, 2000; Pfiffner and Luka, 2000; Thomas and

Marshall, 1999). The limited cultivation and re-establishment frequency also favours predatory insect populations.

Short rotation coppice species enhance the structural diversity of the habitat. This, coupled with a decrease in tillage frequency and the potential for the development of tussocky grasses in the understory, enhances the suitability of the habitat to amphibians during the terrestrial phase of their lifecycle (ARG, 2010; Baker *et al*., 2011; Oldham *et al*., 2000). The enhanced numbers of surface active invertebrates (Holland and Luff, 2000; Pfiffner and Luka, 2000; Thomas and Marshall, 1999) increases insectivorous bird numbers and insectivorous and grass eating small mammal species (Kells and Goulson, 2003; Lye *et al*., 2009).. The fruit of species such as rowan (*Sorbus spp*) and wild cherry (*Prunus spp*) are a potential food source for seed eating birds. The flowers of deciduous trees, especially *Salix spp*. (willow) and *Tilia spp*. (lime) provide a source of nectar and pollen for flying insects (Kirk and Howes, 2012), that are a source of food for bats (JNCC, 2001; BCT, 2013) and insectivorous birds. The enhanced structural diversity of the habitat may be of benefit to reptiles during the early phases of establishment (Brady and Phillips, 2012). The shading produced by later growth stages does not provide a favourable habitat for reptiles.

Nitrate leaching is reduced compared to arable cropping (Langeveld *et al*., 2012). Supplementary nitrogen is not applied and tillage frequency is reduced. This decreases the rate of mineralisation and release of nitrogen from organic matter. A permanent and deeper rooting system utilises the nitrogen within nitrate more effectively than that of an arable crop, rendering it unavailable to leaching (Nair, 2011; Nair and Graetz, 2004).

Soil erosion and surface run-off of phosphate is usually reduced due to reduced tillage frequency (Dimitriou *et al*. 2012; Kahle *et al*., 2007; Langeveld *et al*., 2012). This increases with increased maturity and ground cover.

Slope

An increase in slope gradient increases the risk of surface run-off and soil erosion (Bienes *et al*., 1996; García-Ruiz *et al*., 1995).

Soil texture

Course soil textures, for example those with a high proportion of sand, are vulnerable to nitrate leaching (Smith *et al*., 1996). The risk is lower for soils with an increasingly greater proportion of smaller particle sizes such as clays.

Soils with a high proportion of silt are more vulnerable to surface erosion and phosphate run-off than clay soils whose particles are more tightly bound, or the coarser sand soils that drain more freely (van der Knijff *et al*., 2000).

South aspect

A southern aspect favours reptiles as it allows basking for longer periods throughout the day, including when air temperatures are lower (Brady and Phillips, 2012; Edgar *et al*., 2010).

Topography

Complex topography provides areas exposed to sun and shade at different times of the day, important for effective thermoregulation in reptiles (Brady and Phillips, 2012; Edgar *et al*., 2010).

3.3.17. Terraces

Table 3.23: Impact matrix for terraces

	Ecosystem services			Biodiversity	Management
	Aesthetic services	Mass stabilisation and control of soil erosion	Provision of water for as a material	Reptiles	Labour
Adjacent vegetation structure				✓	
Adjacent wildlife corridors				✓	
Annual rainfall		✓	✓		
Gradient	✓	✓	✓	✓	
Ground cover					
Terraces are a traditional feature of local area	✓				
Regional water stress			✓		
Soil texture		✓	✓		
South aspect				✓	
Terraces are regularly maintained	✓	✓	✓		✓
Topography				✓	

Adjacent vegetation structure

Structurally diverse successional habitat such as rough grassland and scrub provides favourable habitat to reptiles. This habitat declines in suitability with a decrease in structure, for example frequently cut vegetation maintained at a low height, or where succession has proceeded to establish mature woodland with cooler microclimates.

Adjacent wildlife corridors

Diverse, quality hedgerow or linear features with dense structurally diverse vegetation facilitates the potential for reptile dispersal. Movement between and into ponds is reduced with a decrease in hedge structure, and the presence of gaps.

Annual rainfall

The greater the rainfall, the greater the scope for water retention and provision. Locations with high annual rainfall have the greatest risk of soil erosion (in combination with other factors).

Gradient

Land that has a high gradient is likely to benefit the most from terraces with respect to water provision (in combination with other factors). Land that has a high gradient has the highest risk of soil erosion (in combination with other factors). Higher gradients favour reptiles as it allows basking for longer periods throughout the day, including when air temperatures are lower. The aesthetic value of terraces is likely to increase with gradient.

Ground cover

Suitable foraging areas are provided by structurally diverse habitats with, for example, tussocky grasses. Bare soil provides potential basking areas for reptiles but must be located in close proximity to vegetated areas that provide shelter and shade, large areas of purely bare ground do not provide favourable habitat. Frequent tillage decreases habitat favourability.

Terraces are a traditional feature of local area

Where terraces are a traditional feature of a local area their aesthetic significance can increase and they add to the areas natural heritage value.

Regional water stress

The function of terraces to retain and provide water to crops can be most valuable in regions where there is water stress.

Soil texture

Terraces are most effective at trapping and holding rain and irrigation water on medium fine, medium and coarse soils. On fine and very fine soils with poor drainage flooding may occur. Medium fine and fine soil textures have the greatest risk of soil erosion (in combination with other factors).

South aspect

A southern aspect favours reptiles as it allows basking for longer periods throughout the day, including when air temperatures are lower.

Terraces are regularly maintained

If terraces are not regularly maintained, they may not retain water efficiently. Terraces can considerably reduce soil loss due to water erosion if they are well planned, correctly constructed and properly maintained. If not maintained they can encourage land degradation. The aesthetic value of terraces is likely to be higher if are regularly maintained. Without maintenance their aesthetic value may decrease. Regularly maintaining terraces will increase labour costs.

Topography

Complex topography provides areas exposed to sun and shade at different times of the day which favours reptiles.

3.3.19. Traditional stone walls

Table 3.24: Impact matrix for traditional stone walls

	E. Ser.	Biodiversity													
	Aesthetic services	Bees	Beetles (carabids)	Birds	Butterflies and moths	Dragonflies and damselflies (Odonata)	Ferns	Fungi	Hoverflies and hoppers	Lichens	Mosses and liverworts	Pollinating invertebrates	Reptiles	Small mammals (mice, shrews, voles)	Snails
Adjacent trees and woodland				✓											
Adjacent vegetation structure													✓		
Adjacent wildlife corridors													✓		
Age of wall (time since construction/repair)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Annual rainfall							✓	✓			✓				
Condition of wall	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Lichens present															✓
South aspect													✓		
Stonewall has a north-facing side							✓								
Stonewall material							✓			✓					
Stonewalls are a traditional feature of local area	✓														
Typical stone wall maintenance period				✓											

Adjacent trees and woodland

Stonewalls have more value to birds when there is an absence of trees and woodland in the surrounding area.

Adjacent vegetation structure

Structurally diverse successional habitat such as rough grassland and scrub provides favourable habitat to reptiles. This habitat declines in suitability with a decrease in structure, for example frequently cut vegetation maintained at a low height, or where succession has proceeded to establish mature woodland with cooler microclimates.

Adjacent wildlife corridors

Diverse, quality hedgerow or linear features with dense structurally diverse vegetation facilitates the potential for reptile dispersal. Movement between and into ponds is reduced with a decrease in hedge structure, and the presence of gaps.

Age of wall (time since construction/repair)

Stonewalls that have been undisturbed for a long time are best for biodiversity. Older stonewalls are more favourable for fungi and mosses and liverworts, especially if they contain organic substrate, e.g. dust, wind-blown soil, decaying plant matter. Stonewalls that are old, weathered and well established in the landscape tend to be more aesthetically appealing and will add greater value to the areas natural heritage.

Annual rainfall

Stonewalls which have higher levels of moisture, e.g. from higher rainfall, are more favourable for fungi, ferns, and mosses and liverworts.

Condition of wall

Stonewalls in good condition are best for biodiversity. Stonewalls that are in a good state of repair are more favourable for fungi and mosses and liverworts. Stonewalls that are in a good state of repair tend to be more aesthetically appealing and will add greater value to the areas natural heritage.

Lichens present

Snail populations tend to increase when lichens are present.

South aspect

A southern aspect favours reptiles as it allows basking for longer periods throughout the day, including when air temperatures are lower.

Stonewall has a north-facing side

Stonewalls which have shaded areas (i.e. north facing) are more favourable for ferns.

Stonewall material

The type of stone is a major determinant of the type of plant community found on walls. Limestone walls usually have a relatively rich flora, including ferns and lichens, than walls constructed of other materials.

Stonewalls are a traditional feature of local area

Where stonewalls are a traditional feature of a local area their aesthetic significance can increase.

Typical stone wall maintenance period

Maintenance is best undertaken in August to October, to avoid nesting periods for birds.

3.3.20. Trees in line

Table 3.25: Impact matrix for trees in line

	Ecosystem services				Biodiversity
	Filtration/sequestration by flora and fauna	Mediation of smell/noise/visual impacts	Pesticide drift	Pest control	Birds
Pesticides sprayed on adjacent field	✓		✓		
Porosity	✓	✓	✓	✓	
Sensitive features downwind	✓				
Shelterbelt height	✓	✓	✓	✓	
Tree species					✓
Water bodies downwind			✓		

Pesticides sprayed on adjacent field

If pesticides are not sprayed on the adjacent field, then there is no role for the hedge for reducing pesticide drift.

Porosity

Trees with a dense canopy can act as a barrier to flying pests. Shelterbelts with moderate canopy porosity are the most effective in reducing pesticide drift and protecting non-target areas including water bodies. Shelterbelts with low porosity offer the greatest benefit for mediating smell, noise and visual impacts.

Sensitive features downwind

If there are no sensitive features downwind from the shelterbelt, then its benefit with respect to minimising the effects of pesticide drift are minimal.

Shelterbelt height

Tall trees can act as a barrier to flying pests. Tall shelterbelts are the most effective in reducing pesticide drift and protecting non-target areas including water bodies. Tall shelterbelts offer the greatest benefit for mediating smell, noise and visual impacts.

Tree species

Native tree species are best for local biodiversity.

Water bodies downwind

If there are no water bodies downwind from the shelterbelt, then its benefit with respect to minimising the effects of pesticide drift and consequent impact on water quality are minimal.

3.3.21. Woodland

Table 3.26: Impact matrix for woodland

	Ecosystem services								Biodiversity																		
	Aesthetic services	Chemical condition of freshwaters	Flood protection	Global climate regulation by reduction of greenhouse gas concentrations	Mass stabilisation and control of soil erosion	Pollination and seed dispersal	Provision of water for as a material	Provision of water for nutrition	Arachnids	Bees	Beetles (canopy coleoptera)	Beetles (carabids)	Biodiversity (general)	Birds	Butterflies and moths	Conifers	Ferns	Flowering plants	Fungi	Hoverflies and hoppers	Invertebrates	Lichens	Mammals	Mosses and liverworts
Annual rainfall					✓																			
Buffering capacity of soils & rocks		✓																						
Diversity of tree species	✓																		✓					
Ecological zone				✓																				
Feature is a significant component in the local landscape	✓																							
Ground cover (in woods)					✓																			
Herbaceous vegetation in woodland edge										✓	✓	✓			✓					✓				
Level of grazing																		✓						
Level of structural variability	✓										✓				✓			✓						
Local area context													✓											
Mean annual precipitation			✓				✓	✓																
Number of connected terrestrial linear habitats																		✓					✓	
Presence of fruit bearing plants														✓							✓		✓	
Presence of open spaces	✓																	✓			✓	✓		✓
Presence of pollen bearing plants						✓															✓			
Previous land use				✓																				
Proximity to other woodland/forest areas														✓	✓								✓	
Regional water stress							✓	✓																
Risk of acid deposition		✓																						

	Ecosystem services								Biodiversity															
	Aesthetic services	Chemical condition of freshwaters	Flood protection	Global climate regulation by reduction of greenhouse gas concentrations	Mass stabilisation and control of soil erosion	Pollination and seed dispersal	Provision of water for as a material	Provision of water for nutrition	Arachnids	Bees	Beetles (canopy coleoptera)	Beetles (carabids)	Biodiversity (general)	Birds	Butterflies and moths	Conifers	Ferns	Flowering plants	Fungi	Hoverflies and hoppers	Invertebrates	Lichens	Mammals	Mosses and liverworts
Risk of N deposition		✓																						
Slope					✓																			
Soil texture					✓																			
Tree species	✓															✓	✓	✓						
Woodland age (years)	✓		✓				✓	✓				✓		✓				✓	✓	✓	✓	✓		
Woodland commercially harvested		✓			✓																			
Woodland edge profile	✓								✓					✓				✓						
Woodland edge shape	✓												✓	✓										
Woodland edge vegetation density	✓												✓											
Woodland edge width														✓				✓					✓	
Woodland location						✓																		
Woodland type		✓	✓	✓			✓	✓																

Annual rainfall

An increase in annual rainfall generally corresponds to an increased risk of surface erosion.

Buffering capacity of soils & rocks

Soils with a moderate to high buffering capacity have a greater benefit for water quality, and those with a low capacity can have a negative impact.

Diversity of tree species

For fungi there is some evidence that diversity is a function of the diversity of host tree species, although other factors may also play a role (Humphrey *et al.*, 2002). A diversity of tree species is likely to have greater aesthetic value than a monoculture.

Ecological zone

The ecological zone will affect the growth potential of the woodland and thus the amount of carbon it can sequester from the atmosphere. In Europe, Temperate oceanic forest has the greatest potential and Boreal mountain the lowest.

Feature is a significant component in the local landscape

Where woodlands are a significant feature of a local area their aesthetic significance can increase.

Ground cover (in woods)

The absence of vegetation increases the risk of surface erosion.

Herbaceous vegetation in woodland edge

Herbaceous vegetation provides a food source for butterflies, bumblebees, hoverflies and an over-wintering habitat for beetles.

Level of grazing

A limited (low) amount of grazing helps to maintain some open ground, and increases the diversity of plants present (with knock on effects for other groups).

Level of structural variability

A varied structure can be of benefit to numerous species. A woodland with a highly varied structure is likely to have greater aesthetic value than a woodland with limited structure.

Local area context

Increasing woodland/forest in a largely agricultural area will increase habitat diversity, but doing so in a largely forested area may reduce it (Zanchi *et al.*, 2007).

Mean annual precipitation

Where rainfall is high there is scope for greater reduction in water yield, and thus a greater impact on water provision. Where rainfall is high there is the greatest potential for woodlands to reduce water flows and thus contribute toward reducing the risk of flooding in the catchment. An increase in annual rainfall generally corresponds to an increased risk of soil erosion.

Number of connected terrestrial linear habitats

Connected woody habitats, such as hedges, are important for mammals and plants.

Presence of fruit bearing plants

The presence of fruit bearing plants is important as a food source for birds, mammals (Sarlov Herlin & Fry, 2000), and invertebrates (Fry & Salov-Herlin, 1997).

Presence of open spaces

The presence of open spaces aids in maintaining a proportion of early-successional habitat as well as a greater diversity of habitats. A woodland with open spaces is likely to have a greater aesthetic value than a woodland with few of no open spaces.

Presence of pollen bearing plants

Pollen bearing species have been found to be important for invertebrates (Sarlov Herlin & Fry, 2000), whilst guidance on maintaining woodlands for pollinators identifies that they are important for this sub-group of invertebrates.

Previous land use

Previous land use will affect the amount of carbon that can be sequestered in the soil, with arable land having the greatest potential to sequester carbon.

Proximity to other woodland/forest areas

The greater the proximity to other woodland/forest areas the greater the benefit for numerous woodland species (Lazdinis *et al.*, 2005).

Regional water stress

Any reductions in water yield from woodland are of most significance in regions where there is water stress.

Risk of acid deposition

The higher the risk of acid deposition, the greater the risk to water quality.

Risk of N deposition

The higher the risk of N deposition, the greater the risk to water quality.

Slope

An increase in slope gradient increases the risk of soil erosion.

Soil texture

Soils with a high proportion of silt are more vulnerable to surface erosion than clay soils whose particles are more tightly bound, or the coarser sandy soils that drain more freely.

Tree species

Planting fast growing exotic species may have a negative impact on biodiversity (Plantinga & Wu, 2003). Native species are likely to have greater aesthetic value with respect to a natural landscape than exotic species.

Woodland age (years)

Older woodlands have the greatest potential to reduce water yield and thus impact upon the provision of water (Farley *et al.*, 2005). Older woodlands have the greatest potential to reduce water flows and thus contribute towards reducing the risk of flooding in the catchment.

There is evidence that older stands support more natural forest ecosystems than younger ones (Brockerhoff *et al.*, 2008). Older woodlands are likely to have greater aesthetic value than new woodlands.

Woodland commercially harvested

Harvesting woodlands (and subsequent planting with young trees) can reduce nitrate leaching (Bastrup-Birk & Gundersen, 2004). Felling and replanting can increase soil erosion.

Woodland edge profile

A woodland with a 3 stepped edge is likely to have greater aesthetic value than a woodland with only 1 or 2 steps (Sarlov-Herlin & Fry, 2000). A complex structure (with more steps) is beneficial to birds and web producing spiders (Fry & Sarlöv-Herlin, 1997).

Woodland edge shape

A less straight edge, preferably with softness to the edge (i.e. some gaps/shrubby vegetation) provides a diversity of habitats at the large landscape scale (Sarlöv Herlin, 2001). Woodlands that have a curved and variable edge are likely to have a greater aesthetic value than woodlands that have straight and uniform edges.

Woodland edge vegetation density

Dense vegetation provides greater habitat diversity and protection for biodiversity. There is some evidence that people find open forest edges more visually appealing than densely vegetated edges as it allows a view into the forest. It also allows access.

Woodland edge width

The incidence of plants distributed by animals (birds and mammals) is greater in wider forest edge zones (Sarlov-Herlin & Fry, 2000).

Woodland location

When woodlands are located within fields they can provide vital stepping stones for pollinators to navigate across the field.

Woodland type

Coniferous woodland has the greatest potential to reduce water yield and thus impact upon the provision of water (Sahin & Hall, 1996), and thus also contribute towards reducing the risk of flooding the catchment. The type of woodland affects the amount of carbon that can be sequestered from the atmosphere, with coniferous woodland having the greatest potential. The scavenging of atmospheric pollutants is a key source of acid deposition (acidification of surface and groundwaters), with conifers being better scavengers than other tree types, thus having a greater negative impact of water quality.

4.0. The EFA calculator software

4.1. Introduction and overview

The EFA calculator software is a standalone Windows application that has been developed using Microsoft Visual Studio 2010, with an underpinning core database developed using Microsoft Access. The application is designed to work on Windows 7 or higher and requires the .NET framework to be installed on the PC (if this is not installed, the EFA installation package will download and install it). The software has three core functions:

- Primary function: To calculate the contribution of different farm features to meeting the 5% EFA target (including checking implementation rules).
- Secondary function: To calculate the potential impact of different features on ecosystem services, biodiversity and management.
- Tertiary function: To steer farmers towards features which offer the greatest potential benefits (with respect to minimising burdens and maximising benefits).

The software is freely available to download from the web (https://sitem.herts.ac.uk/aeru/efa/). The user downloads a setup file which then installs the application locally on the PC. The software includes facilities to check for updates to the software and core database, and in the case of the latter it can automatically download and install new versions of the database when they are released.

In order to perform the core functions, the software has 8 main graphical user interfaces, each of which has its own detailed functions. These interfaces are:

1. **The welcome screen:** a central interface from which the other parts of the application are accessed.
2. **The new file creation wizard:** an interface designed to speed up the creation of new files, especially for novice users.
3. **The land and feature manager:** the main interface for data entry, where the user creates and describes the features they have on the farm and/or might create to meet the EFA target.
4. **The EFA assessment screen:** the interface for allocating farm features as EFAs and thus calculating their contribution to the 5% target (including compliance with any implementation rules), and thus determining progress towards the target.
5. **The new feature ranking tool:** an interface accessible from the land and feature manager and EFA assessment screens, that allows users to rank features that could be created on the farm against a set of criteria.
6. **The report builder:** an interface that allows users to build reports using the data they have entered, assessments made, and any analyses that have been undertaken.
7. **The settings and options centre:** an interface that provides the user with some basic tools to customise the appearance and behaviour of the software.
8. **The 'Show Me' help centre:** a set of annotated videos that demonstrate how to use the software.

Figure 4.1 provides an over of these interfaces and how they interact with each other. Each interface is described in detail below.

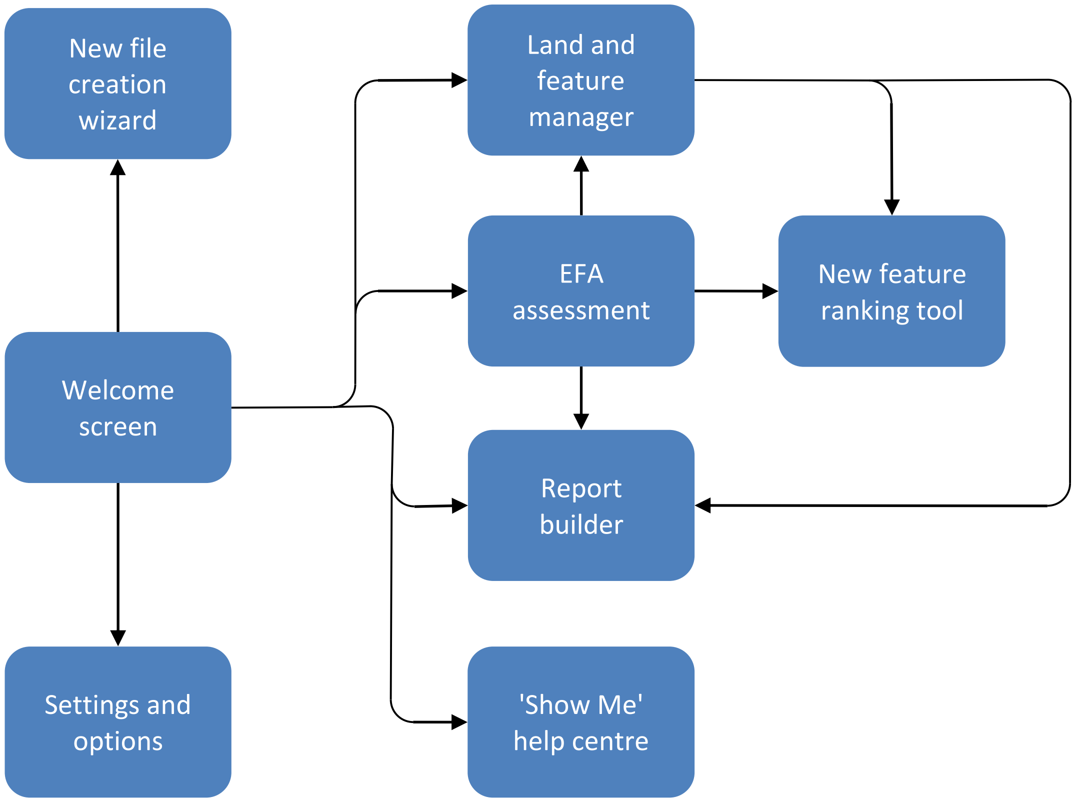


Figure 4.1: Overview of the interfaces in the EFA software

Like many other windows applications, the EFA calculator software works by the user creating a file for their farm. This file is then used to store data about the farm and its features, allocation of features as EFAs and data associated with the impact assessment that is performed on the features.

4.2. Welcome screen

The welcome screen is the interface that opens when the user starts the software (see Figure 4.2). Other than the new feature ranking tool, all the other interfaces and functions can be accessed from this screen.

Upon first use the user is shown 4 items on the welcome screen:

- The navigation key
- Guidance on getting started
- A list of files that have been opened
- The current software and core database version

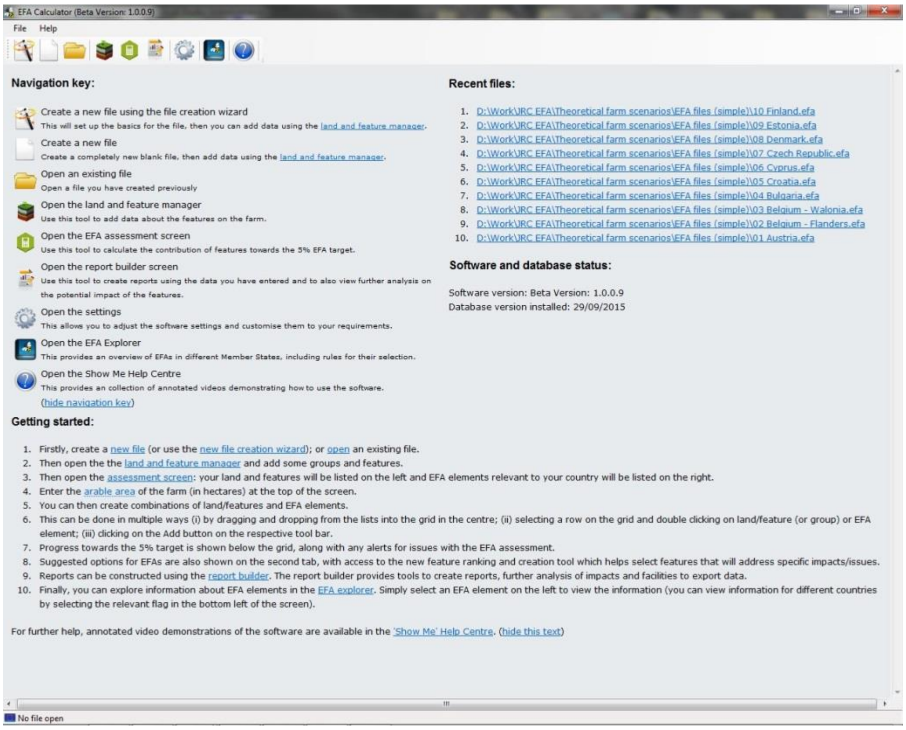


Figure 4.2: The welcome screen interface

The navigation key and getting started text can be hidden by the user once they are familiar with the software (they can be reactivated again on the Help menu and in the options and settings). The list of recent files and software version information are always displayed.

The navigation key shows all the icons that are used on buttons for navigating around the software along with a short description of what they do. As well as providing a key, clicking on the icons in the key also performs the same function as click on the button in the toolbar.

The getting started text provides a brief 10 step guide on using the software. Clicking on the hyperlinks within the text will activate the associated functions/interfaces. Hyperlinks with a dotted underline provide links to definitions, e.g. arable area. The getting started text is designed to be very concise, with more detailed help provided in the Show Me help centre.

The list of recent files provides a quick means of opening previous files. Clicking on the link displayed will open the file is the same way as using the open file dialog on the File menu or toolbar. The list of recent files is also shown in a menu format as sub-menu items on the File menu. This is also the case on the land and feature manager, EFA assessment and report builder screens.

4.3. New file creation wizard

The new file creation wizard is a step by step tool to help users create and setup a new file for their farm. It is possible to create a completely blank file (using the New EFA file on the File menu or toolbar) and this will create a file using the default Member State selected in the settings and options. The new file creation wizard also creates an EFA file, but in the process allows the user to select some basic setup options for the file; add features (excluding data describing those features); and add data that applies to the whole farm (e.g. climate parameters). There are up to four steps to the wizard:

Step 1: Options: Figure 4.3 shows the first step of the new file creation wizard. The user needs to select a file name using the Browse button (just like any other Windows application); enter the arable area for the farm (which is used to determine the EFA target); select the Member State in which the farm is based; whether lists within the software (i.e. EFA elements, features and species) are restricted to those specified by the Member State or the full list is to be shown; the level of detail to be shown (basic settings restrict the amount of data to be entered to the minimum required); what data to use for impact scoring (when a range exists); and whether to group features together or present them in a single list. These options can be changed by typing into the relevant cell and/or double clicking on the cell and selecting from the drop down box.

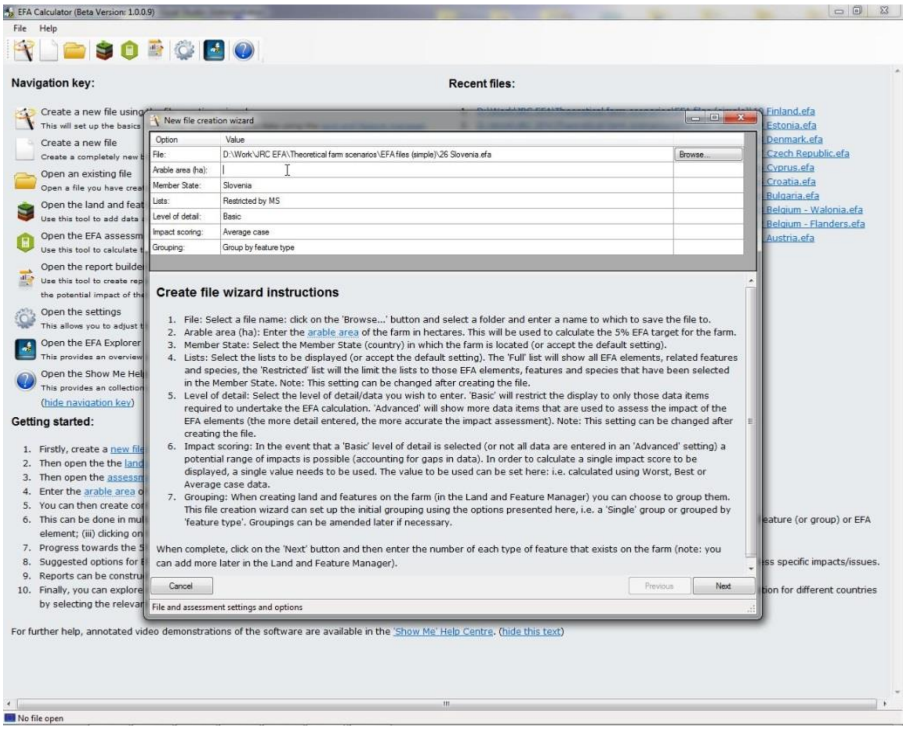


Figure 4.3: Step 1 of the new file creation wizard

Step 2: Features: Figure 4.4 shows the second step of the wizard. The user is presented with a list of features that may exist on the farm (this list may be restricted to only those relevant to EFAs activated in the Member State if this was selected in the options in Step 1). The user enters the number of each feature that they want to create for the farm. This can be features that already exist, features that will be created, or both. Guidance text is presented on the right (when the user clicks on a feature in the grid) to describe what the feature is and what constitutes an individual feature (i.e. usually that it is a distinct feature that is distinguishable from other adjacent features). Details on the requirements for eligibility as an EFA in the Member State are also shown in the guidance.

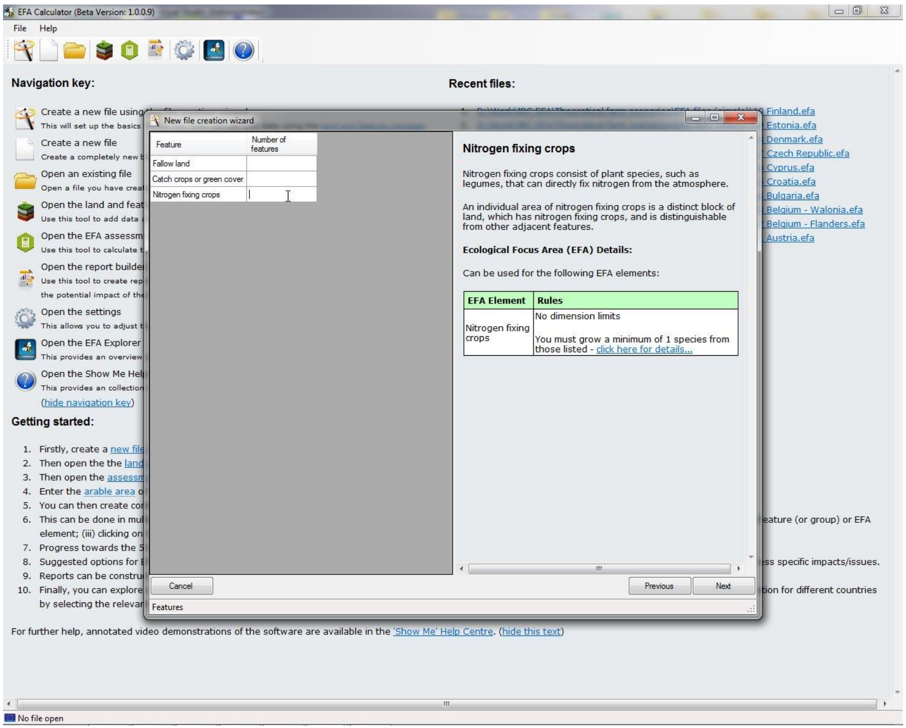


Figure 4.4: Step 2 of the new file creation wizard

Step 3: Whole farm parameters: Figure 4.5 shows the third step of the wizard. The user is presented with a list of parameters that could potentially be applied to the whole farm (e.g. annual rainfall). Clicking on each parameter displays guidance on the right about that parameter and the options available. The user can select values for relevant parameters (and leave them blank where they are not relevant) by double clicking on the cell and selecting from the drop down box. The whole farm data will be used as default values when entering data for each feature (in the land and feature manager), thus speeding up the data entry process. In the setting and options, the user can decide whether to display all whole farm parameters on this screen or restrict the list to only those that are relevant to the features they intend to create.

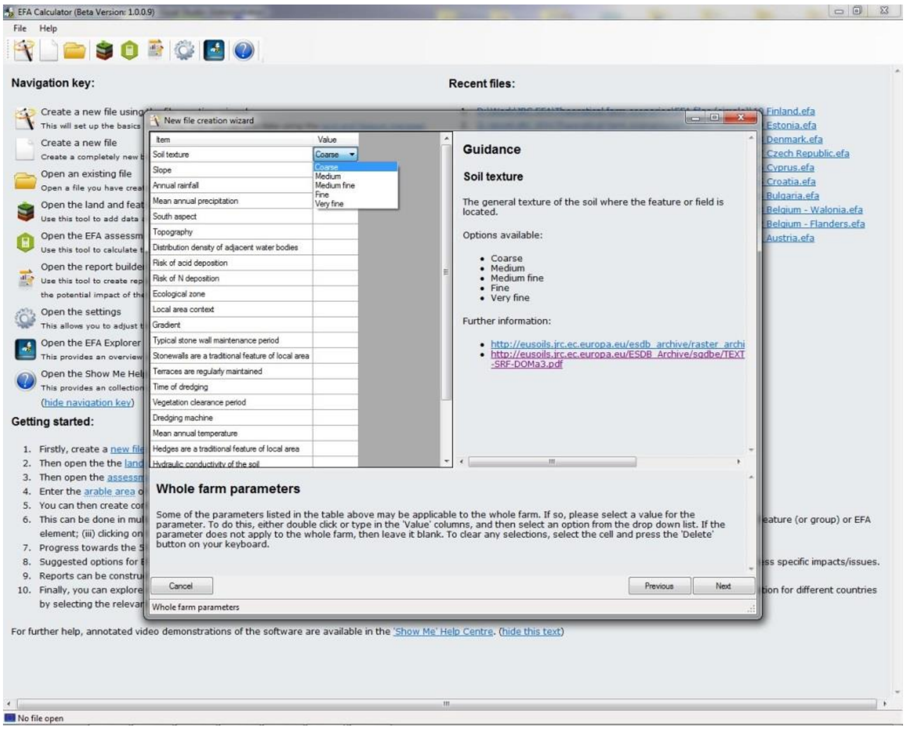


Figure 4.5: Step 3 of the new file creation wizard

Step 4: Summary and check: Figure 4.6 shows the fourth and final step of the wizard. There is no data entry on this screen. It simply allows users to review the data they have instructed the wizard to create. If the user wishes to make some changes they can use the 'Previous' button to return to the previous steps to make any changes. When the user is happy with the data, clicking on the 'Finish' button will create the file (note: no file is created or any data saved, until the finish button is clicked).

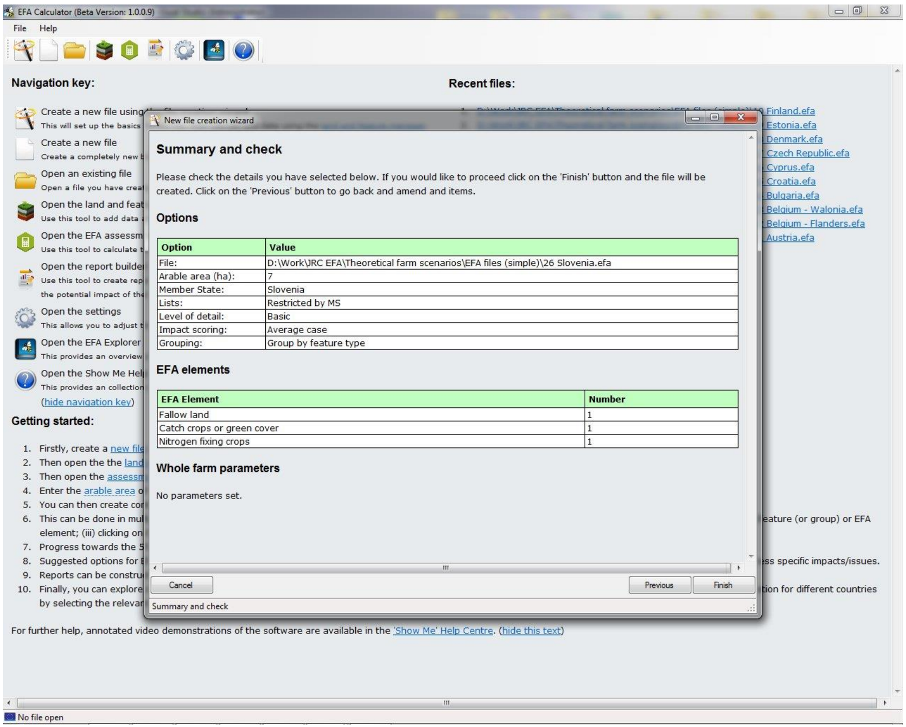


Figure 4.6: Step 4 of the new file creation wizard

Upon completion of the wizard, the file is created and a summary of the file is now displayed on the welcome screen. From here the user can choose to open the land and feature manager to edit the data for the features (e.g. their dimensions).

4.4. Land and feature manager (LFM)

4.4.1. Layout of the LFM

The land and feature manager (LFM) is the main interface for editing data in the software. It is where users can add and delete land or features for the farm, edit the data for individual features, and group features. Figure 4.7 shows the basic layout of the LFM.

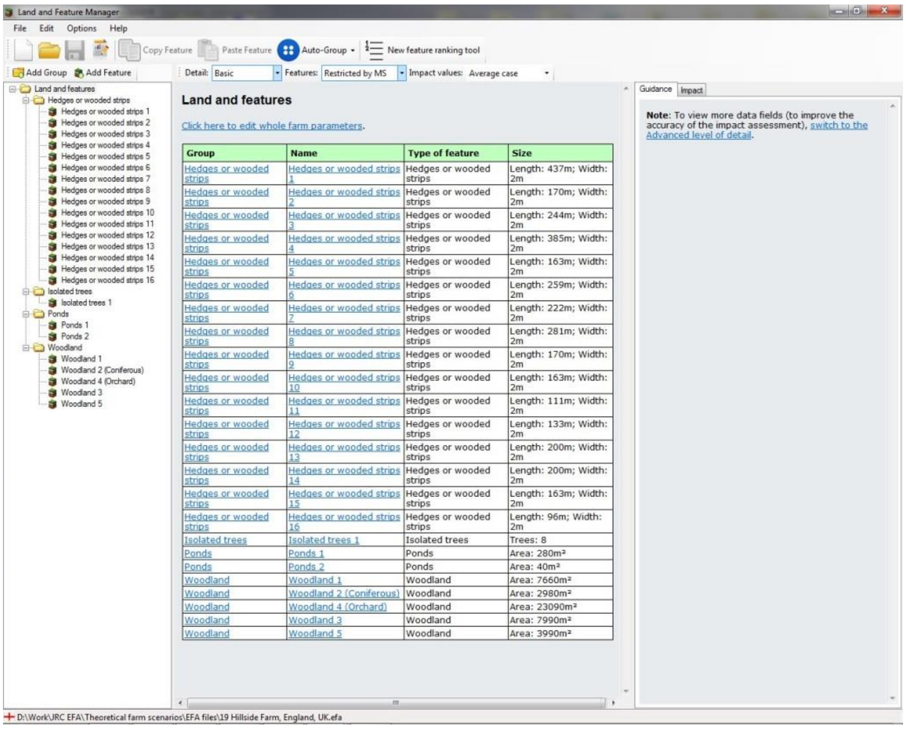


Figure 4.7: Layout of the land and feature manager (LFM)

The land and features that have been created for the farm are listed on the left - this is in the form of tree view (like Windows Explorer) to provide users with the flexibility to organise their data as they see fit. Groups (the folder icon) can be created and then features within a group (alternatively just one group can be created and all features listed within that group). It is possible to create groups within groups and it is also possible to 'drag and drop' groups or individual features into other groups. There is also an Auto-Group function/button on the toolbar to facilitate rapid changes in groupings. It allows users to re-group their land features in one single group, a group for each type of feature, or by whether the features are new or existing features.

When the user clicks on a group, all the land and features within that group are shown in the grid in the centre of the screen (see Figure 4.8). When the user clicks on an individual feature, all the data for that feature is shown in the grid in the centre of the screen (see Figure 4.9). The information panel (with guidance and impact tabs) will be displayed below the grid (when in automatic mode) when viewing a group and will be displayed on the right when viewing an individual feature. If users want the panel to always be displayed below the grid (horizontal) or always to the right (vertical) this can set this on the Options menu at the top of the screen. Users can edit the data (see Section 4.4.2) in the grid in the centre when in Group view or Individual feature view.

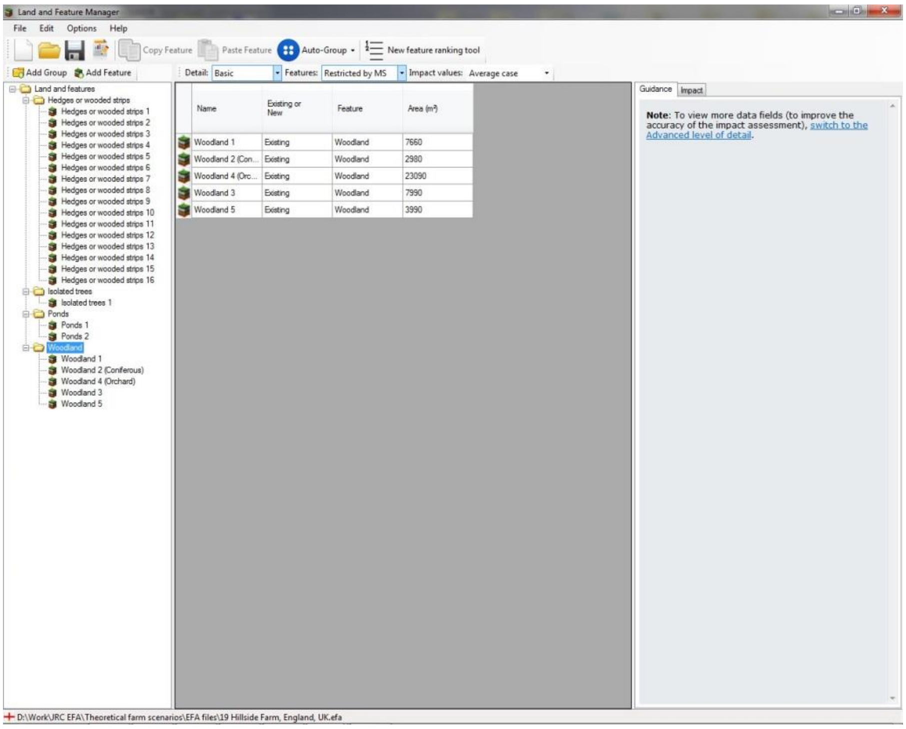


Figure 4.8: LFM: Group edit view

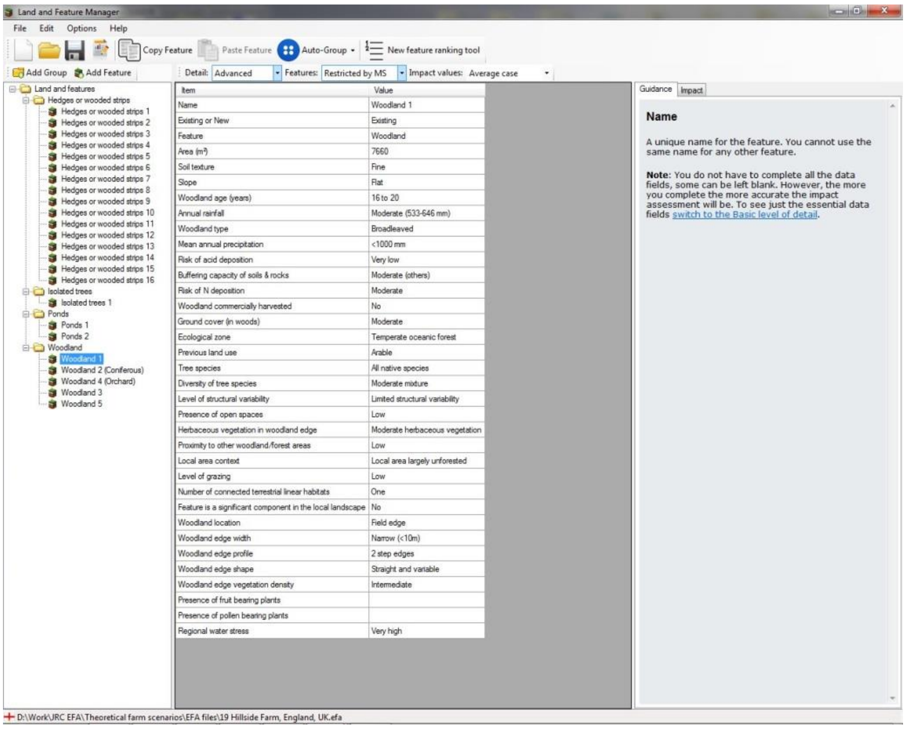


Figure 4.9: LFM: Feature edit view

4.4.2. Editing feature data in the LFM

As described above, there are two views in which data can be edited, the Group or Individual feature view. The editing procedure is the same in both views except in Group view the data is presented horizontally (and you can edit the data for features side by side) and in Individual feature view the data are presented vertically.

Above the central grid there are two settings that can be changed that will affect data entry: Detail (Basic and Advanced) and Features (Restricted by MS and Full list). Selecting 'Basic' will only show the data items that are required in order to do an EFA assessment, thus it keep data entry to a minimum. Selecting 'Advanced' will display the full list of data items (which is substantially more) and these are used to refine the impact assessment. If whole farm parameters have been entered some of these data items will be prepopulated.

Not all data has to be entered (in the advanced mode), but the more that is entered the more accurate the impact assessment will be. In the event that not all data are entered, then a range of potential impact values will exist for the feature. This is because in the absence of one or more data items one or more impact scores (see Section 3.2.5) are unknown and consequently can range from best case to worst case. In this situation the software needs to know which value should be used. By default it is set to worst case (following the precautionary principle), but it can be adjusted by the user. In the toolbar above the editing grid there is a drop down list box for Impact values, from which the user can select: Best, Worst or Average case, and then the software will use these values accordingly (this can also be set during the new file creation wizard).

Editing the data is relatively straightforward and is similar to MS Excel. Users can double click on a cell: for quantitative data this will activate the cell and users can type into it, for qualitative data this will activate a drop down list and the user can then make the list appear by clicking on and selecting an item on the list. Alternatively users can single click on a cell and type directly in the cell, for quantitative data this will go directly into the cell, and for qualitative data the first letter typed will select the first item on the list that starts with that letter.

Data can be saved by clicking on the Save button on the toolbar or the File menu. If the user leaves a group or feature before saving the data they will be prompted to save the data. There is also an Auto-save feature, which can be activated on the Options menu. When Auto-save is activated, the data is saved each time a data item is changed. This ensures that data is always saved, but it can make the data entry process slower – the reason why it is an option that the user can switch on or off.

It is also possible to copy and paste individual features. To do this the user can select a feature, click on the copy feature button in the toolbar and paste the feature either into the same group or a different group, by selecting a place in the try to paste it to (just like copying and pasting files in Windows). This will copy the feature and create a new feature that includes all the data from the copied feature.

4.4.3. Editing whole farm parameters in the LFM

When using the new file creation wizard (see Section 4.3), the user can enter/select data for parameters that apply to the whole farm. If the user wishes to edit this after creating the file, there is a function in the LFM to do this. If the user selects the top of the tree on the left, all the features are displayed in the centre of the screen (See Figure 4.10). Above this display there is a hyperlink to edit the whole farm parameters. Alternatively, selecting 'Whole farm parameters' on the Edit menu will activate the same function.

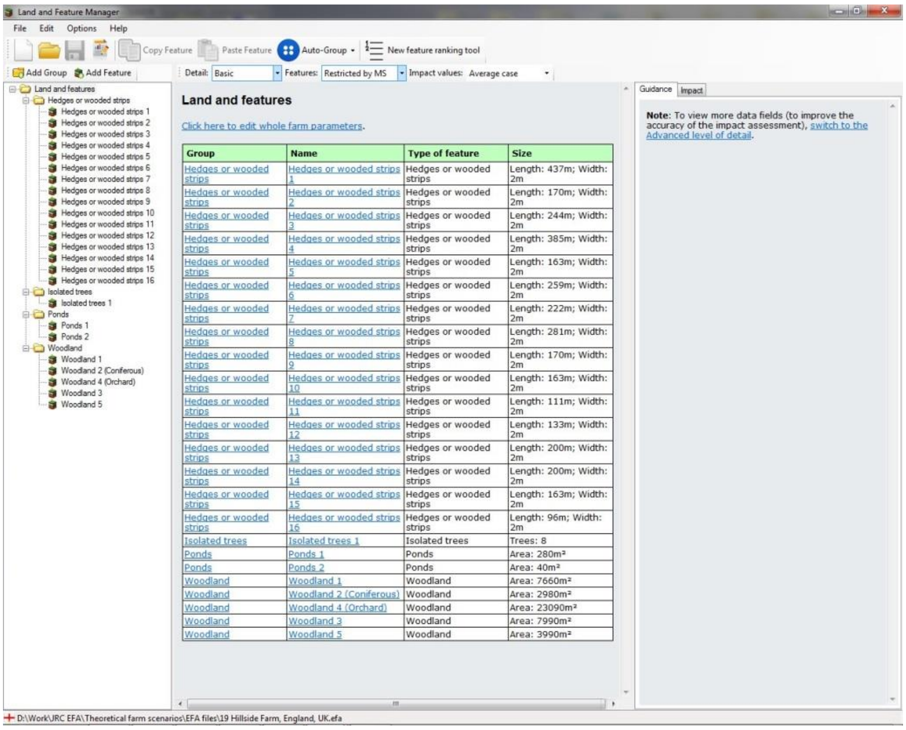


Figure 4.10: LFM: Summary of land and features view

This will display step 3 of the new file creation wizard (see Figure 4.5), and the user can then edit the whole farm parameter data accordingly. Upon saving the data, the user will be asked if they wish to apply all whole farm parameters to all the features (i.e. overwrite the existing data). Selecting yes will overwrite the data, selecting no will save the parameters and use them as default values when creating new features. If the user choses to overwrite the data for existing features, then this will invoke a routine to recalculate the impacts for all the features (as the changes to the whole farm values may result in different impacts).

4.4.4. The information panel - guidance

The LFM has an information panel which can be displayed to the right or below the central grid (determined by the user on the options menu). The information has two main tabs: Guidance and Impact, with the latter having sub-tabs (see Section 4.4.5). The guidance tab is designed to support users when editing data. When the editing grid is displayed (in group or individual feature view), when the user clicks on a cell within the grid guidance text is displayed in the information panel. The guidance text consists of the following:

- The title of the parameter selected
- A description of the parameter / the data required
- In the case of qualitative data, a list of the options that can be selected
- In some instances further information is displayed in the form of hyperlinks to website
- Notes on potential impacts

In relation to the notes on potential impacts, this displays text/guidance on the potential impacts that the parameter selected may have an influence on (following the impact matrices shown in Section 3.3). The purpose of this guidance is to raise the awareness of the user to the effect of different parameters on different impacts. In some instances this may also steer users towards certain practices that may minimise burdens or increase benefits, for example the cutting season and/or frequency of hedgerows.

4.4.5. The information panel - impact

The impact tab on the information panel has two sub-tabs: Indicator bars and Icons. The Indicator bars tab provides a simple overview of the impact of the farm features selected (being the whole farm, a group or an individual feature) with respect to the top-level impact categories, i.e. ecosystem services, biodiversity and management (see Figure 4.11).

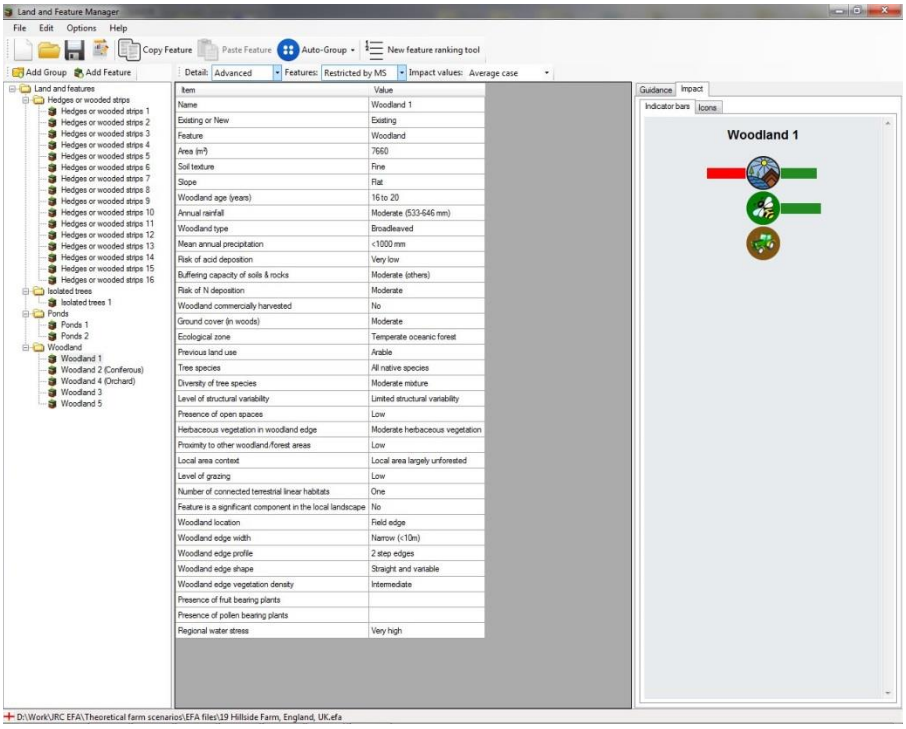


Figure 4.11: LFM: Impact: Indicator bars

The Icons tab provide a more detailed overview of the potential impact of the selected farm features in the form of impact icons, grouped into ecosystem services, biodiversity and management (see Figure 4.12).

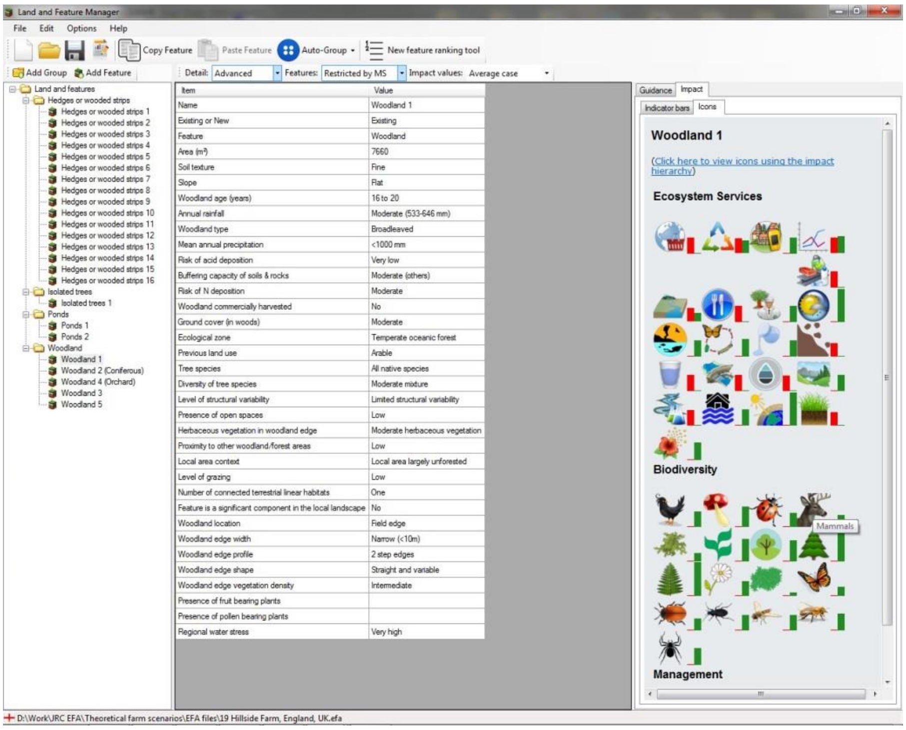


Figure 4.12: LFM: Impact: Indicator icons

The number of icons displayed varies with the number of impacts associated with each feature, but also with the level detail requested by the user (which can be set in the settings and options section of the software). The impact icons are fully explained in Section 4.7.4. The majority of the icons are self-explanatory, especially the biodiversity icons, but in the event they are not clear, hovering the mouse over the icon will display the impact title (as tooltip text) and/or a key to the icons can be displayed by clicking on the icon key hyperlink.

4.5. EFA assessment

4.5.1. The layout

The EFA assessment is the main 'calculator' part of the software. It provides users with a facility to construct EFA assessments, which is essentially the list of EFAs (and associated land and features on the farm) that the users intend to declare. As such it allows users to add and 'declare' the features they have created, calculates the EFA area of those features and thus reports on progress towards the 5% target

Similar to the LFM, the users land and features are presented on the top left side of the screen (see Figure 4.13) using the tree view structure. In the bottom left of the screen is a small report window which displays basic details about any land or features that are selected in the tree view. On the top right of the screen is the list of EFA elements that have been activated in the Member State in which the users farm is based, and below this in the bottom right of the screen is another small report window which displays details about the EFA element that is selected in the list above. In the top middle part of the screen is a grid that displays the currently selected EFA assessment. Each assessment is presented as a tab along the top of the grid. Below the EFA assessment grid, are two reports: 'Progress and alerts', showing progress towards the 5% target and any issues with respect to implementation rules; and 'Suggested additions', which show potential features that could be created/added to the EFA assessment to meet the EFA target.

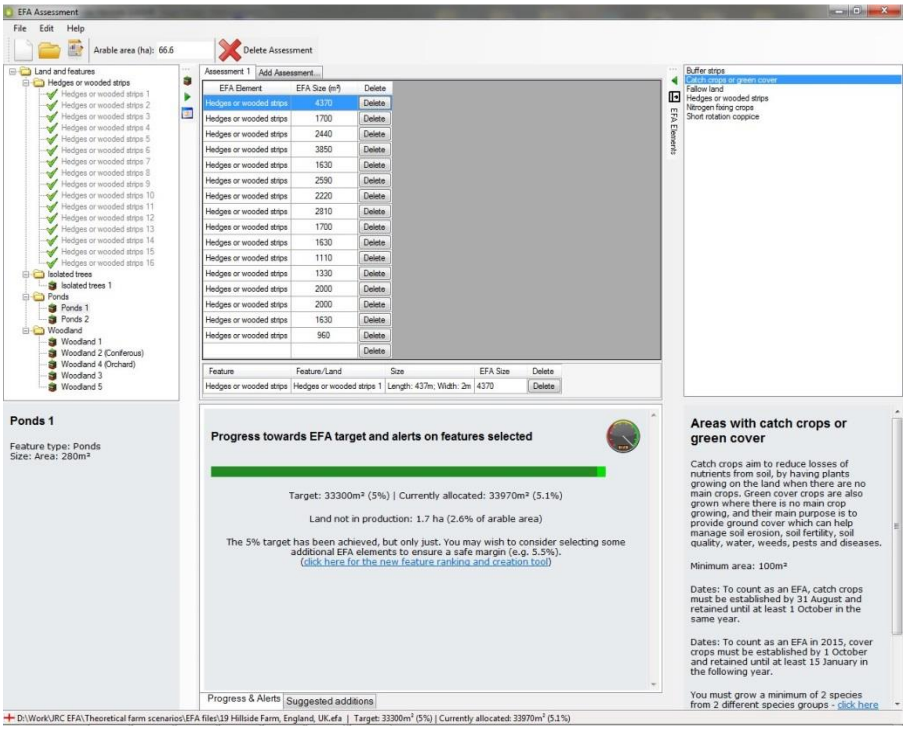


Figure 4.13: Layout of the EFA assessment screen

4.5.2. Creating an EFA assessment

Upon first opening the EFA assessment screen for the first time, a blank EFA assessment (Assessment 1) is displayed. An EFA assessment requires the combination of EFA elements with the users data on land and features. As described in Section 3.2.2, some EFA elements in some Member States can have more than one feature associated with them, hence why EFA elements are separate entities to the land and features. There are a few different ways in which you can add/combine EFA elements and farm land and features:

1. You can drag and drop a farm feature from the tree view on the left into a blank row in the EFA assessment grid in the centre of the screen. The same process can also be done by selecting a blank row, selecting a feature and then either double clicking on the feature or using the add button (green arrow) on the toolbar between the features and grid. Upon adding the feature, if it is only associated with one EFA element then this will be automatically combined. If it is associated with two or more EFA elements then the user will be prompted to select the EFA element that the user wishes to declare for the feature they are adding.
2. You can add groups of features in one go using the same approach as described in point 1 above, but by selecting a group instead of the feature in the tree view of land and features.
3. You can add all land and features to the assessment using the same approach as points 1 and 2 above, except by selecting the land and features at the top of the tree, and if using the toolbar to add them instead the green arrow add button, use the 'Add everything' button.
4. Instead of adding features first, the user can add an EFA element first. This is done in the same way as adding features except the user selects an EFA element from the list of the right, then does a drag and drop, double click or uses the toolbar between the EFA elements and the grid. This effectively adds a 'blank' EFA element to the assessment. The user can then add land and features to an EFA element, by dragging and dropping features onto it in the grid.

The software always checks to see if a feature has been allocated to an EFA element and prevents it from being allocated more than once. If the user tries to add a feature to second EFA element they will be informed that it has already been allocated.

When the user clicks on the EFA element in the assessment grid, a second grid in the middle of the screen (the feature grid) displays the type of features that can be applied to that EFA element, and also the name of the features that have been allocated so far. Dragging a different feature (of the same type) onto an EFA element that already has a feature allocated will replace that feature with the new one.

If the user wishes to delete features from an EFA element, this can be done by clicking on the 'Delete' button on the feature grid. This will clear this feature from the EFA element. If the user wishes to delete an EFA element, then this can be done by clicking on the 'Delete' button in the assessment grid. If the user wishes to delete an entire assessment, this can be done clicking on the 'Delete Assessment' button in the toolbar (one assessment has to be retained, so the last assessment present cannot be deleted).

4.5.3. EFA rules that are checked

When adding land and features to the assessment a number of rules are checked to ensure that the feature is valid. If it is not valid then this is flagged up to the user and the feature/EFA element is excluded from the calculation determining progress towards the target. The rules that are checked (which can vary with Member State) include:

1. Whether the feature being added to the assessment is valid for any EFA element. If it is not, then the software prevents it from being added.
2. If the feature is being added to an EFA element (that has already been added to the grid), the software will check to see if it is a valid feature for the EFA element, if it is not then the software prevents it from being added.
3. Whether the landscape feature being added is on or adjacent to arable land (this applies to Hedges or wooded strips; Isolated trees; Trees in line; Trees in groups and field copses; Field margins; Ponds; Ditches; Traditional stone walls; and Other landscape features).
4. Whether the feature contains any invalid parameters, for example if the substrate for ponds is concrete.
5. Whether the species selected for nitrogen fixing crops is valid.
6. Whether the species for short rotation coppice is valid.
7. Whether the species for catch/cover crops is valid.
8. Whether the number of species (and species groups) for catch crops is valid.
9. Whether all the required dimensions have been specified.
10. Whether the feature dimensions are valid.

In the event that a feature fails any of the rules 3 to 10, the feature will be added to the assessment grid, but it will not be included in the EFA target calculation. This then allows the user to open the LFM and adjust the data where necessary, and then upon returning the EFA assessment this will then be reassessed to determine if it now complies with the rules.

4.5.4. Progress and alerts

Below the assessment grid is a report that displays a progress bar showing progress towards the 5% target as the user adds features to the assessment (see Figure 4.14). Progress on the bar is shown as follows:

- Red = EFA that needs to be allocated to reach the 5% target
- Dark green = Land and features allocated as EFA
- Light green = EFA that has exceeded the 5% target, up to 5.5%

(Note: the colours used on the progress bar can be changed in the settings and options, e.g. to facilitate user who had colour blindness)

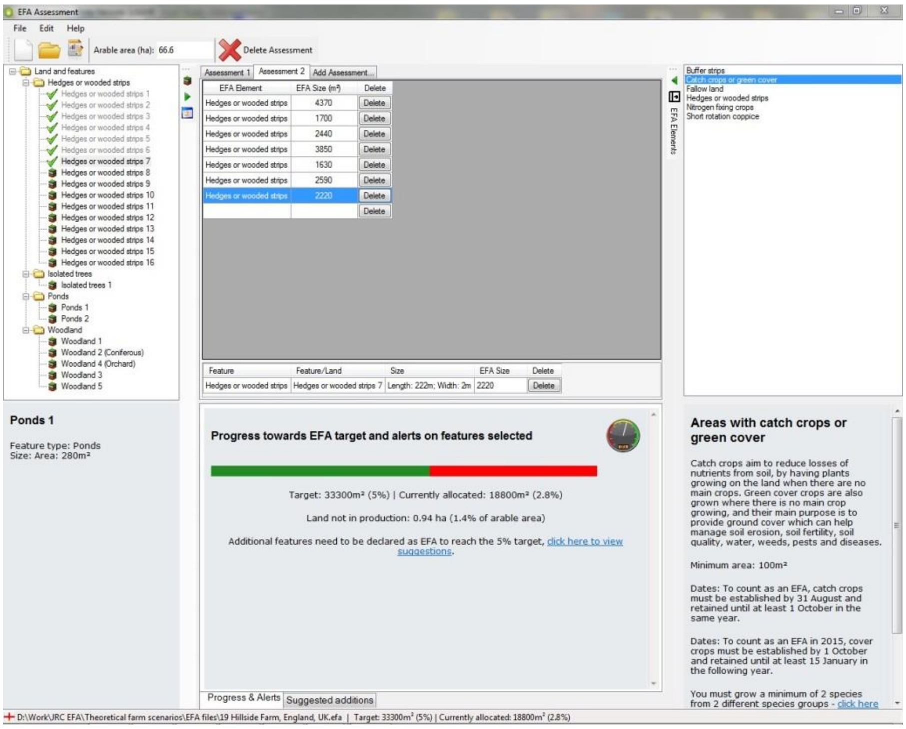


Figure 4.14: EFA assessment: progress report

The progress bar goes up to 5.5% to encourage user to go beyond the 5% target and thus account for any margin of error in the users data. There is also a general encouragement within the software to do more than 5% where possible.

The progress report also shows the percentage of the arable area that is considered 'not in production' due to being allocated to EFA, so that users can take this into account in their decision making.

When a feature has been added to the assessment and has failed one or more of the implementation rules, an alert is shown in the progress report explaining why the feature and associated EFA element has been excluded. The user can then use these alerts to take corresponding action (i.e. either change the data or remove the feature from the assessment.

4.5.5. Options for additions

Below the assessment grid on the 'Suggested additions' tab is a secondary report which lists additional EFA elements that the user could consider creating as new features in order to reach the 5% target, along with the area that would need to be created to reach the target (see Figure 4.15). The user has an option here to use the ranking tool (see Section 4.6) to determine which features it would be best to implement and/or view any previous rankings.

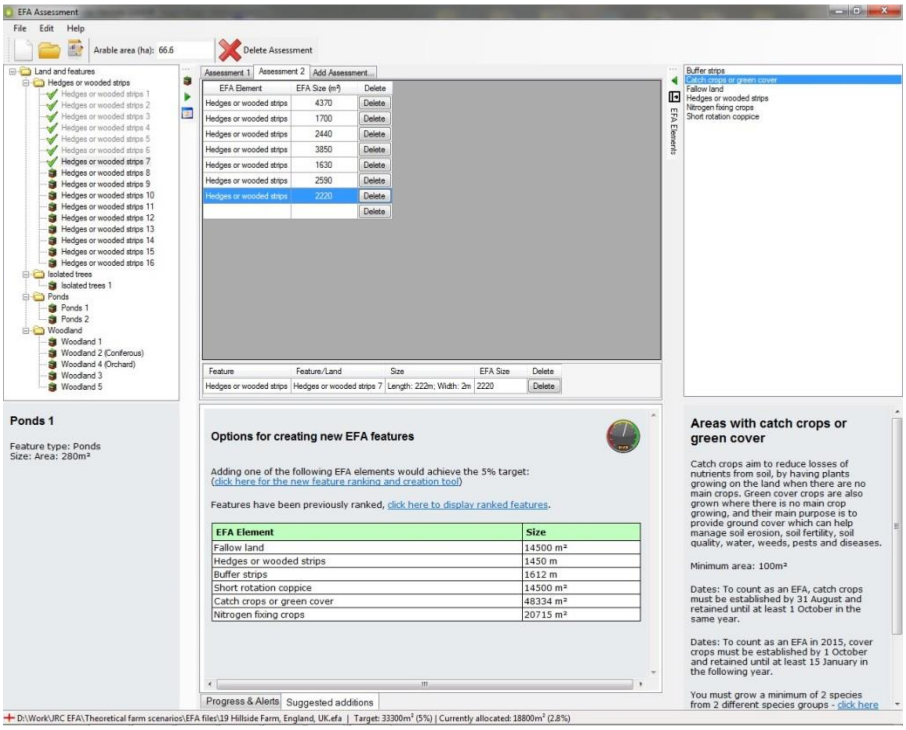


Figure 4.15: EFA assessment: suggested options report

In the event that the 5% target has been reached, the areas of EFA elements to implement to reach the target are not shown. But the user is encouraged to implement more EFAs if possible and to use the ranking tool to guide them.

4.6. New feature ranking tool

The new feature ranking tool is accessible from the LFM and EFA assessment screens. It designed to allow users to identify new features that could be created on the farm in order to meet specific objectives. The ranking criteria and process is described in Section 3.2.7. Figure 4.16 shows the layout of the tool. On the right of the screen the user has a number of options that they can select. This includes selecting the criteria they want to use for the ranking (the objectives they wish to meet) and options for what should be displayed. In the toolbar along the top of the screen, are a drop down list of previously saved rankings and buttons to add new rankings or delete existing ones.

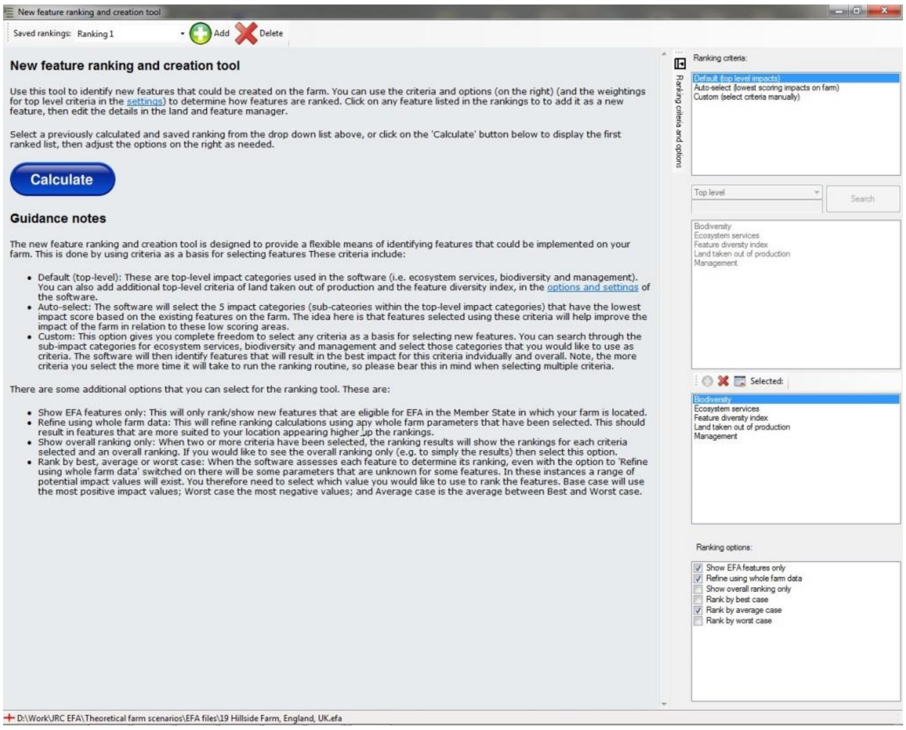


Figure 4.16: New feature ranking tool

The user firstly selects the type of criteria they want to use, using the list in the top right corner. In the event they chose the custom option, they can then use the second and third lists to select the specific criteria they want to use. In all instances, the criteria that are used are shown in the third list.

The user then has a number of options they can choose for calculating and displaying rankings. These are:

- **Show EFA features only**: This will restrict the list of features that are ranked to only those that can be used in EFA elements that have been activated by the Member State. This can be useful when the user is seeking to implement new features to meet their EFA target.
- **Refine using whole farm data**: This will use any whole farm parameter data that has been entered to refine the calculation of the impact values that will be used for the ranking. If this option is not used, then the full range of values for any feature will be used (thus making the choice of best, average or worst case data result in greater differences).
- **Show overall ranking only**: This will simplify the ranking display to show an overall ranking only. If this option is not ticked the ranking for each criterion will be displayed.
- **Rank by best, average or worst case**: This option determines what impact value to use in the ranking that is displayed.

Once the user has selected the criteria and options that they want to use, they then click on the 'Calculate' button and the ranking will be calculated. This can take time in some instances, ranging from a few seconds to a few mins depending on the number of criteria selected by the user (as it involves calculating the impact of each feature on each criterion). Figure 4.17 shows an example of the ranking results that are produced by the tool.

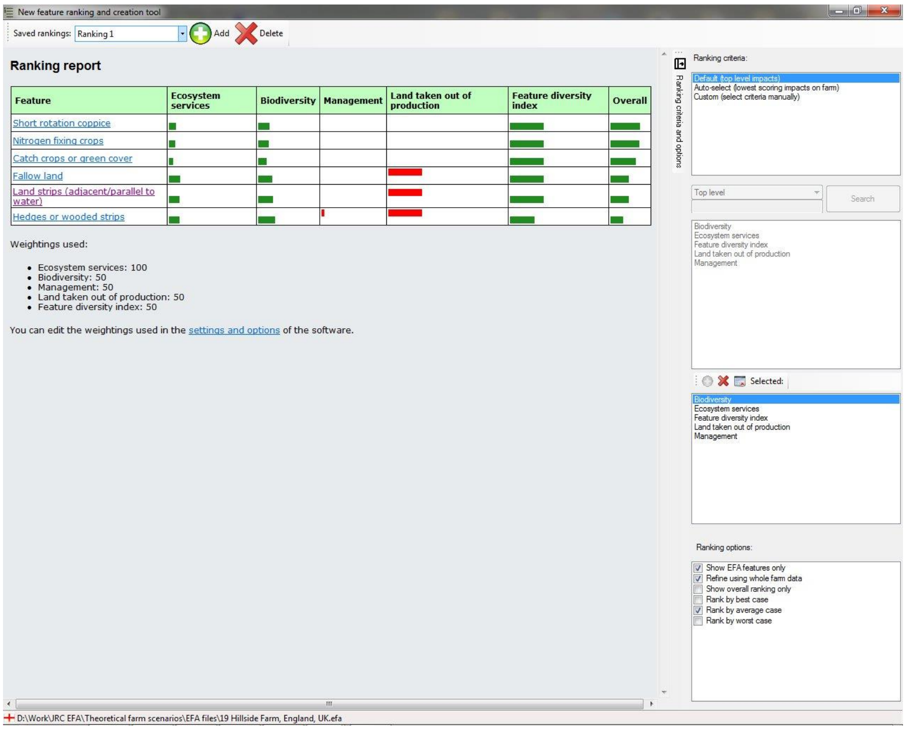


Figure 4.17: New feature ranking tool: example ranking

Should the user wish to create any of the features on the ranked list, clicking on the hyperlink in the list will add the feature to the users land and features (in a new group). These can then be edited and amended by the user in the LFM.

If the user wishes to create a new ranking, this is done by clicking on the Add button – the user then enters a name for the ranking and performs the procedure above. Previously created and saved rankings can then be displayed by selecting them from the drop down list box at the top of the screen. Saved rankings can also be viewed within the report builder.

4.7. Report builder

4.7.1. Layout

The report builder provides a facility for the user to create reports, undertake additional analysis and export data. The layout of the report builder interface is shown in Figure 4.18. The report options are displayed on the right side of the screen with the report itself on the left. The options can be hidden using the button on the toolbar between the options and the report and/or the width of the report can be adjusted by dragging and dropping the splitter between the two.

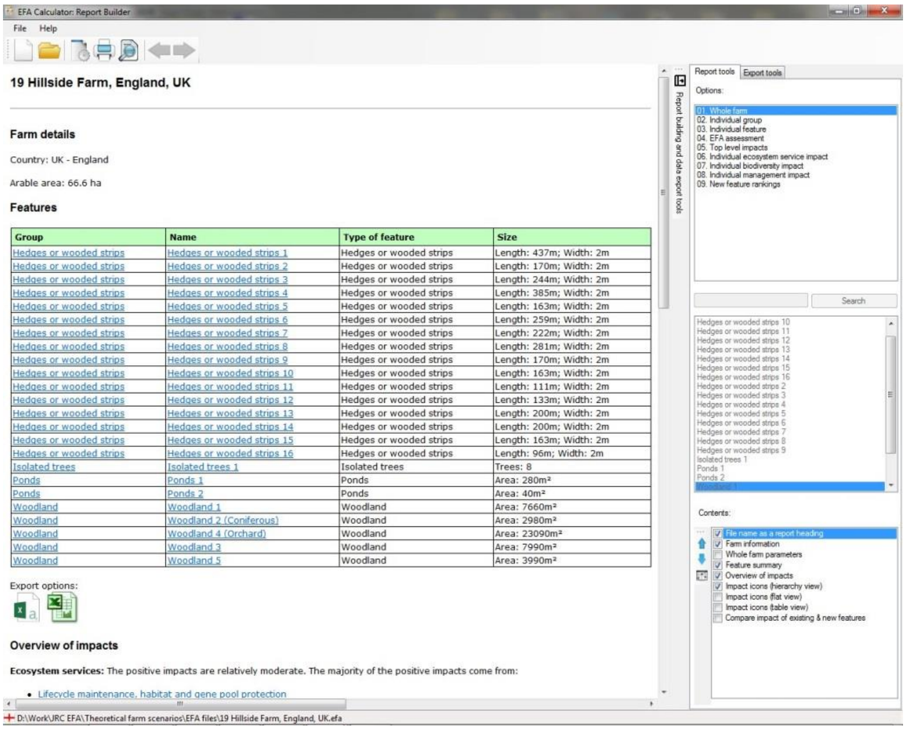


Figure 4.18: Report builder: general layout

There are nine types of report that can be created (see Section 4.7.3) and these are displayed in the top right list. Reports for individual features, groups, assessments, etc. will activate the list in the middle on the right, which allows users to select the feature, group, etc., for which a report is required. Each report has a range of contents that can be included. These are shown in the list on the bottom right of the screen.

4.7.2. Creating reports

To create a report, the user simply selects the type of the report (see Section 4.7.3) they want to create. If the report is for individual features, groups, assessments, etc., then the user selects which feature, group, etc. they want the report for. The user then selects the contents of the report. This is done by ticking the boxes in the contents list for the sections of the report they would like to display. The order of the contents can also be amended, using the arrow buttons to the left of the contents list to move sections up or down as needed. Clicking on the 'default settings' button (below the arrow buttons) will restore both the order and selected sections to their original settings.

As each report option is selected the corresponding report is generated and displayed. The report can then be read on screen, printed (using the buttons on the toolbar at the top or using the File menu) and for some of the tabular data it can be exported (see Section 4.7.5).

4.7.3. Reports available

There are currently nine reports that can be created. These are:

1. **Whole farm:** This will create a report that covers the whole farm (i.e. all the features on the farm). The report includes options to display any whole farm parameters; feature summaries; overview of impacts; impact icons (in three different views); and a table comparing the impact of existing to new features.
2. **Individual group:** This will create report for a selected group of features. This includes feature summaries; an overview of impacts; and impact icons (in three different views).

3. **Individual feature:** This will create report for a selected individual feature. This includes a feature summary; feature parameters; overview of impacts; impact icons (in three different views); and guidance text on feature impacts.
4. **EFA assessment:** This will create a report for a selected EFA assessment. This includes a simple table of the declared EFAs; a detailed table of the declared EFAs (including the farm features associated with each EFA); impact icons (in three different views); and a table comparing the potential impact two or more EFA assessments.
5. **Top level impacts:** This will create a report for a selected top level impact category (i.e. ecosystem services, biodiversity and management). The report is a table that lists all the farm features that potentially have an impact on the selected top level impact category; the total impact expressed as indicator bar; and the impact per hectare. The table can be sorted by any of the columns by clicking on the sort icons in the column headings. Thus allowing the user to sort the table to show, for example, the feature that has the greatest impact.
6. **Individual ecosystem service impact:** This will create the same report as report 5, but for a selected ecosystem service impact category.
7. **Individual biodiversity impact:** This will create the same report as report 5, but for a selected biodiversity impact category.
8. **Individual management impact:** This will create the same report as report 5, but for a selected management impact category.
9. **New feature rankings:** This will create a report showing the ranked features that have been created and saved using the new feature ranking tool (see Section 4.6).

All reports also have the option to include the file name as a heading, farm information (size and location) and standard footer.

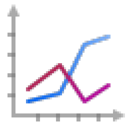
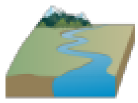
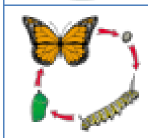
4.7.4. The impact icons

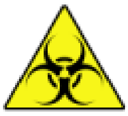
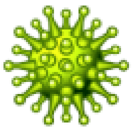
The communication of potential impacts of features is undertaken in the software using impact icons and indicator bars alongside the icons. These provide a visual and graphical means of representing impacts. This was deemed preferable to tables containing numbers as the actual impact scores (see Section 3.2.5) are not very meaningful if they are presented in this way.

Impact icons exist for all impacts in the impact hierarchy (see Section 3.2.3 and Annex C). They key to all the icons is shown in Tables 4.1, 4.2 and 4.3.

Table 4.1: Key to ecosystem service impact icons

Icon	Plain English name
	Provisioning services
	Regulation and Maintenance services
	Cultural services

Icon	Plain English name
	Provision of energy
	Maintenance of physical, chemical, biological conditions
	Provision of materials
	Mediation of flows
	Mediation of waste, toxics and other nuisances
	Nutrition
	Physical and intellectual interactions with biota, ecosystems, and land-/seascapes
	Spiritual, symbolic and other interactions with biota, ecosystems, and land-/seascapes
	Atmospheric composition and climate regulation
	Intellectual and representative interactions
	Lifecycle maintenance, habitat and gene pool protection
	Liquid flows
	Mass flows

Icon	Plain English name
	Mediation by flora and fauna
	Mediation by ecosystems
	Pest and disease control
	Provision of water for nutrition
	Provision of water for as a material
	Water conditions
	Aesthetic services
	Chemical condition of freshwaters
	Disease control
	Filtration/sequestration by flora and fauna
	Flood protection
	Global climate regulation by reduction of greenhouse gas concentrations
	Heritage and cultural services

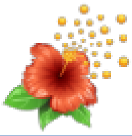
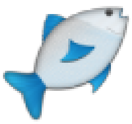
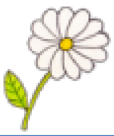
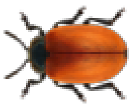
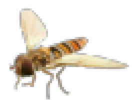
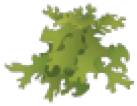
Icon	Plain English name
	Mass stabilisation and control of soil erosion
	Mediation of smell/noise/visual impacts
	Pest control
	Pollination and seed dispersal

Table 4.2: Key to biodiversity impact icons

Icon	Plain English name
	Amphibians
	Birds: All
	Terrestrial plants: Conifers
	Terrestrial plants: Ferns
	Fish
	Terrestrial plants: Flowering plants
	Fungi
	Invertebrates: All

Icon	Plain English name
	Mammals: All
	Terrestrial plants: Mosses and liverworts
	Reptiles
	Mammals: Bats
	Invertebrates: Butterflies and moths
	Invertebrates: Beetles (canopy coleoptera)
	Invertebrates: Beetles (carabids)
	Invertebrates: Hoverflies and hoppers
	Mammals: Small mammals (mice, shrews, voles)
	Birds: Insectivorous birds
	Birds: Birds of prey
	Birds: Seed eating birds
	Invertebrates: Pollinating invertebrates

Icon	Plain English name
	Invertebrates: Soil surface invertebrates
	Invertebrates: Snails
	Lichens
	Biodiversity (general)
	Invertebrates: Bees
	Birds: Woodland birds
	Birds: Scrubland birds
	Birds: Farmland birds
	Aquatic invertebrates: All
	Aquatic invertebrates: Crustaceans
	Terrestrial plants: All
	Aquatic plants: All
	Aquatic plants: Emergent aquatic plants

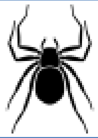
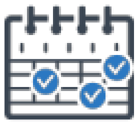
Icon	Plain English name
	Aquatic plants: Submerged and floating aquatic plants
	Birds: Waders
	Invertebrates: Dragonflies and damselflies (Odonata)
	Aquatic invertebrates: Molluscs
	Arachnids

Table 4.2: Key to management impact icons

Icon	Plain English name
	Labour
	Frequency of tasks

Alongside each impact are two impact indicator bars. Figure 4.19 shows an example of an impact that has both bars. These bars express the potential impact of the farm or selected group, feature, assessment, etc. The red bar represents any negative impacts and the green bar any positive impacts (the colours used for the bars can be changed in the settings and options).

Figure 4.19: Report builder: impact icon indicator bars

The size of the bar (i.e. the potential impact), is expressed in relation to a determined maximum value. This maximum value will vary depending on what report has been selected. If this is not done, and for example all values were expressed based on the size of the whole farm, then in some instances impact values would not register, as they would be too small in relation to the maximum, thus making the indicator bars useless. The maximum value is determined as follows:

- **Whole farm (report 1):** The sum of the area of all the features on the farm multiplied by the maximum negative and positive impact values (i.e. -100 and +100).

- **Individual group (report 2):** The sum of the area of all the features in the selected group multiplied by the maximum negative and positive impact values (i.e. -100 and +100).
- **Individual feature (report 3):** The area of the selected feature multiplied by the maximum negative and positive impact values (i.e. -100 and +100).
- **EFA assessment (report 4):** The sum of the area of all the features in the selected EFA assessment multiplied by the maximum negative and positive impact values (i.e. -100 and +100).

The size of the indicator bar that is displayed alongside the icon is then calculated by retrieving the impact score(s) based on the parameters entered by the user for each feature, and expressing this as a percentage of the maximum value determined above.

The impact icons can be displayed in three different ways, as shown in Figures 4.20, 4.21 and 4.22.

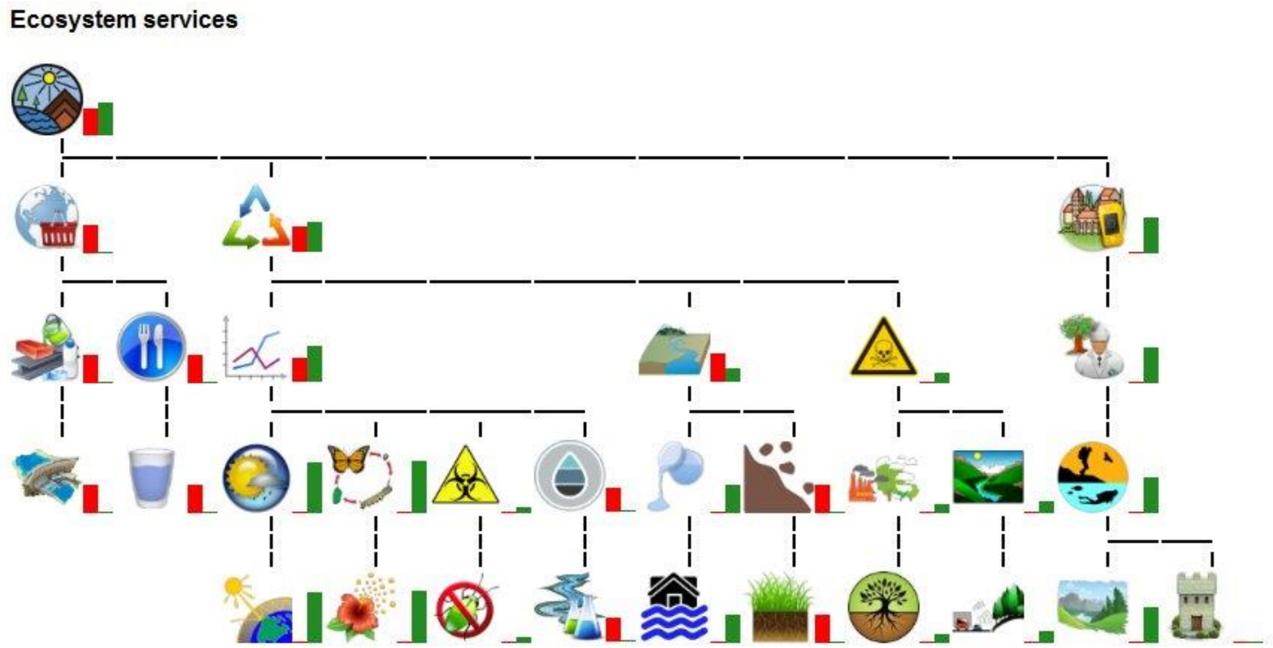


Figure 4.20: Report builder: impact icons (hierarchy view)

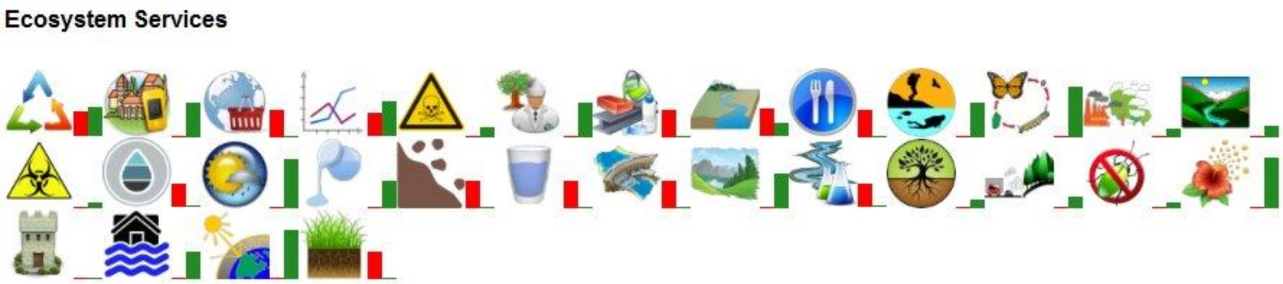
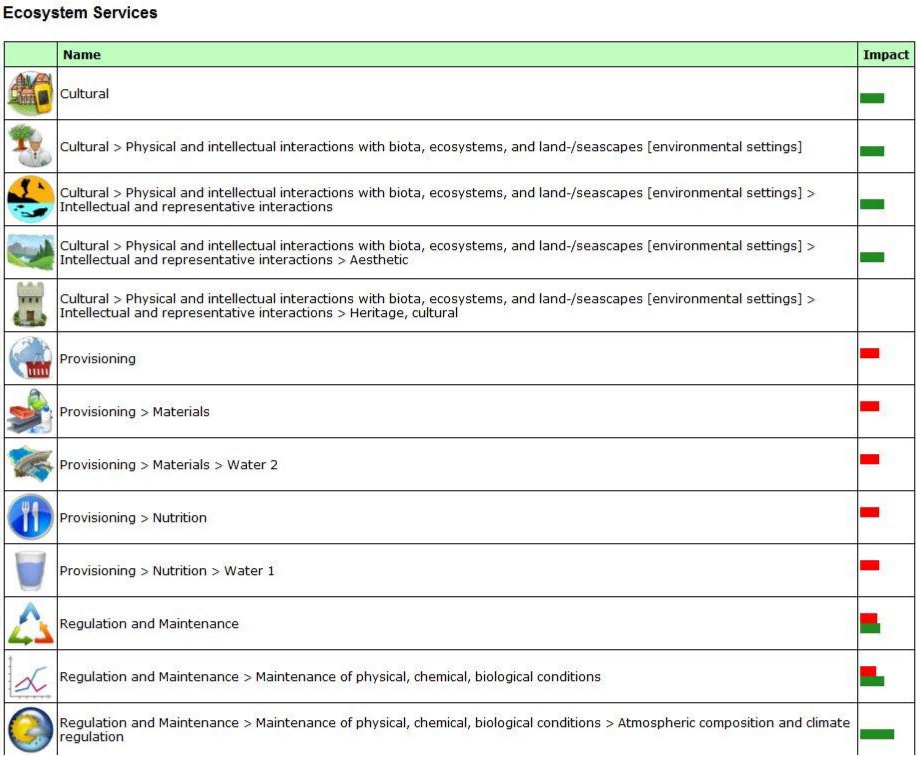


Figure 4.21: Report builder: impact icons (flat view)



Ecosystem Services

	Name	Impact
	Cultural	
	Cultural > Physical and intellectual interactions with biota, ecosystems, and land-/seascapes [environmental settings]	
	Cultural > Physical and intellectual interactions with biota, ecosystems, and land-/seascapes [environmental settings] > Intellectual and representative interactions	
	Cultural > Physical and intellectual interactions with biota, ecosystems, and land-/seascapes [environmental settings] > Intellectual and representative interactions > Aesthetic	
	Cultural > Physical and intellectual interactions with biota, ecosystems, and land-/seascapes [environmental settings] > Intellectual and representative interactions > Heritage, cultural	
	Provisioning	
	Provisioning > Materials	
	Provisioning > Materials > Water 2	
	Provisioning > Nutrition	
	Provisioning > Nutrition > Water 1	
	Regulation and Maintenance	
	Regulation and Maintenance > Maintenance of physical, chemical, biological conditions	
	Regulation and Maintenance > Maintenance of physical, chemical, biological conditions > Atmospheric composition and climate regulation	

Figure 4.22: Report builder: impact icons (table view)

The hierarchy view shows the impacts using a tree structure to display them based on the hierarchy of impacts. This view allows users to visualise the hierarchy and thus how the impacts have been aggregated. This view can require a large amount of space on the screen, making it difficult to view and print in some instances. The flat view is a more compact way of displaying the icons, so is useful to provide a quick view of all the potential impacts. It will display all the icons for which there is a potential impact and to a level of detail (i.e. how far down the hierarchy) that is determined in the settings. However, it does hide the aggregation process to some extent. Finally, the table view lists all the impact categories and presents the indicator bars in a separate column and as horizontal bars. This allows the actual name of the impact category to be displayed within the report, thus can aid interpretation. However, like the flat view, it does hide the aggregation process to some extent.

4.7.5. Exporting data

On the right side of the screen there is a second tab on the options, namely 'Export tools'. Currently there is just one option here, which is to display data export options below tables in the report. Selecting this option will display some additional icons below each table which contains data that can be exported (see Figure 4.23).

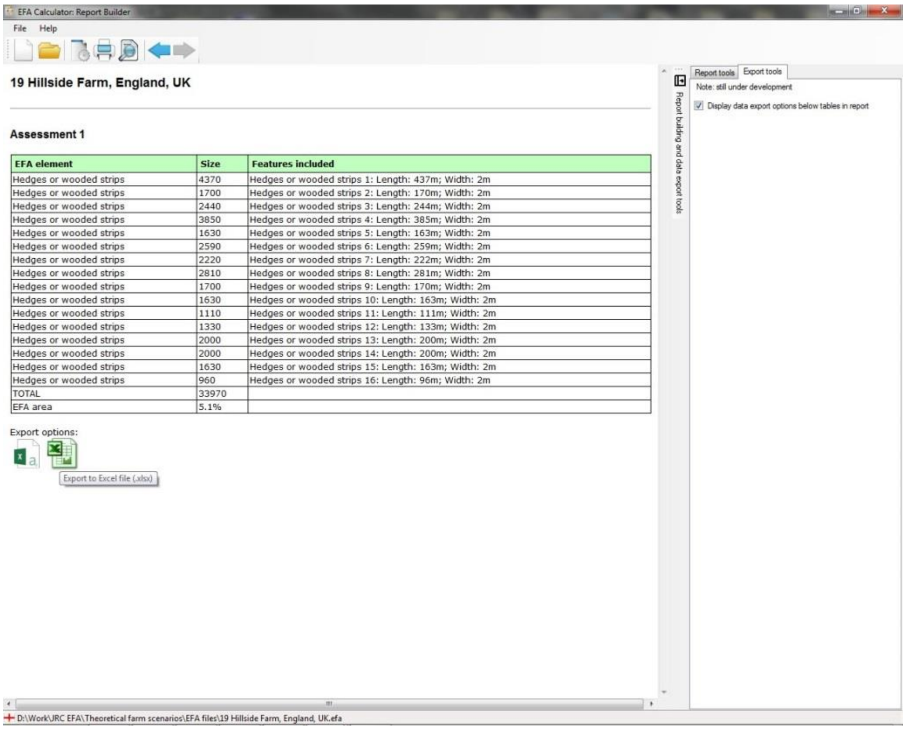


Figure 4.23: Report builder: data export options

Clicking on one of the icons below a table will prompt the user to save the data to a file. This can be to a CSV file or an Excel spreadsheet (an xlsx file).

4.8. Settings and options

The settings and options screens, like many other Windows applications, allow the user to customise the look and the behaviour of the software to better meet their own requirements. There are five sections to the options and settings including:

- General
- Indicator bars and icons
- Impact aggregation weights
- Database
- Ranking weightings

The 'General' section covers a range of miscellaneous settings. It includes default values, used when the user creates a new file, including: the Member State; whether to show full or restricted lists; and the level of detail (basic or advanced). It also has options to determine whether to show the splash screen at the start; whether to display the getting starting text and navigation key on the welcome screen; whether to show all whole farm parameters in the new file wizard; and whether the Auto-save function is activated in the land and feature manager. The user can also decide what size of icons to use in the top toolbar on some of the main screens.

The 'Indicator bars and icons' section provides the user with a number of facilities to change how the impact indicator bars and icons are displayed. This includes changing the colours used on the indicator bars (which aid colour blind users); the size of the icons displayed (which can help users with respect to their screen size and resolution); and the level of detail with respect impact icons (i.e. whether to display all icons down to the class level or just those at the section level - thus providing users with some control of the complexity of information displayed). Users can also set whether to use best, worst or average case data for the impact assessment when a range of values exist.

The 'Impact aggregation weights' section provides users with a facility to change the weightings used in the impact aggregation process (see Section 3.2.6). This facility is probably something that only very advanced users may adjust. By default, all the weightings are equal (100), but if a user would like to place more emphasis on a particular impact they can decrease the weight of other impacts. For example, if they are more interested in birds (under biodiversity) they may decrease the weight for all the other biodiversity impact categories. Then when the biodiversity impact score is calculated (aggregated up from the lower impacts), the overall score for biodiversity will be more sensitive to any impacts on birds. Figure 4.2.4 shows the interface for editing the weightings. The user selects a top level impact category in the drop list box in the toolbar. The impact hierarchy is then shown using a tree view. Clicking on an impact category in the tree view will show any sub-impacts in the grid on the right, along with their weightings. These weightings can then be edited. To restore default weightings click on the default settings button in the toolbar.

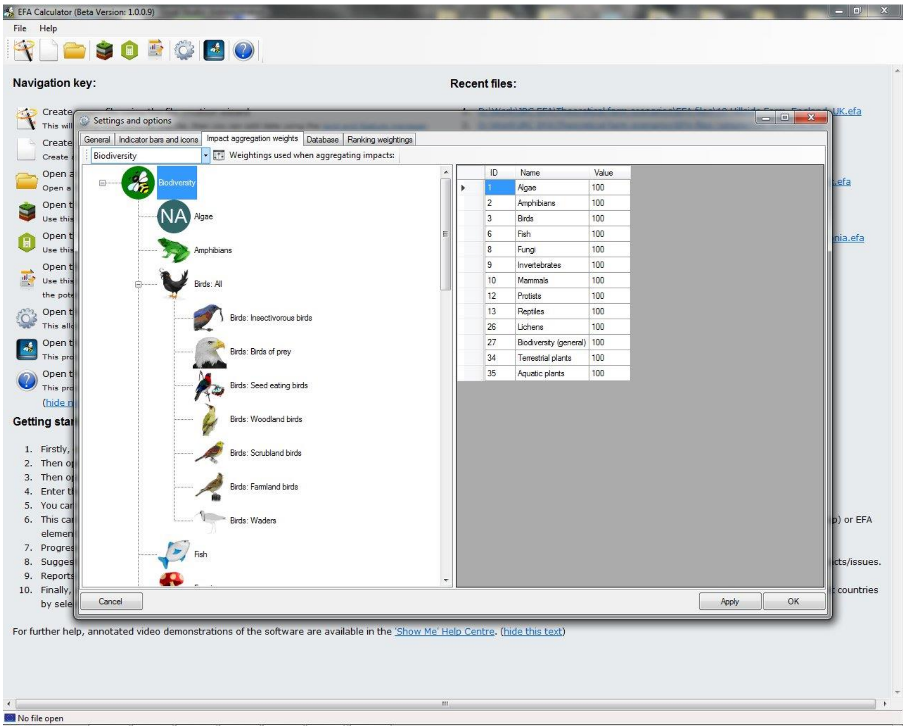


Figure 4.24: Settings and options: impact aggregation weights

The 'Database' section provides a facility to check for and download any database updates. The version of the core database is a date when it was last updated. The date of the version installed is displayed here (and also on the welcome screen). If a new version is available it will be displayed here and a button enabled to automatically download it.

The 'Ranking weightings' section provides the user with a facility to set the weightings used for the top level impact criteria (ecosystem services, biodiversity and management) when calculating an overall ranking in the new feature ranking tool (see Section 4.6). When calculating the overall ranking, the criteria can be weighted equally (which they are by default) or the user may wish to increase the importance of one of the criteria (e.g. by reducing the weight of the others). This section also allows the user to activate two additional top level ranking criteria (land taken out of production and the feature diversity index – see Section 3.2.7).

4.9. Show Me help centre

In order to make the software easier to use a Help system has been provided known as the 'Show Me help centre'. The title is derived from the fact that the centre consists of a number of annotated videos which demonstrate how to use the software – hence the user would be asking 'show me how to…' This is a more effective means of help and support, than a written user manual, as the user can actually see the process on the screen rather than having to interpret text.

Upon opening the help centre (which opens in the users internet browser), the user is presented with a list of the help videos that are available. They then click on a video and this will start the demonstration. There are built in controls to allow the user to pause, play, or navigate backwards and forwards in the video.

4.10. The core database and its administration

As mentioned in Section 4.1, the software has a core MS Access database that underpins the software. This database stores a variety of data and information, including:

- Member States: A list of all the Member States covered by the software (32 in total, with 2 regions for Belgium and 4 countries for the UK).
- EFA elements: A list of the EFA elements and data on which ones have been activated in each Member State, including the units of measurement and any conversion and weighting factors.
- EFA rules: Data that are used to support the rules that are checked by the software (see Section 4.5.3).
- Farm features: A core list of farm features that can be associated with the EFA elements, and data on which features can be applied to which EFA element in each Member State.
- Impact categories: A list of ecosystem service, biodiversity and management impact categories and data on the impact hierarchy.
- Parameters and parameter classes: A list of parameters and parameter classes that are used to describe the farm features, and data on which classes belong to which parameters.
- Impact scores: Data on the combination of farm features, impact categories and impact scores (see Section 3.3).

Numerous other data items are also stored in the database including definitions and some pre-processed data (designed to speed up the software when run by users).

A bespoke interface has been developed to administer the core database. This performs a variety of functions including:

- Setting the activation status of each EFA element in each Member State, the units of measurement used and any conversion and weighting factors.
- Creating new parameters and parameter classes and allocating classes to parameters.
- Setting the default weighting values for impact aggregation.
- Adding and editing impact scores for combinations of features, impacts and parameters (using the two different scoring approaches – see Section 3.2.5).
- Setting the rules with regard to the species that can be used for catch crops, short rotation coppice and nitrogen fixing crops, including allocation of species into different groups in different Member States.
- Setting rules on dimension limits for different EFA elements in different Member States.
- Setting which features can be used for different EFA elements in different Member States. This includes determining which units of measurement are needed to different features, and any specific dimension rules for features that are part of an EFA (for example maximum widths for hedges and ditches that are part of Field margin EFA in Scotland).

- Setting rules for any invalid parameters. For example, concrete or plastic substrate for ponds not being allowed for the ponds EFA.

There are currently a number of functions and processes that are not facilitated by the administration interface. These include:

- The addition of new Member States: Currently these need to be added by directly editing the MS Access database.
- The addition of new impact categories. Currently these need to be added by directly editing the MS Access database, including setting up the data describing where the impact category appears in the hierarchy.
- Deleting of any parameters or classes. This can only be done by directly editing the MS Access database (albeit there is no major need to delete parameters and classes as any obsolete ones can either be ignored or reused when adding new ones).
- Allocation of catch crop species to groups (used for the impact assessment). The parameters CC species groups 1 and 2 are used for the impact scoring, but users enter data for the two catch crop species they grow. Thus the species need to be allocated to CC species groups 1 and 2, and currently this can only be done by directly editing the MS Access database.

5.0. Testing the EFA calculator software

5.1. Functionality testing

Functionality testing has been an ongoing process throughout the development of the software. It has included:

- **Installation testing:** This has involved checking that the installation processes (including downloading updates) works properly in a range of common software/hardware environments (e.g. operating platforms).
- **Fault testing**: The tool has been tested over a range of conditions under which it will be used. The objective here has been to detect and repair any major defects and programming bugs that prevent the software from correctly functioning.
- **Performance and stability testing:** Tests have been undertaken to ensure that the tool performs to a satisfactory level in terms of its responsiveness and stability by running the tool with large input data sets so that it needs to cope with a high work load. This has included assessing how quickly tasks are performed and processed to ensure that occur within a reasonable time. In some instances this has required changes to the distribution of processing so that it does not all occur in one go, and also allowing some customisation of the software by the user to meet their needs (for example, the development of an option to manually or automatically save data – the latter ensures every change is saved as the user proceeds, but can make data entry slower as the save routine is frequently invoked).
- **Validity testing**: The software has been tested with known input and output data. The process checked that the correct data is being retrieved from the core database, it is being processed correctly, that it responding correctly to the type of inputs and calculations made are correct.
- **Usability testing:** We believe that to a large extent 'good' software should be intuitive and flow in a logical and organised manner. This testing has included:
    - **Ease of use:** This has included, for example, an assessment of the tools navigation processes and pathways and whether the right balance between user-flexibility and in-built user-control has been achieved.
    - **Usefulness of embedded help:** This has considered if the embedded data input checks are adequate and working correctly. We have also evaluated the associated 'help videos' to see if they are sufficiently informative and address all the areas where help may be required.
    - **Functionality:** This has involved checks to evaluate if the tool has achieved its end objectives and if the functions and facilities within the tool behave as the end user would expect. This has also checked if the speed of operations is acceptable.
    - **Interpretation and readability:** This has involved an assessment of how easy it is to interpret the tools outputs and guidance. This has included if the descriptive text used in the tool (on buttons, functions, in the help videos, reports etc.) is understandable. For example, do they effectively avoid the use of jargon, repetition, abbreviations and complex scientific language? We have also checked that it is fully compliant with level AA of the Web Content Accessibility Guidelines (W3C, 2008).

The functionality testing has largely been undertaken by the tool development team. However, there has been some feedback on the tool provided by JRC (as versions have been released and made available as the project has progressed) and a few external experts have also provided feedback on the tool (at the workshop at JRC on 10 June 2015, and subsequently since then).

5.2. Theoretical farm scenarios

5.2.1. Introduction

The second phase of testing, albeit this has run concurrently with the first phase, has involved testing the software using a number of hypothetical farm scenarios and data sets. The scenarios have been split into two parts:

1. Simplified scenarios: 32 scenarios covering all Member States (including 2 regions in Belgium and 4 countries in the UK).
2. Detailed scenarios and analysis of the results: 25 scenarios in 16 Member States.

The simplified scenarios provided a test of all EFA elements and associated features for all Member States, ensuring that all were set up correctly in the database. The detailed scenarios provided a test of the software using 'real world' data and thus provided an opportunity to explore the outputs of the software, e.g. the contribution of existing features to the 5% EFA target and the impact assessment data.

5.2.2. Simplified scenarios

The first part of the testing using hypothetical farms focused on testing the EFA software using one hypothetical farm in each Member State (to ensure that those Member States not covered by the detailed scenarios were tested).

The process of creating these hypothetical farms was simpler than the detailed case studies and involved the following:

- Selecting a random location within the Member State.
- Using the average utilised agricultural area (UAA) for each Member State for 2010 (Eurostat, 2013) to derive the arable area for the farm (see Table 5.1).
- Creating 1 of each feature required for the EFA elements activated in the Member State.
- The size of each feature was set within the limits defined by the Member State and/or was set at a size so that in total all the features accounted for ~5% of the arable area.
- The EFA software settings were set to Basic (so only minimum data was required) and an 'average case' setting for the impact assessment.

Table 5.1: Simplified hypothetical case studies

ID	Member State	Arable area (ha)
1	Austria	19.2
2	Belgium - Flanders	31.7
3	Belgium - Walonia	31.7
4	Bulgaria	12.1
5	Croatia	5.6
6	Cyprus	3
7	Czech Republic	152.4
8	Denmark	62.9
9	Estonia	48
10	Finland	35.9
11	France	53.9

ID	Member State	Arable area (ha)
12	Germany	55.8
13	Greece	4.8
14	Hungary	8.1
15	Ireland	35.7
16	Italy	7.9
17	Latvia	21.5
18	Lithuania	13.7
19	Luxembourg	59.6
20	Malta	0.9
21	Netherlands	25.9
22	Poland	9.6
23	Portugal	12
24	Romania	3.4
25	Slovakia	77.5
26	Slovenia	6.5
27	Spain	24
28	Sweden	43.1
29	UK - England	90.4
30	UK - Northern Ireland	90.4
31	UK - Scotland	90.4
32	UK – Wales	90.4

5.2.3. Detailed scenarios and analysis

5.2.3.1. Method

These scenarios have been constructed from real farm data (where possible); including farms from other research projects (e.g. Tzilivakis *et al*., 2010; Warner *et al*., 2010) and have been anonymised. Much of the data collected for previous projects was on the agronomic practices of the farm, thus the majority of this data is not applicable to the EFA calculator. Key data that is needed for the EFA software is the size of the features on the farm, e.g. length of hedgerows, and associated parameters to describe them, e.g. number of hedgerow trees or floral diversity. To derive this data a combination of Google Earth and Google maps has been used. This allowed features to be identified from aerial photos. This was supplemented in some instances with photographs of features (embedded in Google Earth) and/or using Google Street View where available. Dimensions for features were derived using Google My Maps, which has basic GIS functions to measure the length and area of features. In a few instances, local knowledge also supplemented the information and data gathered for the farms. In a few instances, grassland farms were considered as arable farms, in order to make them eligible for EFA – grass fields were simply allocated as arable fields.

For each scenario, the following process/tasks were undertaken:

- Existing features were identified, measured and assessed to determine their attributes.
- Data entered into the EFA calculator software using the land and feature manager.
- Creation of an EFA assessment, adding all EFA eligible features (to determine their contribution to the 5% EFA target).
- Generation impact assessment overview text for existing features.

- Generation of ranked EFA elements (identified as options to increase the area of EFA) for EFA eligible features only.
- Generation of ranked EFA elements, but for all EFA features including those which are not eligible for EFA in the Member State for the case study.

In relation to the last two tasks, the EFA calculator software allows users to set their own ranking criteria. However, in this the following criteria (and weightings) were used across all the case studies:

- Ecosystem services (100)
- Biodiversity (50)
- Feature diversity index (50)
- Management (50)
- Land taken out of production (50)

The weightings for the last 4 were reduced (from the default of 100) so that Biodiversity and Feature diversity index (which both impact on biodiversity) combined have the same weight as Ecosystem services, and likewise for Management and Land taken out of production. So effectively the weightings are:

- Ecosystem services (100)
- Biodiversity (100) (Biodiversity: 50 and Feature diversity index: 50)
- Management (100) (Management: 50 and Land taken out of production: 50)

Also, the features that are displayed in the rankings only include features that can be created as new features and not those that can only be existing features, for example it is not possible to create new ancient stones. Thus features such as these are excluded from the rankings, resulting in the following possible list of new features:

- Agroforestry
- Catch crops or green cover
- Ditches
- Fallow land
- Hedges or wooded strips
- Isolated trees
- Land strips (adjacent/parallel to water)
- Land strips (other)
- Nitrogen fixing crops
- Ponds
- Short rotation coppice
- Terraces
- Traditional stone walls
- Trees in line
- Woodland

In some instances not all the parameters could be completed for a feature, for example the timing of hedge cutting or ditch clearing, as this was not known from previous data and/or could be determined from the aerial photography. In such instances these data field were left blank. As such the software will calculate the impact based on the settings in the software (best, worst or average can be set). For these case studies an average case setting was selected.

There are 25 hypothetical case studies in 16 Member States to provide a variety of climatic and topographic scenarios. All the farms have more than 15 ha of arable land and are thus eligible for EFA. Table 5.2 shows the basic details of the case studies; a summary of each case study is presented in Annex F; and results/findings are summarised in Section 5.2.3.2.

Table 5.2: Detailed hypothetical case studies

ID	Member state	Farm size (ha)	Arable area (ha)
1	Croatia	585	565.2
2	Cyprus	67.3	64.3
3	Denmark	585	569.8
4	France	229	207.6
5	Germany	844	811
6	Germany	1033	999
7	Germany	85.1	83
8	Greece	36.8	36.6
9	Hungary	1690	1645
10	Ireland	20	20
11	Italy	92.7	85.5
12	Italy	44.9	31.9
13	Netherlands	109	105.8
14	Poland	66	60.7
15	Romania	1490	1487.1
16	Slovenia	357	302
17	Spain	753	647.9
18	Sweden	373	351.6
19	UK – England	77.3	66.6
20	UK – England	288	90.7
21	UK – England	266	94.4
22	UK – Scotland	93.2	80.9
23	UK – Scotland	112	105.4
24	UK – Scotland	113	101
25	UK – Scotland	488	284

5.2.3.2. Results

Table 5.3 shows the existing features on the farms that have been included within each case study.

Table 5.3: Features covered by case studies

CS	MS	Agroforestry	Ancient monuments	Ancient stones	Archaeological sites	Catch crops or green cover	Ditches	Fallow land	Garrigue	Hedges or wooded strips	Isolated trees	Land strips (adjacent/parallel to water)	Land strips (other)	Natural monuments	Nitrogen fixing crops	Ponds	Short rotation coppice	Terraces	Traditional stone walls	Trees in line	Woodland
1	HR						✓			✓						✓				✓	
2	CY	✓							✓											✓	
3	DK									✓		✓				✓					✓
4	FR									✓			✓			✓					✓
5	DE						✓			✓											✓
6	DE						✓			✓	✓	✓				✓				✓	✓
7	DE																			✓	✓
8	GR	✓						✓			✓										✓
9	HU						✓			✓										✓	✓
10	IE						✓												✓		
11	IT									✓	✓									✓	
12	IT									✓			✓								✓
13	NL									✓										✓	✓
14	PL												✓								✓
15	RO						✓													✓	
16	SI						✓			✓											✓
17	ES																				✓
18	SE						✓					✓	✓								✓
19	UKE									✓	✓					✓					✓
20	UKE						✓			✓	✓									✓	
21	UKE									✓			✓								✓
22	UKS									✓						✓					✓
23	UKS				✓		✓			✓											✓
24	UKS																		✓		✓
25	UKS									✓									✓		✓

A number of features have not been covered:

- Ancient monuments
- Nitrogen fixing crops

- Ancient stones
- Catch crops
- Natural monuments
- Short rotation coppice
- Terraces

Ancient monuments, Ancient stones and Natural monuments have not been identified on any of the case study sites. With regard to catch crops and nitrogen fixing crops, it is not possible to determine if the farm happens to grow these (and/or not possible to observe this from aerial photographs). Finally, none of the farms had terraced land.

Table 5.4 provides an overview of the impact of the existing features. This is the aggregated score for the top level impact categories (ecosystem services, biodiversity and management) for all the existing features on each hypothetical farm, which are then categorised into the following bands (for both positive and negative values):

- Very low (-20 to 0 or 0 to 20)
- Low (-40 to -21 or 21 to 40)
- Moderate (-60 to -41 or 41 to 60)
- High (-80 to -61 or 61 to 80)
- Very high (-100 to -81 or 81 to 100)

Table 5.4: Overview of the potential impact of existing features

CS		Ecosystem services		Biodiversity		Management
	MS	Positive	Negative	Positive	Negative	Negative
1	HR	Moderate	None	Moderate	None	Very low
2	CY	Low	Low	Low	None	None
3	DK	Moderate	Moderate	Moderate	None	Very low
4	FR	Moderate	Moderate	Moderate	None	Very low
5	DE	Moderate	Moderate	Moderate	None	Very low
6	DE	Moderate	Moderate	Moderate	Moderate	Very low
7	DE	Moderate	Moderate	Moderate	Moderate	None
8	GR	Very low	Very low	Low	Low	None
9	HU	Low	Low	Moderate	None	Very low
10	IE	High	None	Moderate	None	Very low
11	IT	Moderate	None	Moderate	Moderate	Very low
12	IT	Moderate	Moderate	Moderate	None	Very low
13	NL	Moderate	Moderate	Moderate	Moderate	Very low
14	PL	Moderate	Moderate	High	None	None
15	RO	Low	None	Moderate	None	Very low
16	SI	Moderate	Moderate	Moderate	None	Very low
17	ES	Moderate	Moderate	High	High	None
18	SE	Low	Low	Low	None	Very low
19	UKE	Moderate	Moderate	Moderate	Moderate	Very low
20	UKE	Moderate	None	Moderate	Moderate	Very low
21	UKE	High	High	High	High	Very low
22	UKS	Moderate	Moderate	Moderate	None	Very low
23	UKS	Low	Low	Very low	None	Very low
24	UKS	High	High	High	None	None
25	UKS	Moderate	Moderate	Moderate	None	Very low

Table 5.5 shows the contribution of existing features (associated EFA elements) to each EFA element to the 5% target. Shaded cells illustrate that the EFA element has not been activated in the Member State. It also

shows the percentage of the arable area that is effectively out of production due to the existing features. Note: this will not always correlate with the EFA target as some features do not take land out of production and other features are weighted in the EFA calculation, whereas the land taken out of production is simply the unweighted area of the land taken up by the features.

Table 5.5: Contribution of existing features to EFA target

CS	MS	Afforested areas	Agroforestry	Buffer strips	Catch crops or green cover	Ditches	Fallow land	Field margins	Hedges or wooded strips	Isolated trees	Nitrogen fixing crops	Other landscape features	Ponds	Short rotation coppice	Strips along forest edges (NO PRODUCTION)	Strips along forest edges (WITH PRODUCTION)	Terraces	Traditional stone walls	Trees in groups and field copses	Trees in line	TOTAL (%)	Arable area not in production (%)
1	HR					0.98														0.29	1.3	0.6
2	CY		5.3																		5.3	0
3	DK			0.4																	0.4	0.2
4	FR	3.2							0.89							0.15			0.1		4.3	3.7
5	DE	3.39				0.01			0.21										0.05		3.7	3.5
6	DE	0.854		0.015		0.374			0.44	0.001		0.003								0.564	2.3	1.6
7	DE	0.87																	0.24	0.16	1.3	1.1
8	GR						9.93												0.799		10.7	10.5
9	HU	2.38				0.116			0.011											0.195	2.7	2.5
10	IE					0.400															0.4	0.2
11	IT								0.31	0.01										0.1	0.4	0.2
12	IT	1.29							0.45							0.1			0.7		2.5	2
13	NL																				0.0	0
14	PL	8.55														0.25					8.8	8.6
15	RO					0.19														0.05	0.2	0.1
16	SI																				0.0	0
17	ES	14.60																			14.6	14.6
18	SE							0.7													0.7	0.5
19	UKE								5.1												5.1	2.6
20	UKE								2.3												2.3	1.2
21	UKE								0.2												0.2	0.1
22	UKS							0.8													0.8	0.5
23	UKS							1.9													1.9	1.3
24	UKS																				0.0	0
25	UKS							0.4													0.4	0.3
	TOT	35.13	5.3	0.415	0	2.07	9.93	3.8	9.911	0.011	0	0.003	0	0	0	0.5	0	0	1.889	1.359		

Table 5.5 shows that in many instances the existing features are not sufficient to meet the 5% EFA target. Figure 5.1 shows this data graphically and highlights that only 5 of case studies exceeded the target with their existing features. Of those farms that do not reach the target the average is 1.3% (with a mode of 0.4%).

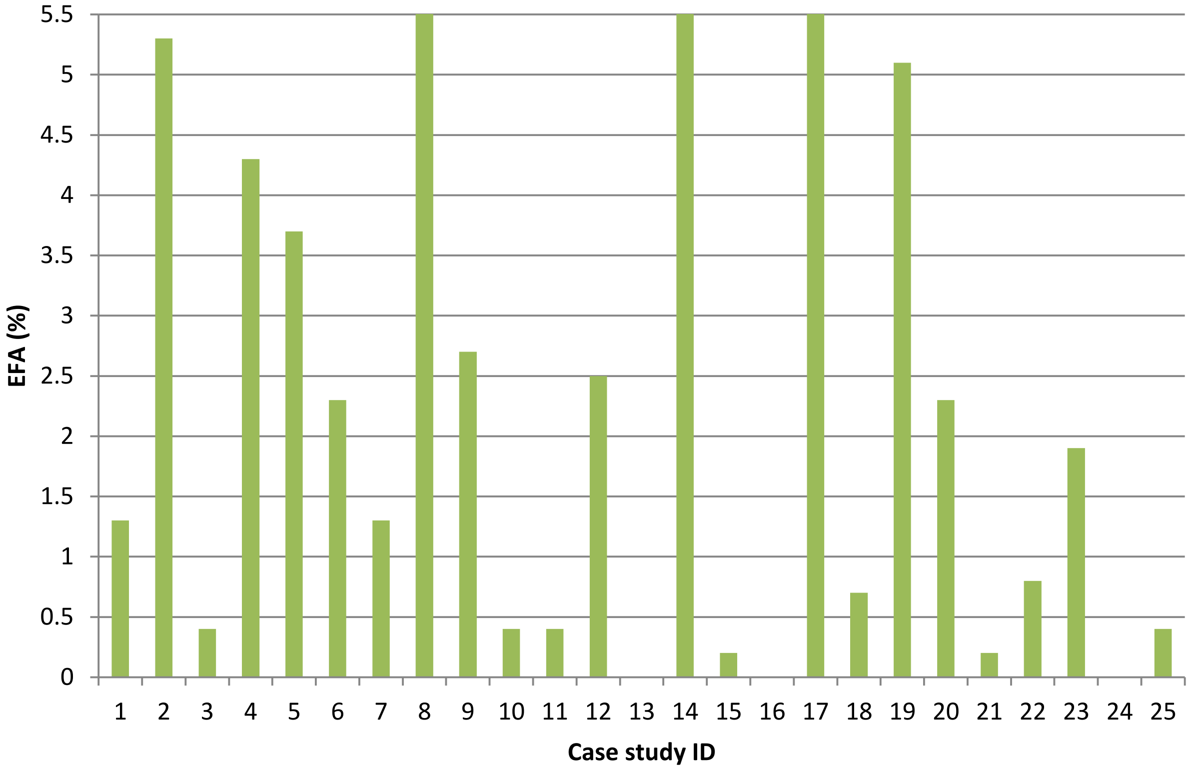


Figure 5.1: Percent EFA provided by existing features in case studies

Consequently these farms would need to explore implementing new features in order to meet that target. The EFA calculator software has a facility to rank features (see Section 4.6) to steer users towards those that would have the greatest benefit with respect to ecosystems services, biodiversity and management and their associated sub-impact categories (depending on the criteria selected).

A common set of ranking criteria have been applied to each hypothetical case study and the ranking process performed twice, firstly for just features related to EFA elements activated in the Member State, and secondly for all features. The results of these ranking processes (in terms of the order) are shown in Tables 5.6 and 5.7.

Table 5.6: Ranking of features (EFA only)

CS	MS	Agroforestry	Catch crops or green cover	Ditches	Fallow land	Hedges or wooded strips	Isolated trees	Land strips (adjacent/parallel to water)	Land strips (other)	Nitrogen fixing crops	Ponds	Short rotation coppice	Terraces	Traditional stone walls	Trees in line	Woodland
1	HR		3	12	8	10	6	11	4	2	7	1		13	9	5
2	CY	2			4			5		1						3
3	DK		2		4			5			3	1				
4	FR	1	4	11	12	8	6	13	7	3	9	2	15	5	10	14
5	DE	1	4	11	12	8	7	13	5	3	9	2	15	6	10	14
6	DE	1	4	10	9	8	6	13	5	3	7	2	15	14	11	12
7	DE	1	5	9	11	12	7	13	6	3	8	2	4	14	10	15
8	GR			3	6			5		1					4	2
9	HU	1	4	10	11	8	6	12	5	3	7	2	14		9	13
10	IE		3	7	6	8		9		2		1			5	4
11	IT	1		8	9	13	6	12	4	3	7	2	14	11	10	5
12	IT	1		8	10	11	5	13	7	4	6	3	2	12	9	14
13	NL		3						4	2		1				
14	PL		3	9	10	4	5	11	6	2	7	1			8	12
15	RO		3	11		6	7	10	4	2	8	1	12		9	5
16	SI		2		3					1						
17	ES	1			3					2						4
18	SE	1	4		6			7	5	3		2				
19	UKE		3		4	6		5		2		1				
20	UKE		3		4	6		5		2		1				
21	UKE		3		4	6		5		2		1				
22	UKS		2	5	6	4		7	3	1						
23	UKS		2	5	6	4		7	3	1						
24	UKS		2	5	6	4		7	3	1						
25	UKS		3	5	6	4		7	2	1						

Table 5.7: Ranking of features (All features)

CS	MS	Agroforestry	Catch crops or green cover	Ditches	Fallow land	Hedges or wooded strips	Isolated trees	Land strips (adjacent/parallel to water)	Land strips (other)	Nitrogen fixing crops	Ponds	Short rotation coppice	Terraces	Traditional stone walls	Trees in line	Woodland
1	HR	1	4	13	9	11	7	12	5	3	8	2	15	14	10	6
2	CY	6	4	11	13	9	8	14	5	2	10	1	3	15	12	7
3	DK	1	4	7	10	11	6	14	5	3	9	2	15	13	8	12
4	FR	1	4	11	12	8	6	13	7	3	9	2	15	5	10	14
5	DE	1	4	11	12	8	7	13	5	3	9	2	15	6	10	14
6	DE	1	4	10	9	8	6	13	5	3	7	2	15	14	11	12
7	DE	1	5	9	11	12	7	13	6	3	8	2	4	14	10	15
8	GR	3	4	10	14	7	6	13	5	2	9	1	15	12	11	8
9	HU	1	4	11	12	9	7	13	5	3	8	2	15	6	10	14
10	IE	1	4	11	10	12	7	13	5	3	8	2	14	15	9	6
11	IT	1	4	9	10	14	7	13	5	3	8	2	15	12	11	6
12	IT	1	5	9	11	12	6	14	8	4	7	3	2	13	10	15
13	NL	1	4	8	10	11	6	12	5	3	7	2	15	14	9	13
14	PL	1	4	11	12	5	7	13	8	3	9	2	15	6	10	14
15	RO	1	4	13	10	7	8	12	5	3	9	2	15	14	11	6
16	SI	1	4	10	11	13	7	12	5	3	8	2	15	6	9	14
17	ES	1	4	9	11	7	6	12	5	3	8	2	15	13	10	14
18	SE	1	4	9	10	11	6	12	5	3	7	2	15	14	8	13
19	UKE	1	5	9	11	13	7	12	6	4	8	3	2	15	10	14
20	UKE	1	4	9	10	13	7	12	5	3	8	2	15	14	11	6
21	UKE	2	5	9	11	12	7	13	6	4	8	3	1	14	10	15
22	UKS	1	5	12	13	9	8	14	6	4	10	3	2	7	11	15
23	UKS	1	4	12	13	10	7	14	5	3	9	2	15	6	11	8
24	UKS	1	5	11	12	7	8	13	6	4	9	3	2	14	10	15
25	UKS	1	5	11	12	7	8	13	4	3	9	2	15	6	10	14

The data in Table 5.7 has been further processed to generate Figures 5.2 and 5.3. These use the mode of the data in Table 5.7 to show the most commonly suggested ranking order (based on the criteria selected) of the features. Figure 5.2 also shows the range in the rank of each feature and Figure 5.3 shows the range expressed using standard deviation.

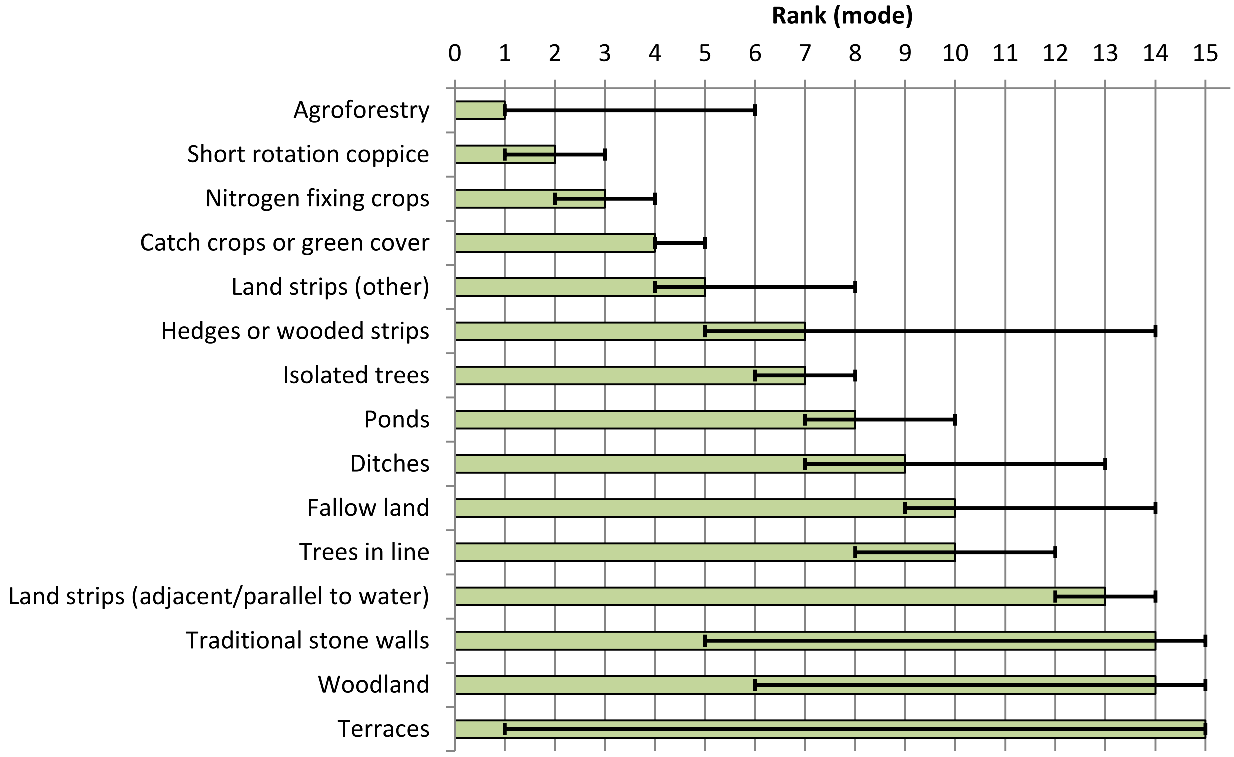


Figure 5.2: Typical rank (mode) with range

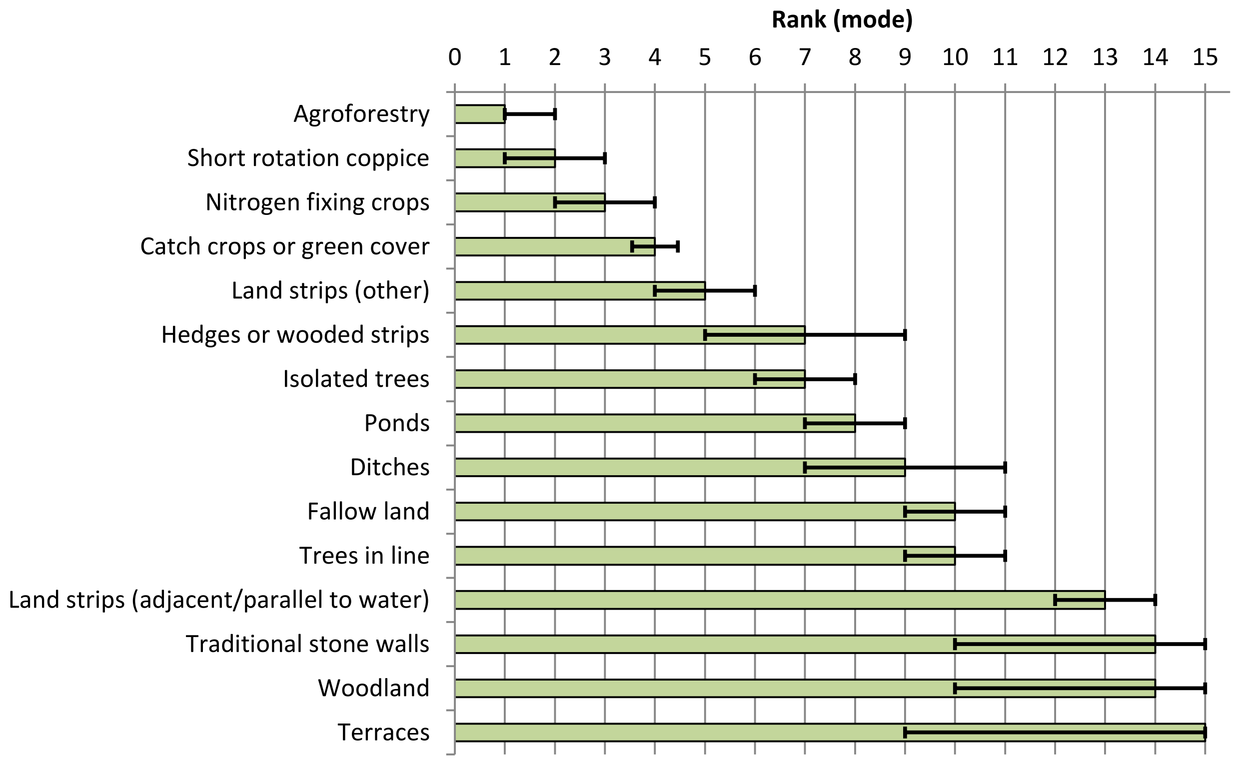


Figure 5.3: Typical rank (mode) with standard deviation (capped)

Features which still involve production, such as agroforestry, N fixing crops and short rotation coppice are tending to come out at the top. This is probably because their ranking is increased by land taken out of production criterion, whilst they also have benefits for biodiversity and ecosystem services, and as none of the farms had these features, their rank with respect to the feature diversity index is also increased.

Features which take land out of production, but which have significant benefits for ecosystem and biodiversity tend to fall into the middle rankings, albeit there are some significant variations in the rank, for example for hedges and wooded strips, ditches, and traditional stone walls.

Woodland is second from bottom of rankings, albeit with significant variation. This is partly because it is taking land out of production and also because many of the farms had some areas of woodland already, and consequently it scores a low rank of the feature diversity index.

Terraces are at the bottom of the rankings. This is partly an anomaly that arises because in many instances terraces are not applicable, e.g. as the farm is flat with little or no gradient. This anomaly is reflected in the range, as Figure 5.2 shows that terraces are ranked at or near the top for some scenarios.

6.0. Discussion

6.1. Introduction

There is little doubt this was an ambitious project to undertake in a relative short period of time (9 months). However, despite this resource issue, the project has still produced some valuable and practical outputs including a compilation of current knowledge on the potential impacts of EFAs; development of novel impact assessment techniques; and the development of a software application to support the implementation of EFAs and the transfer of knowledge.

This section of the report reviews and discusses the approaches taken; the outputs that have been delivered; and highlights the advances that have been made and the strengths of the approach, whilst acknowledging weaknesses and identifying areas for improvement.

6.2. Review and critique of the approach

6.2.1. Introduction

The main purpose of the project was to develop and test a software tool that aims to help farmers identify the most ecologically sound and pragmatic solution for implementing the Ecological Focus Areas (EFAs) on their farm. This included conducting an extensive knowledge and literature review for all the EFA elements in order to define their potential impact on ecosystem services, biodiversity and management; converting the findings from the review into a knowledge base that could support a software tool; and the development and testing of the tool.

A key challenge was, given the time available, to cover the breadth of EFA elements to a depth that was sufficiently detailed to differentiate impacts (i.e. by defining the parameters and classes that potentially give rise to different impacts – see Section 3.2.4). There is also an inherent trade-off between the level of scientific detail that is available and the requirement to develop a simple and easy to use software tool. There were inevitably compromises and simplifications that needed to be made.

6.2.2. The literature review and synthesis of the knowledge

The first task involved collating the scientific evidence that would form the foundation of the software tool. The bulk of this work was undertaken within a 3 month period at the start of the project, so there was only a short amount of time to gather and synthesise the evidence. Given more time, no doubt more evidence could have been collated, however the intensive 3 month period did result in over 350 papers, reports and guides being reviewed, resulting in the synthesis provided in the interim report (Section 2). The review was structured using the 19 individual EFA elements specified in the legislation. However, as described in Section 3.2.2, during the development of the impact assessment framework it became apparent that some EFA elements consist of two or more farm features. In hindsight, it may have been advantageous to undertake the review using the farm features as the basis of structuring the review. However, this was not detrimental to the project as the majority of information required for the project to proceed had been gathered.

6.2.3. The impact assessment techniques

The objective of the next stage of the project was to analyse the knowledge synthesised in the first stage and convert it into a set of guidelines, criteria and rules that could be used to underpin the EFA calculator software. There were two processes that needed to be undertaken to achieve this. Firstly, the development of impact assessment techniques and framework that would be used to appraise and structure the knowledge gathered, and secondly, the application of those techniques.

The development of the impact assessment techniques and framework is described in detail in Section 3 and Annex C. Given the time and resources available the project focused on seeking to use established techniques and frameworks. This was achieved to a limited extent, especially for ecosystem services by using the CICES framework (Haines-Young & Potschin, 2013), but for biodiversity and management no established or common techniques and frameworks could be identified and/or were fit for purpose for this project, especially with respect to biodiversity. As described in Annex C.4, the topic of biodiversity indicators and metrics is huge; has been debated for many decades; there are many different contexts and purposes; and little consensus on the best approach. Some tools and frameworks did offer potential but lacked sufficiently detailed information that would allow then to be utilised in this project. An example of this is the Gaia Biodiversity Yardstick developed by CLM (CLM, 2015) in the Netherlands and which is being integrated with the Cool Farm Tool (Cool Farm Alliance, 2015; McCormack *et al*., 2014). This appears to use a scoring approach to assess the performance of a farm in relation to biodiversity. However, there is little or no information published on this technique in the scientific literature. To date, the approach taken, the degree of peer review, and the overall robustness of the technique are not known and so its use within this tool would not facilitate sufficient scientific transparency.

Another issue, which was explored during the development of the impact assessment framework, is that different techniques for different impacts tend to have different metrics and units of measurement. Ideally all the impacts should be measured and assessed using units relating to the impact itself (e.g. greenhouse gas emissions, losses of nutrients, diversity of species, population of species, etc.). However, it was apparent at the outset of the project that given the breadth of features and impacts that needed to be covered, finding a common way to handle multiple metrics and units was going to be difficult. The consequence, as with many other similar projects, was that a bespoke score/index needed to be developed. The scoring system developed (see Section 3.2.5) is relatively simple (albeit it does distil a lot of complex and data intensive parameters) and could be regarded as subjective in some instances due to the use of expert judgement. However, at the same time its simplicity facilitated rapid development of the software and provides a mechanism for 'fine tuning' the impact assessment. The scores went through several iterations as they were adjusted during the development and testing of the software, and there is scope for this process to continue in the future using feedback from users and possibly work to ground truth the tool (see Section 6.4). So although the approach is not perfect, it is flexible and does provide a workable and upgradeable solution.

The work undertaken to allocate scores to the impacts was split into two approaches, quantitative (using meta-modelling) and qualitative (using a risk factor approach). The majority of the scoring was done using the qualitative approach (the quantitative was only used for some ecosystem service impacts). It could be argued that all the impacts should have been assessed qualitatively, so that the approach was consistent. This would have also overcome some complex technical issues in the software with regard to data storage and retrieval for the quantitative data. However, it is also considered that the meta-modelling was worth doing as it gave a reasonable indication of where different features sat relative to each other for some impacts, and provided a slightly more objective approach to assigning a score compared to those impacts based on expert judgement alone. As such it was retained for this prototype.

The second phase of this work involved processing the knowledge gathered in the first task using the impact assessment framework, to derive the impacts, impact scores and parameters that affect the impacts for each farm feature (see Section 3.3). This was a challenging task to undertake in a relatively short space of time and there is certainly scope for improvements to be made (see Section 6.3 and 6.4). Additionally, this work was being undertaken as the software was being developed. This meant that as the impact scores were being added to the core database, a number of issues emerged which consequently required adjustments to how the scoring process was done. For example, at the start of the scoring process, all combinations of parameters for a feature-impact were generated and then scores were created for these combinations (this was the same for both the quantitative and qualitative approaches). However, for some of the qualitative scoring, the number of parameters resulted in a large number of combinations requiring scoring (e.g. some feature-impacts have over 100,000 combinations of parameter classes). This resulted in the size of the database significantly increasing, processing time increasing to the extent it made the tool impractical to use, and in some instances it was not even possible to display the grid to edit the data on the screen as it required too much memory or would take 20-30 minutes to load. This consequently required a rethink on how the scoring was done and resulted in an adjustment to the scoring process, with the introduction of the 'automated' approach to calculating the score (see Section 3.2.5.3). The full combination approach is now only undertaken for the quantitative approach and where a manual approach is required for the qualitative approach.

6.2.4. Software development and testing

The software development started at the outset of the project. This was necessary given the time available for the project. Some aspects could be implemented prior to the core database and knowledge being collated, synthesised and structured. Although the development started early, it was still ambitious to develop a fully functioning software tool within 9 months. However, this has been achieved, albeit there is scope to improve the software tool in places.

A number of core software tool functions were identified as being necessary early in the project schedule and thus these could be developed while other tasks were being undertaken. Additionally, as soon as a basic functioning tool was available (a pre-Alpha version) this was made available to JRC facilitating early feedback. Consequently, there was time to incorporate suggestions. Testing and revising the software tool was then an ongoing process until the end of the project.

With regard to the testing tasks, there were two parts: functionality testing and testing using theoretical farm scenarios. These two testing processes overlapped as the second part effectively provided an additional functionality test by running 'real' data through the software. The hypothetical farm scenarios involved creating 40+ farm scenarios. The original plan was to create these using data from farms that had been studied in previous national and EU projects. Some of these were used, but many of the farms from previous projects did not have the required data (e.g. some previous projects focused on agronomic practices and thus data on farm features had not been gathered). An additional issue was that data on the size of features is required for the EFA calculator, and this was time consuming to gather and/or generate (more time than had been originally anticipated). To overcome these issues the approach to the hypothetical farm testing was split into two parts: simplified and detailed (see Section 5). The simplified scenarios tested all EFA elements in all Member States, 32 in total (thus ensuring that all combinations functioned correctly) using completely hypothetical data. The second phase then constructed 25 detailed scenarios in 16 Member States based on real data derived from previous projects in some instances supplemented using actual locations identified on Google maps and Google Earth. Basic GIS functions were used to derive dimension data and aerial photos to qualitatively describe the features. This detailed approach provided the means to run 'real' data through the software. It also highlighted some general issues with regard to the use of the tool which allowed it to be further refined for the tasks it needed to perform. Overall the testing process worked well and it detected a number of issues that were subsequently addressed.

6.3. Review and critique of the outputs

6.3.1. Introduction

There are two key outputs from the project: the knowledge base that was collated and structured in the first two tasks and the software that was developed as the delivery vehicle for that knowledge. The software testing (including the hypothetical farm scenarios) can also be considered an output from the project.

6.3.2. The knowledge base

6.3.2.1. Introduction

The challenge here was to convert and structure the scientific and practical knowledge gathered from the 350+ publications that were reviewed (see Section 2 and Annex A for the coverage of the review) into a knowledge base that could be used to support a simple and easy to use software application. This involved determining the key potential impacts of each feature and the variables (parameters and classes) that influence those impacts. Currently there are a total of 230 feature-impact combinations (see Section 3.3) that have been created in the core database. These are characterised using 138 different parameters containing 708 parameter classes. There is scope to increase the level of detail (number of parameters and classes) describing the features and their associated impacts, but the outcome of this would be an increase in data input demands, making it less practical, less simple and less easy to use. A balance had to be found between providing enough detail to make the software responsive in terms of changes in impact from changes to parameter classes, whilst not making the software overly 'data hungry'. Additionally, in some instances, the scientific evidence gathered in the first task was lacking for some features and impacts consequently resulting in variable levels of detail (e.g. some feature-impacts have one parameter with 2 or 3 classes, whilst others have 10 parameters, each with 4 or 5 classes). This section explores some of this variability and thus highlights some of the strengths and weaknesses in the knowledge base, especially with respect to the level of detail covered for different features and impacts.

6.3.2.2. Strengths and weaknesses

Tables 6.1 and 6.2 provide an overview of the relative level of detail (basic (1), moderate (2) and advanced (3) – shaded cells are not applicable) that was available for each feature-impact combination for ecosystem services and biodiversity respectively. There is no table for management impacts as there was only one criterion (labour). It should be noted that the figures shown in Tables 6.1 and 6.2 are just a crude assessment to provide a general indication of potential strengths and weaknesses, which are then explored below.

Table 6.1: Analysis of knowledge base: ecosystem services

	Features																			
Impact categories	Agroforestry	Ancient monuments	Ancient stones	Archaeological sites	Catch crops or green cover	Ditches	Fallow land	Garrigue	Hedges or wooded strips	Isolated trees	Land strips (adjacent/parallel	Land strips (other)	Natural monuments	Nitrogen fixing crops	Ponds	Short rotation coppice	Terraces	Traditional stone walls	Trees in line	Woodland
Aesthetic services		1	1	1		2			2	1			1		2		2	2		2
Heritage and cultural services		1	1	1						1										
Provision of water for as a material																	2			3
Provision of water for nutrition																				3
Global climate regulation by reduction of greenhouse gas concentrations																				2
Pollination and seed dispersal	2					1	2	1	2		2	2		2	1	2				1
Pest control	2				3		2		1					2		2			1	
Chemical condition of freshwaters						3									3					3
Microbial/pathogen run-off											3									
Nitrate leaching	3				3		3							3		3				
Nitrogen run-off											3									
Pesticide drift									2		2								2	
Phosphate run-off	3				3		3				3			3		3				
Sediment bound pesticides											3									
Soluble pesticide run-off											3									
Flood protection						2														2
Mass stabilisation and control of soil erosion	3				3		3				3			3		3	3			3
Filtration/sequestration by flora and fauna									1		1								1	
Mediation of smell/noise/visual impacts									1										1	

Table 6.2: Analysis of knowledge base: biodiversity

	Features																			
Impact categories	Agroforestry	Ancient monuments	Ancient stones	Archaeological sites	Catch crops or green cover	Ditches	Fallow land	Garrigue	Hedges or wooded strips	Isolated trees	Land strips (adjacent/parallel	Land strips (other)	Natural monuments	Nitrogen fixing crops	Ponds	Short rotation coppice	Terraces	Traditional stone walls	Trees in line	Woodland
Amphibians	3				3	1	3			2	3	3		3	3	3				
Aquatic plants: All						2									3					
Aquatic plants: Emergent aquatic plants						2									2					
Aquatic plants: Submerged and floating aquatic plants						1									1					
Biodiversity (general)						1									3					1
Birds: All						1			3	1					3			2	1	3
Birds: Birds of prey	3				3		3				3	3		3		3				
Birds: Farmland birds									1											
Birds: Insectivorous birds	3				3		3				3	3		3		3				
Birds: Scrubland birds									1											
Birds: Seed eating birds	3				3		3				3	3		3		3				
Birds: Waders															1					
Birds: Woodland birds									1											
Fish						1									2					
Fungi			1															1		1
Invertebrates: All								1	1	2										2
Aquatic invertebrates: All						1									3					
Aquatic invertebrates: Crustaceans						1														
Aquatic invertebrates: Molluscs															1					
Arachnids																				1
Invertebrates: Bees									2									1		1
Invertebrates: Beetles (canopy coleoptera)																				1
Invertebrates: Beetles (carabids)																		1		1
Invertebrates: Butterflies and moths									1									1		2
Invertebrates: Dragonflies and damselflies (Odonata)															2			1		
Invertebrates: Hoverflies and hoppers															2					1

Impact categories	Features																			
	Agroforestry	Ancient monuments	Ancient stones	Archaeological sites	Catch crops or green cover	Ditches	Fallow land	Garrigue	Hedges or wooded strips	Isolated trees	Land strips (adjacent/parallel	Land strips (other)	Natural monuments	Nitrogen fixing crops	Ponds	Short rotation coppice	Terraces	Traditional stone walls	Trees in line	Woodland
Invertebrates: Pollinating invertebrates	3						3				3	3		3		3		1		
Invertebrates: Snails			1															1		
Invertebrates: Soil surface invertebrates	3				3		3				3	3		3		3				
Lichens																		1		1
Mammals: All						1		1	1						2					2
Mammals: Bats	3						3		2	2	3	3		3		3				
Mammals: Small mammals (mice, shrews, voles)	3				3		3				3	3		3		3		1		
Reptiles	3		1		3		3	1		2	3	3		3		3	2	1		
Terrestrial plants: All						1														
Terrestrial plants: Conifers																				1
Terrestrial plants: Ferns																		2		1
Terrestrial plants: Flowering plants	3				3		3	1	1	1	3	3		3		3				3
Terrestrial plants: Mosses and liverworts			1						1	1								2		1

Tables 6.3 and 6.4 show the relative strengths and weaknesses with respect to ecosystem services and biodiversity, first for features and secondly for impacts. Strengths are where the average score from Table 6.1 and 6.2 exceeds 2 and weaknesses are where the average score is 1.

Table 6.3: Strengths and weaknesses of the knowledge base: features

	Ecosystem services	Biodiversity
Strengths	• Agroforestry • Catch crops or green cover • Fallow land • Land strips (adjacent/parallel to water) • Nitrogen fixing crops • Short rotation coppice • Terraces • Woodland	• Agroforestry • Catch crops or green cover • Fallow land • Land strips (adjacent/parallel to water) • Land strips (other) • Nitrogen fixing crops • Ponds • Short rotation coppice
Weaknesses	• Ancient monuments • Ancient stones • Archaeological sites • Garrigue • Isolated trees • Natural monuments	• Ancient stones • Garrigue • Trees in line

Table 6.4: Strengths and weaknesses of the knowledge base: impacts

	Ecosystem services	Biodiversity
Strengths	• Provision of water for as a material • Provision of water for nutrition • Chemical condition of freshwaters • Microbial/pathogen run-off • Nitrate leaching • Nitrogen run-off • Phosphate run-off • Sediment bound pesticides • Soluble pesticide run-off • Mass stabilisation and control of soil erosion	• Amphibians • Aquatic plants: All • Birds: Birds of prey • Birds: Insectivorous birds • Birds: Seed eating birds • Invertebrates: Pollinating invertebrates • Invertebrates: Soil surface invertebrates • Mammals: Bats • Mammals: Small mammals (mice, shrews, voles) • Reptiles • Terrestrial plants: Flowering plants
Weaknesses	• Heritage and cultural services • Filtration/sequestration by flora and fauna • Mediation of smell/noise/visual impacts	• Aquatic plants: Submerged and floating aquatic plants • Birds: Farmland birds • Birds: Scrubland birds • Birds: Waders • Birds: Woodland birds • Fungi • Aquatic invertebrates: Crustaceans • Aquatic invertebrates: Molluscs • Arachnids • Invertebrates: Beetles (canopy coleoptera) • Invertebrates: Beetles (carabids) • Invertebrates: Snails • Lichens • Terrestrial plants: All • Terrestrial plants: Conifers

With regard to the features, the greatest strengths are, not unsurprisingly, associated with features that could be considered land management activities or are known to be important features in the landscape. Consequently, there is a significant amount of literature and knowledge on their potential impacts, which is reflected in the knowledge base.

Many of those features which fall in the 'Other features' EFA element had only a basic level of detail. These include ancient monuments, ancient stones, archaeological sites, garrigue, and natural monuments. All these features are fairly rare and potentially very niche habitats. Additionally, they are features that cannot be created as new features on the farm (it is not possible to create new ancient features and garrigue is a semi-natural habitat which develops over time). Literature on the benefits of these features to ecosystem services and biodiversity, and their management, was lacking. In the case of garrigue there is some information describing the value of the habitat (see Section 2.2.11), but little information on its management in the context of EFAs was found.

Isolated trees were moderately covered under biodiversity, but only basic details were covered for ecosystem services. Little literature was identified on ecosystem service impacts of isolated trees, thus only expert judgement was used to determine that they may have some aesthetic and heritage and cultural services. It is possible that there are other potential impacts, for example on provision of water, carbon sequestration, pollination and seed dispersal, and soil erosion, but details on such impacts could not be derived in the time available.

Trees in a line were moderately covered under ecosystem services, albeit as in the case of isolated trees there is scope for improvement. However, for biodiversity the coverage was very basic. Only the impact on birds was covered and then only one parameter (the tree species) was used to differentiate the impact score. The consequence of this is that this feature is particularly sensitive (in the context of sensitivity analysis, i.e. a change to a single parameter (the tree species in this instance) results in a significant change in the impact score). Ideally more parameters need to be added to reduce this sensitivity. There is however a lack of literature that specifically examines the potential impact of trees in a line. It could be argued that trees in a line should be considered as a variation on a hedge and as such the literature on hedgerows could be drawn upon to improve the knowledge base for trees in a line. However, it is possible that some lines of trees could be markedly different in structure compared to some hedgerows, especially with respect the vegetation at the base and gaps between the trees. This potential difference was considered significant enough in this project to justify not using the knowledge on the impacts of hedgerows on biodiversity as a surrogate for trees in a line.

With regard to impacts, the priority ecosystem services to cover at the outset of the project were pollination, pest control, water quality control and soil erosion, and these have been covered to a moderate to advanced level. For ecosystem services, the strengths in Table 6.4 are a good reflection of the literature and knowledge that is available relating to land use and ecosystem services (i.e. knowledge on water flows, pollutants and soil erosion). The weaknesses for ecosystem services are a reflection of the limited parameters that were defined for these impact categories. For heritage and cultural services, there was little literature on the impact on these services, and thus the parameters used here were largely based on expert judgement. With respect to filtration/sequestration by flora and fauna and mediation of smell/noise/visual impacts, these were only applied to hedgerows and trees in a line. There is scope to apply these to other features and there may be more detailed information available. However, with respect to mediation of smell/noise/visual impacts, this a relatively simple set of parameters in that clearly the bigger and more dense a feature is, the greater the scope for mediation of smell/noise/visual impacts – thus to some extent this is a reflection of the simplicity of the process.

With regard to impacts on biodiversity, the strengths seem to reflect the available literature (i.e. covering some of the key species groups: amphibians, birds, invertebrates, mammals, plants and reptiles). The weaknesses for biodiversity appear to relate to more species specific impacts, as such the level of detail tended to be lower. However, it must also be remembered that the data in Table 6.2 needs to be interpreted in the context of the impact hierarchy. For example, farmland, scrubland and woodland birds are impacts associated with hedgerows and have been flagged up as a weakness here. However, hedgerows also have detailed information for the impact category 'Birds: All', of which farmland, scrubland and woodland birds are sub-impacts in the impact hierarchy. Thus they are simply strengthening the detail, and perhaps should not be viewed as a weakness in the knowledge base. This is a similar case for invertebrates and aquatic plants.

With regard to impacts on management, as described above there was only one criterion (labour) which was applied to hedges or wooded strips; ditches; terraces; ancient monuments; archaeological sites; ancient stones; and traditional stone walls. A basic level was applied to all of these except for ditches which had a moderate level of detail. Other potential management impact categories were provisionally: skills and knowledge; frequency; economic costs; temporal restrictions; and production. The latter was deemed to be too complex to undertake in a robust and credible way, thus only an assessment of land taken out of production was undertaken in the software. The evidence base for potential impacts specifically from EFA features which would introduce management burdens (e.g. beyond those in place for GAEC requirements) is limited. Consequently, the impacts that were determined are very basic and were restricted to simple assessments of potential increases or decreases in labour requirements. For example, more frequent clearing of ditches or cutting of hedges was identified as impacting upon labour. There is considerable scope for improvement for the management impact category and this is discussed in Section 6.4.

6.3.2.3. Impacts not covered

The analysis above highlights the strengths and weaknesses of what was covered, but there are a number of impacts that, perhaps, have not been covered and/or have been covered for some features but not others, especially with respect to ecosystem services.

Firstly, there were some impacts that were included for some features but not for others and which could potentially apply. These included:

- Provision of water (as material and for nutrition): This impact was determined for woodland (and to a limited extent for terraces) to account for the fact that woodland can significant affect the hydrology in a catchment (i.e. reduce water yield). This is detrimental for water provision, but can be beneficial with respect to flooding (the same data is used inversely for the flood protection impact category). Other features could also impact on water provision including agroforestry; ditches; hedges or wooded strips; isolated trees; ponds; and short rotation coppice. The approach taken for woodland was a quantitative meta-model approach, based on quantities of water. Whether such an approach could be applied to these other features is questionable (e.g. the data may not be known), and thus they may require a more qualitative approach.
- Global climate regulation by reduction of greenhouse gas concentrations: The impact was determined for woodland only, to account for the carbon sequestration (above and below ground) potential of the woodland. The approach taken for woodland was also a quantitative meta-model approach (IPCC, 2006; Tzilivakis *et al*., 2013) and there is scope to take the same approach with a number of other features including: agroforestry; hedges or wooded strips; isolated trees; land strips (vegetated); short rotation coppice; and trees in a line. This would require additional meta-modelling to calculate values for these.
- Flood protection: This impact was determined for woodland and ditches. As described above, woodland used a meta-model approach and ditches took a qualitative risk factor approach. Similar to provision of water above, other land management activities could impact flood protection including: agroforestry; hedges or wooded strips; isolated trees; ponds; and short rotation coppice. However, the evidence required to determine the potential impact of these features may be lacking.
- Biodiversity: As the evidence for biodiversity was gathered from a wide variety of sources for different features, the information on the impacts on different species varied considerably. Consequently there

are some inconsistencies in the species covered by different features, thus some potential omissions. These include:
- Amphibians: Hedges or wooded strips; terraces; traditional stone walls; trees in line; woodland
- Birds: Terraces
- Fungi: Fallow land; hedges or wooded strips; isolated trees; trees in line
- Mammals: Terraces
- Reptiles: Ditches; hedges or wooded strips; ponds; trees in line; woodland
- Terrestrial plants: Terraces; trees in line

Secondly, there are number of potential impacts that have not been covered for any feature. Given the breadth of potential impacts, especially all those listed for ecosystem services in the CICES framework, there are inevitably some impacts that were not covered (the priority was to cover pollination, pest control, water quality control, soil erosion and biodiversity). Some of the key potential impacts include:

- Provision of biomass: Features such as woodland, short-rotation coppice and agroforestry have potential to positively impact with respect to the provision of biomass. Parameters such as tree species and planting density could be used to calculate potential yield in given scenarios.
- Provision of energy: Features such as woodland, short-rotation coppice and agroforestry also have potential to positively impact with respect to the provision of energy by accounting for the potential energy content of the biomass calculated above.
- Other cultural services: The impact on cultural ecosystem services was largely restricted to heritage and aesthetic services. Other cultural services could also be impacted upon by the features including: spiritual/sacred/religious/symbolic services; or educational and scientific services.

Finally, impacts on biodiversity have been assessed in the context of species and species groups. As such it is not a direct assessment of biological diversity. Impacts on biological diversity were partially covered under the generic impact category of 'biodiversity (general)', where the evidence related to impacts on biodiversity that were generically positive or negative (i.e. where no specific species were mentioned). However, in terms of tangible biological diversity metrics, this impact was not directly covered in the project. The complexity and/or site specific nature of some of the metrics that do exist for biological diversity were deemed not very meaningful given the broad-scale nature of the tool and the complex arguments entailed in understanding the benefits of species diversity in different local circumstances.

6.3.2.4. Features not covered

The features that are covered by the knowledge base are those that are required for EFAs (see Section 3.2.2). However, there are potentially other features on farms that will impact on ecosystem services, biodiversity and management. For example, grassland is a notable omission that potentially has significant impacts on ecosystem services and biodiversity. This is not an issue in the context of the objectives of this project (i.e. to assess the potential impacts of EFA elements and associated features on the farm). However, in the context of a broader application of the software tool it does present some issues. The software calculates the potential impact of all the features on the farm, or rather all those that the user can enter into the software. It then presents the results of the impact assessment as the impact for individual features, groups of features and consequently the whole farm. This is useful, but also slightly misleading due to the omission of other features such as grassland, which, although are not EFAs, could have potential impacts. The tool has the capacity for other farm features to be added to the database and assessed in the same way alongside the EFA features, but this would require additional work including a review of the current scientific evidence for those features (this is discussed further in Section 6.4).

6.3.3. The software

6.3.3.1. Introduction

The software is the delivery vehicle for the knowledge base that was collated. The aim was to create a simple tool that can support farmers in calculating the 5% EFA target using different options. It needed to estimate the amount of each EFA element to be declared in order to reach the 5% target; assess each option with respect to its potential impact on ecosystem services, biodiversity and management; and facilitate the ranking of different options. Like any software package, there were varying degrees of complexity and sophistication that could be employed to develop the tool. However, a balance needed to be struck between enough complexity for valid assessment and maintaining simplicity/ease of use. This balance was achieved by integrating the software design and development with the tasks and processes generating the scientific outputs. As such the review of literature was structured taking account of the requirements of the software and the software development was undertaken taking account of nature of the scientific evidence emerging from the review. This section of the discussion reviews and critiques the software that has been developed and also reviews the results of the testing phase, particularly the detailed hypothetical farm scenarios (see Section 5.2.3).

6.3.3.2. The EFA Calculator software

The software is fully described in Section 4, including screen shots of the graphical user interfaces, and the software is freely available online to download and explore. It was ambitious to develop the software within 9 months as, although in some respects it is simple, it is a relatively sophisticated tool.

As with any tool that attempts to make an assessment of potential environmental impacts the knowledge it is attempting to capture and communicate is inherently complex, which works against the criterion of designing a 'simple to use' to tool. To overcome this issue, the design philosophy from the outset was to provide the user with options to customise the tool to the level of detail they require. Upon first using the tool users are asked if they want to 'keep it simple' or whether they want to see 'all the detail'. Selecting one of these options sets up the software to one extreme or the other (the user can then adjust the detail shown in the settings and options as they proceed with using the software). Using the basic (simple) setup the software only displays the necessary detail to undertake the core function of calculating the 5% EFA target. The impact assessment is still undertaken in the background (using default impact data options of worst, best or average case data), but the user is not presented with the detailed data input that is used to increase the accuracy of the impact assessment calculation. If the software only needed to perform the 5% EFA target calculation, then the user interfaces would probably have been designed differently, and possibly the need for bespoke software would have been doubtful as the calculations could be easily created in an Excel spreadsheet. But given the requirement to assess potential impacts and also the functions to check EFA implementation rules, then software and the interfaces developed are fit for purpose, albeit there is always scope for improvement in any software application (see Section 6.4).

There are a number of calculation and processing routines that underpin the user interfaces. Many are quite simple, but others are complex, especially the impact assessment routines. The more complex the calculation routines the slower the software, thus a balance is required between keeping the speed of the software acceptable such that it is practical to use, without compromising the necessary complexity and calculations. This has been achieved by ensuring the code for calculation routines is as efficient as possible, undertaking some pre-processing in the core database to speed up calculations when the user operates the tool, and redistributing the calculation routines where possible to avoid doing too many calculations at one time (i.e. reducing peaks in the processing requirements of the software). Two areas that have proved to be particularly problematic are in the land and feature manager (see Section 4.4) and the new feature ranking tool (see Section 4.6). When the user edits data in the land and feature manager, the impact of the feature edited needs to be recalculated. This involves retrieving data from the core database and then aggregating it using the impact hierarchy, and on some computers this can take 1 or 2 seconds. Originally the software always automatically saved the data each time it is edited, consequently if the user was rapidly entering data, each data entry would take 1-2 seconds making the process slow and clunky. To overcome this problem, auto-save has been made an option alongside manually saving. This means that the user can switch off the auto-save option and make numerous rapid edits to a feature or group of features, without any delays, and then click the save button, thus the slower impact calculation routines are done in one go. Similarly in the new feature and ranking tool, the same impact assessment routines are invoked to the do the ranking calculations. There was little that could be done to overcome the slowness of these calculations, thus the user interface allows users to set all the options for the ranking, then they click on the calculate button. The user is also warned that the more criteria they select the slower the process will be. This is not ideal, but within the realms of acceptability.

The outputs from the software consist of a range of tables, text and graphics. Other than numerical data on dimensions of features and amounts allocated to EFA, a conscious decision was made during the development of the software to avoid presenting numerical data, especially with respect to potential impacts. The reasons for this were firstly to not overload the user with large tables of numbers; and secondly the impact scores are relative impact indices and do not use any established units, and thus if numbers are presented they could be interpreted differently and/or imply an incorrect level of precision. Thus the impacts are presented using indicator bars, which can then be visually compared on the screen. This also has the advantage of providing the user with an immediate visual impact to see the areas where there are greatest positive and negative impacts, which may not be so easy if a table of numbers were presented. There may be a desire by some users to see the numbers, perhaps to export them and generate further analysis, but this was considered quite advanced and not necessarily something the average user would want to do. However, it could be considered as an option to implement in the future, perhaps as a data export option (see Section 6.4).

Finally, it should be acknowledged that the current version of the software is still considered a Beta version, and thus is a prototype. Some of the functions and features that have been implemented are exploratory and novel ideas to see how well they work. Should the software evolve and develop, then some of these may be dropped and others developed further, based on feedback from users.

6.3.3.3. Testing the software using hypothetical farm scenarios

The software has undergone a range of tests (see Section 5) since the first pre-Alpha version was released (in month 4 of the project, April 2015). This has resulted in numerous improvements to the software and made it fairly robust with respect to any errors or bugs. This section reviews the testing that was done using hypothetical farm scenarios, based on real world data, and some findings that emerged from this process.

Ideally the testing of the software would have entailed trials with end users, but the resources for this were not available (testing with actual users was limited to just a few internal and external experts). Given this resource constraint, the next best option was to operate the software as a potential end user using 'real world' data. The process (described in Section 5.2.3) involved using aerial photos of real locations to determine the features present, their size, and to a limited extent their qualities. This process in itself was interesting, as it revealed that a significant amount of data can be liberated by using a combination of aerial and ground photos, with the latter allowing features to be viewed and evaluated at ground level. This is no substitute for on-farm surveys and observations on the ground, but it was satisfactory for testing the software.

The process of collating and entering the data did highlight a number of issues that resulted in improvements to the software. This included the auto-save issue mentioned above, improvements to guidance on data entry; the development of a variety of report options in the report builder (see Section 4.7); and the identification a few bugs that had not been experienced during the standard functionality testing. The process also generated a substantial amount of data that is partially explored in Section 5.2.3.2. There is scope to analyse this data further (and generate additional data) to examine the performance of the software with respect to the outputs it produces, especially in relation to what might be expected in certain situations (i.e. locations, soil types, features, etc.). A potentially interesting and valuable study would be to compare the results of the software to what has actually been observed on the ground to see how well they match up (see Section 6.4), but this is beyond the scope of this project. However, some interesting aspects did emerge from the analysis including:

- Contribution of existing features to the EFA target: Out of the 25 case studies/hypothetical farms, only 3 reached the 5% EFA target based on their existing features; 2 were above 4%, but the majority (14) were below 2.5%. Although this is a very small sample from random locations across the EU, it highlights that in many instances farms may need to create new features on their farms in order to meet the 5% target. Note: as described in Section 5.2.3.2, areas of catch/cover crops and nitrogen fixing crops could not be determined from the aerial photograph approach, so these are not included in these figures.
- Ranking of new features: Given that many of the farms would need to create new features, the new feature ranking tool was run for each farm to see what features the software suggests should be implemented. It should be noted that the results of the ranking tool are entirely driven by the criteria used and thus these should be taken into account when interpreting the results of the ranking. However, this test revealed that a number of features were frequently ranked at the top of the list of suggested features, and they included agroforestry, N fixing crops and short rotation coppice. These features tended to be ranked highly as they performed well across all the criteria, i.e. they provide reasonable benefits for ecosystem services and biodiversity, with minimal management burden and without taking land out of production. Other features, e.g. hedges, ponds and ditches, do score higher for ecosystem services and biodiversity, but have a management burden and take land out of production, resulting in a lower overall ranking. The process also flagged up some anomalies, especially with respect to terraces. The range of rankings across the farms showed that terraces could be ranked from the very top to the very bottom. When at the bottom, this was usually when the farm was flat and consequently the impact scores for terraces would be zero. However, if there was any gradient/slope at all on the farm, to the extent it would not be considered flat (even a shallow gradient), terraces often appeared towards the top of the rankings, and often in scenarios where they would not be an expected feature. For example, one of the hypothetical farms in the UK has a moderate slope on some of the land and consequently terraces ended up being suggested as the number one option to implement. However, terraces are not a common feature in the UK and definitely not where this farm is located. Even when the parameter 'Terraces are a traditional feature of local area' is set to 'No', the feature still appears at the top of the rankings. This may be down to the criteria selected for the ranking process and/or it may be due to how the impacts for terraces have been scored. Alternatively, the suggestion of terraces may not be scientifically incorrect for some locations (even when they are not a common feature in the region) as they could be beneficial and it may simply be down to being a costly practice that farms are unwilling to implement (i.e. the cost-benefit ratio is too high). As such it is probably an area that could be further explored in the future (see Section 6.4) to see if it can be amended to refine the outputs of the software.

Further testing of the tool, especially on real farms, will no doubt liberate additional data and feedback which could be used to refine the software.

6.4. Future developments, options and opportunities

Given the nature of the project it is inevitable that there are areas where improvements could be made. Additionally, scientific understanding is continually growing and evolving and thus we need to acknowledge this evolution and ensure that it is reflected in the tools and information that are made available to farmers across the EU. The discussion above has identified a number of areas where there is scope for further development in the future. These, and others, are explored further below.

There is, and will always be, scope to improve the scientific knowledge base that underpins the tool. The analysis undertaken in Section 6.3.2 revealed a number of strengths, weaknesses and issues that could be explored in the future. Firstly, with respect to impacts these include:

- Provision of water: This ecosystem service was only explored for woodland and terraces, thus there is scope to extend this to cover other EFA features including agroforestry; ditches; hedges or wooded strips; isolated trees; ponds; and short rotation coppice.
- Provision of biomass and energy: These ecosystem services were not explored for any features. They could potentially be developed for woodland, short-rotation coppice and agroforestry.
- Global climate regulation by reduction of greenhouse gas concentrations: This ecosystem service was only explored for woodland. There is scope to extend this to cover other EFA features including agroforestry; hedges or wooded strips; isolated trees; land strips (vegetated); short rotation coppice; and trees in a line.
- Flood protection: This ecosystem service was only explored for woodland and ditches. There is scope to extend this to cover other EFA features including agroforestry; hedges or wooded strips; isolated trees; ponds; and short rotation coppice.
- Other cultural services: The impact on cultural ecosystem services was largely restricted to heritage and aesthetic services. There is scope to extend this to cover spiritual/sacred/religious/symbolic services; or educational and scientific services for a number of features.
- Biodiversity: The evidence gathered for biodiversity impacts of different features came from a variety of sources using a variety of approaches. As such there are some inconsistencies across features and some omissions. There scope to improve the approach taken by developing a more harmonised approach to assessing biodiversity impacts. For example, the impact criteria (species groups) were derived from the literature that was gathered – there is scope to rationalise these and then review the literature again, seeking evidence using the rationalised impact categories and thus structuring the information in the more harmonised way.
- Management: As described in Section 6.3.2.2, the project aimed to develop impact categories for management in the same way as exists for biodiversity. However, little evidence was obtained specifically on the management implications of EFA features, and thus it was limited to some basic assessments on the potential impacts on labour only. The management/production implications of features was partly enhanced with the addition of an assessment of the impact in respect of land taken out of production by features, but there is scope to improve management impacts within the knowledge base and the software. For example, there may be scope to add additional parameters and classes to cover the additional field operations required for catch and cover crops, such as additional sowing and removal operations (tillage or herbicide) before drilling the main crop. This might start to capture this information in a format to aid assessment, although it comes at a cost of increasing the data requirements of the software, and thus impacts upon ease of use. An alternative approach would be to provide more contextual information on management implications in the form of guidance (perhaps in the EFA explorer or the report builder) to flag up potential management issues to users on a more generic basis. There may also be scope to draw upon other projects, especially those that have involved case studies, such as the work undertaken on Best Environmental Management Practices (BEMPs) in the Agriculture sector (Antonopoulos *et al*., 2015) developed according to Article 46 of the Eco-Management and Audit Scheme (EMAS) regulation(EC, 2009).

Secondly, with respect to features, areas with scope for improvement include:

- Ancient monuments, ancient stones, archaeological sites and natural monuments. These were covered to a basic level, but they were very similar, so it's possible that they could have been combined to simplify the tool. However, an alternative option would be to explore each of them further to see if the evidence exists to differentiate them further with respect to their impacts.

- Catch crops and green cover: The evidence gathered in this study tended to be focused on winter crops. It is possible that some crops may be present during the summer in the southern EU to prevent water or wind erosion and thus this may not be fully reflected in the evidence base gathered for this project. Also, the impact assessment for cover crops was based on 13 species groups, thus there could be scope develop this further into a more species specific approach.
- Garrigue: This semi-natural habitat was only covered to a basic level. Difficulty was experienced in finding scientific evidence in a form that was suitable to support this tool (the evidence collated was largely generic and descriptive, rather than specific detailed information on impacts). Further research could help improve understanding of this feature and its benefits as an EFA, which are not currently reflected in the tool.
- Isolated trees: Further research is needed on the impact of isolated trees, especially with respect to ecosystem services.
- Terraces: This proved to be a problematic feature to cover in the software. This is partly because it is a feature that can be implemented to address a specific impact (i.e. soil erosion), which can be reduced by the implementation of terraces. While at the same time terraces can be a cause of greater soil erosion if they are not properly managed and maintained. This issue was overcome to some extent by a manual risk factor approach (see Section 3.2.5.3) to account for this. There is also an issue with respect to the appropriate location for terraces (i.e. the circumstances in which they should be implemented), which is perhaps not adequately captured in the knowledge base, and which may explain the high rankings that terraces achieve in some instances (as described in Section 6.3.3.3).
- Trees in a line: This feature is similar to hedgerows, but it is significantly different enough not use the evidence of the impact of hedgerows as a surrogate. Although this may be ok for some impacts (e.g. effects of sheltering), it may not be for many others (e.g. biodiversity). Consequently, more scientific evidence on the potential impacts of this specific feature would be valuable.

Another option for the future (that was raised in Section 6.3.2.4) is with respect to features on the farm that are not associated with any EFA elements, but which could also have impacts on ecosystem services and biodiversity, for example grassland. At the moment an assessment of the impacts of the farm as a whole is limited to the features covered by EFA elements, but clearly other features can also have an impact. The knowledge base and the software are fit for purpose, in the context of assessing EFAs. However, if the ideas and concepts are extended to cover assessing the whole farm, then any omissions, such as grassland, need to be added. This is feasible to do using the existing framework and database that underpins the software. However, it is beyond the scope of this project as it requires additional literature reviews and data structuring.

With regard to the EFA calculator software, like any application there is always scope for it to be improved and for it to evolve. Inevitably there is always a long wish list of additional functions and options that could be implemented to enhance and improve it. Ultimately this should be driven by user feedback, but as the EFA calculator is a prototype that has been largely tested internally, this feedback does not exist yet. However, there are two areas where it is likely that improvements could be made and these are to do with facilities for data import and data export. At the moment there are no functions for the import of data (e.g. from other farm software applications), thus users have to enter all the data within the EFA software. Some of this data may already exist in an electronic format in other applications, thus it would be useful if it could be imported. Unfortunately, this data can be in variety of formats and structures that are unknown, and as such direct import is difficult or impossible. Similarly, being able to export data to other applications could also be useful. There are some limited functions for exporting some of the tabular data in the report builder of the EFA calculator. This data can be exported to MS Excel or CSV format, thus can be manipulated further where necessary. There may be scope to enhance these export processes further (e.g. the idea to export the impact scores as numeric data suggested in Section 6.3.3.2), but again these sort of ideas should be driven by user demand to ensure they fully meet the requirements of end users.

Finally, although a substantial amount of scientific evidence has been gathered in a short space of time to create the knowledge base, it is likely that there will be inconsistencies in what is suggested and potential impacts for a farm (using the software) and what actually happens on the ground. In longer term all tools of this nature (that assess environmental impacts) would benefit from work to ground truth the outputs from the tool with actual observations on the ground. This would generate primary data that would be valuable to further develop, refine and improve the tool. It could also liberate data that could make the use of the tool more effective on farms and also data that could be valuable for policy development in the future (i.e. are the interventions being implemented on the ground leading the desired and anticipated outcomes).

6.5. Findings and conclusions

6.5.1. Achievements of the EFA Calculator project

Table 6.5 outlines what has been achieved within this project against the project objectives (see Section 1.2). In all instances the aims and objectives have been achieved.

Table 6.5: Achievements made against project objectives

Aims and objectives	Status and notes
Aim: To develop and test a software tool that aims to help farmers identify the most ecologically sound and pragmatic solution for implementing EFAs on their farm	ACHIEVED
Objective 1: To conduct an extensive knowledge and literature review for all the different EFA elements in order to define their contribution to ecosystem services and biodiversity, taking account of various characteristics such as size, location, connectivity etc.	ACHIEVED: over 350 papers, reports and guides have been reviewed.
Objective 2: To design and develop a simple software tool that will support farmers calculate their 5% EFA and include various user functions for ranking potential solutions in terms of their contribution to ecosystem services, biodiversity and management.	ACHIEVED: software developed and made available ahead of schedule.
Objective 3: To assess the functionality and usability of the developed tool and pilot it using data for 40 theoretical farms.	ACHIEVED: software fully tested over 4 months and tested using 32 simplified scenarios covering all Member States and 25 detailed case studies covering 16 Member States

In addition to these aims and objectives, there were a number of requirements for the software in terms of its functionality that needed to be met. These were partially outlined in the tender specification and also the software specification that was drafted at the outset of the project to clarify the requirements. These requirements have all been met and in many instances exceeded.

6.5.2. The impact of EFA features

The implementation of EFAs forms a core part of the 'greening' measures of the Common Agricultural Policy (CAP), with the aim of having positive environmental impacts, especially with respect to biodiversity. For some farms their existing features may be sufficient to reach the 5% EFA target, while other farms will need to implement new EFA options activated in their Member State. All the options available are designed to bring about positive outcomes, but clearly the scope of that benefit is variable and in some instances there could even be potentially negative impacts if some options are implemented in inappropriate places. EFAs are of course supplemented with GAEC and SMR requirements, so the scope for any negative impacts should be minimised, but there is still scope for variable positive impacts depending the circumstances in which they are implemented.

This project has aimed to address this issue by reviewing the current scientific understanding of the potential impact of EFAs on ecosystem services, biodiversity and management, and converting this into a knowledge base which underpins a software tool to support farmers. At a basic level the tool simply supports the process of allocating and declaring farm features as EFAs and thus determines the contribution towards the 5% target, and this alone is a useful function. It also provides feedback on the potential impact of those farm features on ecosystem services, biodiversity and management. This information is provided using simple icons and indicator bars. This helps raise awareness of the potential impact of features on the farm and also guidance on which parameters associated with those features may give rise to increased benefits or decreased burdens. In the event that a farm has to create new EFAs, the same potential impact information can be used to help steer farms towards those features and associated EFAs that are likely to have the greatest benefits for that farm, taking account of farm specific data (e.g. climate, topography, soil type, etc.).

Assessing the potential impact of an EFA is not simple. In some instances there is a vast array of scientific evidence, sometimes with consensus, sometimes without, and in other instances there is patchy or little evidence. The process of analysing and converting this diverse information into a common format that can used in the context of a decision support tool inevitably involves compromises and trade-offs. There is a difficult balance to be struck between maintaining enough scientific detail for the tool to be credible and robust whilst meeting the requirement for simple and easy to use software tools which will aid adoption on farms. It also has to be remembered that this is not a scientific tool, but a tool that aims to transfer scientific knowledge into the agricultural industry. It is about guidance and direction towards positive outcomes, rather than an assessment of absolute impact.

6.5.3. Conclusions

To conclude, a lot of work has been undertaken in a relatively short-period time and some practical outputs have been developed. However, it is important to acknowledge that the tool is a prototype and thus has strengths and weaknesses, with scope for improvement and development in the future, as outlined in this report.

It is also important to recognise that although the software has been designed for use by farmers, the most likely users are farm advisors, such as agronomists. This is not an uncommon user base for tools of this type. Many farmers do not have the time (and some do not have the IT skills) to research and synthesize information on a diversity of topics. Thus they often turn to trusted sources of information, such as farm advisors. This has been taken into account in the design of the tool (e.g. with the option for basic and advanced levels of detail) in order to maximise the potential user base (i.e. simple to encourage use by farmers themselves, and detailed for those that have more time and require more detailed information, such as advisors).

Another important aspect to consider is that tools, like the EFA calculator, ideally need to seamlessly integrate with other applications, tools and services that farms use on a regular basis. Such commercial mainstreaming is essential for widespread adoption of the concepts and ideas that have been explored in this project and related studies, especially those which are encouraging practices and decision making that will lead to environmental improvements. For example, farms that have software applications for recording activities and/or GIS tools for mapping features on the farm, to meet their commercial or legal requirements, are more likely to integrate environmental aspects into their decision making if there is an option or plug-in for those applications that would introduce routines and algorithms such as those developed in this project. If such as approach were to be pursued, then there would need to be a dialogue with commercial software companies, to explore how these ideas and concepts could be developed, integrated and delivered on the farm.

Finally, the software will remain available on the project website (http://www.herts.ac.uk/aeru/efa/) and the software will be maintained (in terms of fixing bugs identified) for a year after completion of the project. There is, therefore, scope for users to have access to the tools and provide feedback. This would be valuable information to support any opportunities in the future to develop the tool further and build on the foundations developed in this project.

Annex A. Literature review methodology

A.1. Introduction

It is beyond the resources of this project to undertake a full systematic literature review. However, there are a number of specific elements of a systematic review that have been incorporated within the literature review undertaken for this project in order to ensure that:

- As much relevant scientific evidence as possible is collated within the available time,
- The review is relatively systematic within the resources that are available, and
- The processes adopted are scientifically rigorous and transparent.

There are various types of search strategies that could be used. That adopted for the EFA-calculator project is an enhanced 'protocol-driven' strategy. Standard protocol-driven searches rely solely on literature databases as the main source of information. However, it is our opinion that literature reviews should not rely on protocol-driven searches alone as this can limit access to information and introduce bias. Ideally, the search strategy should involve a combination of 'protocol-driven', 'snowballing' and 'personal knowledge' approaches (Greenhalgh & Peacock, 2005).

Ideally all literature reviews need to be conducted according to a pre-defined plan and this is particularly important when resources are limited. Consequently, such a plan (known as the review protocol) was developed for this project with the overall aim of ensuring that the review was, comprehensive, consistent and transparent. The 'review protocol' describes in detail the approach that has been subsequently adopted for undertaking the search for relevant material and how this was evaluated in terms of the project aims and objectives.

The review protocol includes:

- Establishment of the review boundaries. This was considered important to ensure that resources were used effectively, that the study did not spiral out of control and the aims and objectives of the project were delivered.
- Development of a search strategy. This strategy included the search approach, literature databases searched, search engine tools utilised, and keywords and phrases used, etc.
- Development of the study Inclusion Criteria. These criteria established the 'standards and condition' that were needed to be met by each study in order that the aims and objectives of the project were met and the assessment of an additives potential to deliver positive environmental effects was based on the best possible quality data.
- Development of 'knowledge logging forms' to enable the information within the relevant literature to be extracted and recorded for use by the project.

A.2. Literature review boundaries

The first part of the plan was to define the boundaries for the literature review. These were:

- To cover all EFA elements as described in the relevant European Regulations (EC, 2014) and given in Table A1 below. The EFA elements were subdivided, for convenience, into four areas each allocated to a different researcher. These were (i) terrestrial and landscape features such as hedgerows, trees and field margins, (ii) water associated features such as ponds and buffer strips, (iii) cropping elements such as short rotation coppice, nitrogen fixing crops and catch crops. Finally, (iv) 'other features not listed above but protected under GAEC7, SMR 2 or SMR 3' are quite special cases and sometimes Member State specific so these were separated out as these require special, case by case literature reviews.

- The types of documents considered will be limited to peer-reviewed research papers and research reports, due to time constraints.
- The review would be constrained to research published after but including 1980 (other documents, derived from 'snowballing', that are earlier than 1980 may also be included if deemed relevant)
- The review would be constrained to research published in English only.
- Studies appropriate to European research only (i.e. covering the EU-28).

Table A1: EFA elements

EFA Elements
Terrestrial and landscape features:
• Land lying fallow (per 1 m^2)
• Terraces (per 1 m)
• Hedges/wooded strips (per 1 m)
• Isolated tree (per tree)
• Trees in line (per 1 m)
• Group of trees/Field copses (per 1 m^2)
• Field margin (per 1 m)
• Traditional stone walls (per 1 m)
Water associated features:
• Ponds (per 1 m^2)
• Ditches (per 1 m)
• Buffer strips (per 1 m)
Cropping features:
• Strips of eligible hectares along forest edges (per 1 m): Without production
• Strips of eligible hectares along forest edges (per 1 m): With production
• Areas with short rotation coppice (per 1 m^2)
• Afforested areas as referred to in Article 32(2)(b)(ii) (per m^2)
• Areas with catch crops or green cover (per 1 m^2)
• Areas with nitrogen fixing crops (per 1 m^2)
• Hectares of agro-forestry (per 1 m^2)
Other features not listed above but protected under GAEC7, SMR 2 or SMR 3 (per 1 m^2)
• Ancient monuments
• Land management practices
• Member State specific elements

A.3. Search strategy and its implementation

The next step was to develop a comprehensive search strategy with the primary objective of ensuring that that literature review is as comprehensive as possible. The process undertaken was as follows:

- Firstly the potential value of the literature databases available to the project team via initial exploratory and cursory searches was evaluated. From searches of these online systems four databases appeared to offer the most promise. These were Science Direct, Google Scholar, Web of Science and Cambridge Journals online. It appeared that the majority of the journals covered by the other available databases were also covered by these four and were largely an overlap in available resources. Due to resource constraints initial searches were confined to the first two databases (i.e. Science Direct and Google Scholar). Only if/when results were found to be scant or gaps in knowledge identified were the other two databases to be explored. The selected databases were used as the main source of studies and each were then searched according to the following search strategy.

- An initial set of search terms was developed by identifying a list of appropriate keywords and search strings for each of the four areas (see Table A1 above). A brain-storming exercise was then undertaken to identify synonyms, aliases, different spellings, language translation, truncation, plurals and singular, using wildcards etc. of the keywords/strings initially established. In addition keywords given on research papers were examined and added to the list where appropriate (See Table A2 for the full list). However, it was also noted that many of these search term variants would automatically be included in the search as they are established in the database search routines. Searches were undertaken such that each EFA feature was used in conjunction (via the Boolean Operator 'AND') with each primary search terms (e.g. 'Ditch' AND 'Pollination'). Where appropriate the search phrase used was extended to cover all alias's and synonyms using the Boolean 'OR' operator (i.e. ('Ditch' or 'Dyke' or 'trench') AND 'Pollination')
- Each online database was systematically searched using the list of search terms and the results stored. Data describing the search undertaken in terms of the database used and keywords applied, date, researcher etc. were recorded on the appropriate data logging form. Duplicate entries were then removed.
- On the basis of the title and abstract of the articles returned each paper was initially screened to check its relevance to the project and the review aims and objectives, according the 'Study inclusion criteria'. The only exception to this rule was that relevant review papers were also included as a rich source of additional studies and background information via snowballing.
- Each article passing the original screening was then obtained as the complete full text and the bibliographical information, very brief summary of the paper and the key information were extracted on to 'knowledge logging sheets'. These sheets were used as the 'raw' evidence for developing the criteria and guidelines (Section 3) underpinning the EFA-calculator.
- The reference list within each article was then screened for additional articles that had not been previously recovered (snowballing). These were, subsequently, also checked for relevance and full papers recovered as appropriate. In addition, where it was evident that a particular journal is a rich source of useful articles the journals website is also being searched. Similarly author tracking has also been carried out. Key authors, organisations and institutes undertaking key areas of work covered by the literature review have been identified and searches for further work that has been undertaken by those authors, organisations and institutes is being undertaken.

Table A2: Search terms used

Search area	EFA feature (synonyms) and associated terms	Primary search terms (synonyms)
Terrestrial and landscape features	• Land lying fallow • Terraces (stepped terrain) • Hedges (hedgerows, linear feature) • Wooded strips (woodland, forests, boundary) • Trees (shelter belts) • Isolated trees (parkland) • Field margins (green lanes, grass strip, grass margin sward, linear feature, boundary, edges) • Copses • Stone walls (boundary) • Landscape (connectivity, fragmentation, network, structure, heterogeneity)	• Pollination (fecundity) • Biodiversity (wildlife, birds, mammals, insects, invertebrates, bees, pollinators, beneficials, predators, species diversity) • Environmental impact (environmental degradation, conservation) • Pest control (pest management, pest regulation, biological control, pests and disease) • Water quality (nitrate leaching, phosphate, water pollution) • Soil erosion (soil loss) • Ecosystem services • Management

Search area	EFA feature (synonyms) and associated terms	Primary search terms (synonyms)
	• Semi-natural habitat • Habitat (foraging area)	• Agri-environment
Water associated features	• Pond (pool, water course, water body, wetland) • Ditch (dyke, dike, trench, channel, water course, water body) • Buffer strip (vegetative strip, vegetative buffer)	• Pollination (fecundity) • Biodiversity (wildlife, birds, mammals, insects, invertebrates, bees, pollinators, beneficials, predators, species diversity) • Environmental impact (environmental degradation, conservation) • Pest control (pest management, pest regulation, biological control, pests and disease) • Water quality (nitrate leaching, phosphate, water pollution) • Soil erosion (soil loss) • Ecosystem services • Management • Agri-environment
Cropping features	• Forest edges • Afforested areas • Catch crops • Short Rotation Coppice • Green cover • Nitrogen-fixing crops • Agroforestry (intercropping)	• Pollination (fecundity) • Biodiversity (wildlife, birds, mammals, insects, invertebrates, bees, pollinators, beneficials, species diversity) • Environmental impact (environmental degradation, conservation) • Pest control (pest management, pest regulation, biological control, pests and disease) • Water quality (nitrate leaching, phosphate, water pollution) • Soil erosion (soil loss) • Ecosystem services • Management • Agri-environment
Other features	Other landscape features under GAEC or SMR, e.g.: • Archaeological sites (ancient monuments) • Trees (alleys and groups) • Landscape features linked to rice cultivation • Vegetated slopes (known as Garrigue (scrubland) in Malta) • Wetlands	

A.4. Study inclusion criteria

A full systematic review would usually include protocols for screening and critical appraisal of the documents found during the literature search. It is beyond the resources for this project to operate fully documented screening and critical appraisal processes, e.g. developing and using a bespoke Quality and Relevance Assessment Framework (QRAF). However, during the literature review process general scientific quality criteria has been used by the researchers for determining whether a study is of a suitable quality to support the evidence that will underpin the EFA software. These criteria include:

- Study falls within the specified boundaries (see Section A.2).
- Clearly defined aims, objectives and context.
- Completeness of data.
- Clear defined study type and methodology appropriate to the aims and objectives.
- Where appropriate the design and interpretation of the study allow for appropriate statistical analysis of the data which has subsequently been conducted.
- Endpoints are appropriate and answer the specific aims and objectives of the study.
- A clear description of outcome evaluation and assessment is described.
- The conclusions are fully supported by the data.
- Any study limitations are discussed and considered in the conclusions.

A.5. Knowledge logging forms

In order to ensure that the knowledge identified by the literature review can be easily accessed and used for the development of criteria and guidelines (Section 3) that will underpin the tool information within each paper/study collated needs to be extracted onto a 'knowledge logging form'. This form is loosely formatted due to the variety of data that will need to be collected (qualitative and quantitative for a wide variety of related topics) and includes the following information:

- Full reference
- URL where appropriate
- Document type e.g. academic paper, research report etc.
- Place the research was conducted where appropriate
- EFA element addressed
- Impact addressed (e.g. ecosystem service, biodiversity)
- Summary of the document

An example is provided in Annex B.

Annex B. Example knowledge logging form

Internal ref.	KL1 & KL5
Reference	• Cranmer, Louise, Duncan McCollin, and Jeff Ollerton. "Landscape structure influences pollinator movements and directly affects plant reproductive success" Oikos 121.4 (2012): 562-568. • Cranmer, Louise. (2004) The influence of linear landscape features on pollinator behaviour. Dissertation, University of Leicester (PhD thesis)
Impact Category	Pollination
EFA Elements	Hedgerows, embankments, artificial linear landscape features
Source type	Academic paper, single study & associated PhD thesis
Research location	United Kingdom
URL	http://onlinelibrary.wiley.com/doi/10.1111/j.1600-0706.2011.19704.x/abstract;jsessionid=65DF089B988D4AD465781FA0E6822377.f03t01?deniedAccessCustomisedMessage=&userIsAuthenticated=false

Research to investigate if landscape structure influences pollination. Bumblebee flight behaviour was observed along hedgerows and artificial linear features. Results showed that:

- Hedgerows and artificial linear landscape features can influence flight directions of pollinators and that these features can have a profound effect on plant reproductive success i.e. increased pollinator activity, pollen receipt and set seeds.
- Overall hedgerow connectivity in a landscape is important to bumblebee movement and therefore to plants that require pollinator bumblebee services.
- The connectivity of patches was much more important that the attractiveness of the patches. Connected patches were visited significantly more frequently by bumblebees than isolated patches.
- Bumblebees more likely to fly along hedgerows than adjacent open land.
- Pollinator abundance increased as the number of connections per patch increased. Generally plants in patches with four or five connections produced between 7-23% more seeds than similar plants in isolated patches.

Annex C. Development of the impact assessment framework

C.1. Introduction

Given the limited time and resources available for the project, there was little scope to develop completely new assessment frameworks, and there was little sense in 're-inventing the wheel' if existing approaches could be utilised. Thus efforts focused on seeking out existing frameworks (or elements of frameworks) that can be used "off the shelf". If no "off the shelf" tools are suitable, then those which could be easily modified to meet the requirements of the project and the EFA calculator were sought. Failing that, a bespoke approach has been developed, but one which is synergistic with other tools and approaches (e.g. using common terminology), in effort to provide some harmonisation where possible.

Prior to seeking out such tools, it was necessary to define and clarify the requirements in order to assess those tools which are 'fit for purpose' and those which are not. The tools that are available within each of the impact categories are explored (Sections C.3 to C.5) to determine what can (and cannot) be used "off the shelf" and/or with minimal modification to meet the requirements.

With regard to requirements there are number of aspects to consider including:

- Impact taxonomy and aggregation hierarchy
- Definition of performance: what is meant by performance in the context of assessing the potential impact of EFA elements
- Scale and units: absolute versus relative values
- Parameters: attributes that change the relative functional impact of an EFA element

A secondary aspect that needed to be drawn out of literature review (Section 2), and embedded in the criteria, rules and guidelines, is the issue of accounting for the benefits of combinations of EFA elements. This is discussed in Section C.6.

C.2. Requirements

C.2.1. Impact taxonomy and aggregation hierarchy

The EFA calculator has three 'top-level' impact categories of ecosystem services, biodiversity and management. However, the information collated on the functional impact of EFA elements in the literature review (Section 2) is not directly against these top-level impact categories. The impacts tend to be more specific, e.g. impacts on pollination and seed dispersal or a specific species. An impact category classification (taxonomy) with an associated hierarchy is required in order aggregate the more specific impacts within the top-level impact categories.

The process of aggregation in environmental assessments has been debated for decades (e.g. Funtowicz *et al*., 1990; Girardin *et al*., 1999; Niemeijer, 2002; Pennington *et al*., 2004; Rowley *et al*., 2012; Stein *et al*., 2001) and the techniques used and degree of aggregation are often a topic for disagreement. It is an age old battle between the need to simplify data and information to aid decision making whilst not losing important detail or transparency which could also be of importance with respect to the decisions being taken. The EFA calculator is not immune to this problem. Given the range of potential impacts on ecosystem services, biodiversity and management, the number and amount of raw (non-aggregated) impact indices and data is not conducive with the simple and easy to use criteria for the EFA calculator. As such some aggregation is required to facilitate simple assessment and interpretation within the confines of a software tool, e.g. simple indicator bars to reflect the potential performance of an EFA element in relation ecosystem services, biodiversity and management. Consequently, to facilitate this aggregation some form of impact hierarchy is required. This does not necessarily hide detail or reduce the transparency of the system, it simply provides a means by which to manage the level of detail, e.g. by providing users with the facility to choose the level of detail that they require.

C.2.2. Definition of performance

An important distinction in any impact assessment is whether impacts are assessed on the basis of a change from a baseline situation (baseline impact assessment (BIA)) or whether they are assessed on a functional basis (functional impact assessment (FIA)). For example, 100m of hedgerow could be declared as an EFA. This could be a hedgerow that is newly created/planted or an existing hedgerow. The new hedgerow is a change from the baseline, but in the case of the existing hedge there is no change from the baseline. Thus in the context of a BIA, the existing hedge has no impact whereas the new hedge does have an impact. However, in the context of an FIA, the assessment would be concerned with the impact the hedge has in terms of the functions and services it provides (for both biodiversity and ecosystem services). Both the new and existing hedges would have an impact in the context of an FIA, with the impact (performance) being determined by the attributes of the respective hedges in the circumstances in which they are located. Therefore, the performance of each EFA element will be based on the function it performs in relation to ecosystem services and biodiversity. This applies to both existing and new features (including features that may have been specifically created for EFA). Performance will not be based on changes to a baseline.

C.2.3. Scale and units

The objective is to define criteria, rules and guidelines that will qualify and quantify the functional effect/impact of each EFA element on range of impact categories: ecosystem services, biodiversity and management to facilitate the comparison of different EFA elements. Ideally this would involve quantifying impacts using standard established absolute units, e.g. reduction in Nitrogen loss of 50 kg ha^{-1}. However, this would require modelling/calculations and/or site specific survey data of a sophistication that is both beyond the time and resources of this project and beyond the scope of the EFA calculator (indeed it would not fit with the objective of being simple and easy to use).

Another aspect to consider is that ideally when 'whole farm' planning, the location of options and interventions (such as EFA elements) would normally be laid out on a farm map to ensure they are located in the most suitable position. As the EFA calculator does not involve mapping, on-site surveys or remote sensing data, in some respects it is not taking such a 'whole farm' perspective – as it cannot account for the exact position of each EFA element in relation to the others and/or other features on the farm. The EFA calculator has been designed to assess each individual EFA element in isolation. However, it is possible for whole farm aspects to be considered as part of the assessment of individual elements. For example, when describing an individual EFA element, it will be possible to account of site specific parameters and potential interactions with other farm components and EFA elements. However, it is acknowledged that there is limit to this within the scope of this project and the EFA calculator tool.

The focus of this project and the EFA calculator is to assess the functional impact of EFA elements on ecosystem services, biodiversity and management on a given farm. Given the range of potential effects and impacts that might arise across these impact categories and the issue of absolute units outlined above, providing an assessment of actual impact is challenging. What is more feasible (and pragmatic) is to assess relative performance. Relative performance does not provide an absolute scale of end impact, but would provide a measure of the relative (positive and negative) function of EFA elements in relation to end impacts. In some instances, where the evidence exists, it may be possible to correlate performance with absolute end impacts, but in many instances the performance score would simply be relative index.

C.2.4. Parameters

The final requirement is to be able to identify parameters which affect the relative functional impact of an EFA element. These parameters (and classes within them) will relate to the attributes of the EFA elements and the circumstances in which they exists (e.g. the local environment), and when varied the relative functional impact will also vary. Parameters could also be classified into 'fixed' and 'variable'. Fixed parameters will be those attributes that are relatively fixed for the given circumstances, e.g. soil type. Variable parameters will be those attributes where it is possible for them to be changed, e.g. management options or dimensions. This differentiation will provide scope for the EFA calculator software to identify where parameters could be changed to increase the relative functional impact of the EFA element.

C.3. Ecosystem services

C.3.1. Introduction

The concept of ecosystem services is not a new one. As Balbi *et al*. (2015) highlight, the life support functions of ecosystems where highlighted as early as the mid-19th century and by the 1970s the term 'environmental services' from well-functioning ecosystems was being used. However, ecosystem service assessment frameworks and metrics did not really emerge till the 2000s and since the turn of the millennium there have been a plethora of ecosystem service studies, frameworks, tools and systems. Some of these are explored below in the context of the requirements of this study.

C.3.2. Ecosystem services taxonomy and hierarchy

There are numerous and multiple classifications of ecosystem services (Balmford *et al*., 2011; de Groot *et al*., 2002; Fisher *et al*., 2009; Haines-Young & Potschin, 2010; McInnes *et al*., 2008; MEA, 2003 & 2005). One of the most holistic and commonly used is the Millennium Ecosystem Assessment (MEA) framework (summarised in Table C1 in Annex C). The MEA framework is however, very generic and hides a lot of detail and complexity (Fischer *et al.*, 2009; Wallace, 2007). This has been addressed to some degree by a number of authors through the disaggregation of broad ecosystem services into more detailed elements (e.g. Balmford *et al.*, 2011; LUC, 2010; Haines-Young & Potschin, 2010) or through the linking of multiple services and processes (e.g. Fischer *et al.*, 2009). The complexity arises from the fact that there are many inter-linkages between multiple processes, functions, infrastructures, goods and services, such that trying to overlay a rigid classification onto this is inherently difficult, and almost impossible unless a number of assumptions and simplifications are made.

Balmford *et al*. (2011) have attempted to address this issue by disaggregating ecosystem services into three interlinking sets core ecosystem processes, beneficial ecosystem processes and ecosystem benefits (see Figure D1 in Annex D). This classification is useful for separating processes from benefits. However, it is still very simplified. Additionally, as previously mentioned, the reality is that many of these processes are interlinked, and benefits emerge from a complex interaction of multiple services and processes (Fisher *et al*., 2009).

Another issue that commonly arises is variability in detail. This was an issue that was recognised in the Character and Quality of England's Landscapes (CQuEL) project. CQuEL is Natural England's principal integrated monitoring project, which aims to provide place-based evidence about the character and function of landscapes and the provision and quality of selected ecosystem services delivered by England's natural environment. The ecosystem services used in CQuEL are based on those used in the MEA, however it was identified that some services covered a wide range of facets and could do with splitting down, while others were 'small' and would benefit from grouping together (LUC *et al*., 2010). Consequently a nested hierarchy of services was developed. The hierarchy of services is set out in Table D2 in Annex D and draws on the MEA, the work of the European Environment Agency on CICES (Common International Classification of Ecosystem Services), and a suggested hierarchy that was considered by McInnes *et al*. (2008) – in reality this latter hierarchy was more concerned with working backwards to the potential functions and from these, back to the assets and processes that help provide these functions.

As described above, the nested hierarchy shown in Table D2, partly relates to the both the MEA and work being undertaken for the CICES project (Haines-Young & Potschin, 2010). The CICES project is attempting to build a common classification system which is also consistent with accepted categorisations and conceptualisations and allow the easy translation of statistical information between different applications. Table D3 in Annex D shows the CICES Structure (Haines-Young & Potschin, 2013).

The CICES framework does seem to be emerging as the more established and common framework to use, and was also used recently in the second MAES report (Maes *et al*., 2014). As such it would seem appropriate to adopt its taxonomy and structure within this project and the EFA calculator.

C.3.3. Ecosystem services performance metrics

The CICES framework does not provide a means of quantifying (or even qualifying) ecosystems services. It only provides and taxonomy and hierarchy. The process of quantifying ecosystem services is inherently complicated, if only due to the diversity of goods and services they encompass (as illustrated with the classifications shown in Annex D).

The second MAES report (Maes *et al*., 2014) explores this issue from the perspective of identifying and developing indicators of ecosystem services. The aim is for these indicators to be utilised at the level of Member States to map and assess ecosystem services. These indicators are overlaid on the CICES framework and aim to measure the condition of an ecosystem or the quantity of an ecosystem service at a given CICES level. For example, the following indicators are listed for 'Pollination and seed dispersal':

- Number of pollinator species
- Number of bee hives
- Abundance of pollinators (maps)
- Areas managed for gene conservation
- Pollination potential (maps)
- Surface area of dependent crops
- Honey production (modelling)
- Honey consumption

However, for this project we are not aiming to map and assess ecosystem services being delivered from a farm, but assess the relative functional impact of EFA elements on ecosystem services. This may involve, for example, assessing the benefit of an EFA element with respect to some of the indicators listed above, such as abundance of pollinators, but it is unlikely that absolute quantified numbers can be determined.

In many instances it is likely that expert judgement (based on the evidence gathered in the literature review (Section 2)) will be used to 'score' the relative functional impact. Such approaches have been used before. For example, Cole *et al*. (2009) used a scoring system to assess the delivery ecosystem services by environmental stewardship options. Each option was scored 1 or 2 for low or high impact, positive or negative, whether it was location specific (i.e. needed to be applied in a particular location for that ecosystem service to be delivered) and scored for the degree of confidence (1= low confidence and 2 = high confidence). Figure C.1 shows an extract from one of the matrices that emerged from this process, with stewardship features on the left and ecosystem services across the top, and Green cell = positive impact: Red cell = negative impact; Amber cell = positive and negative impact.

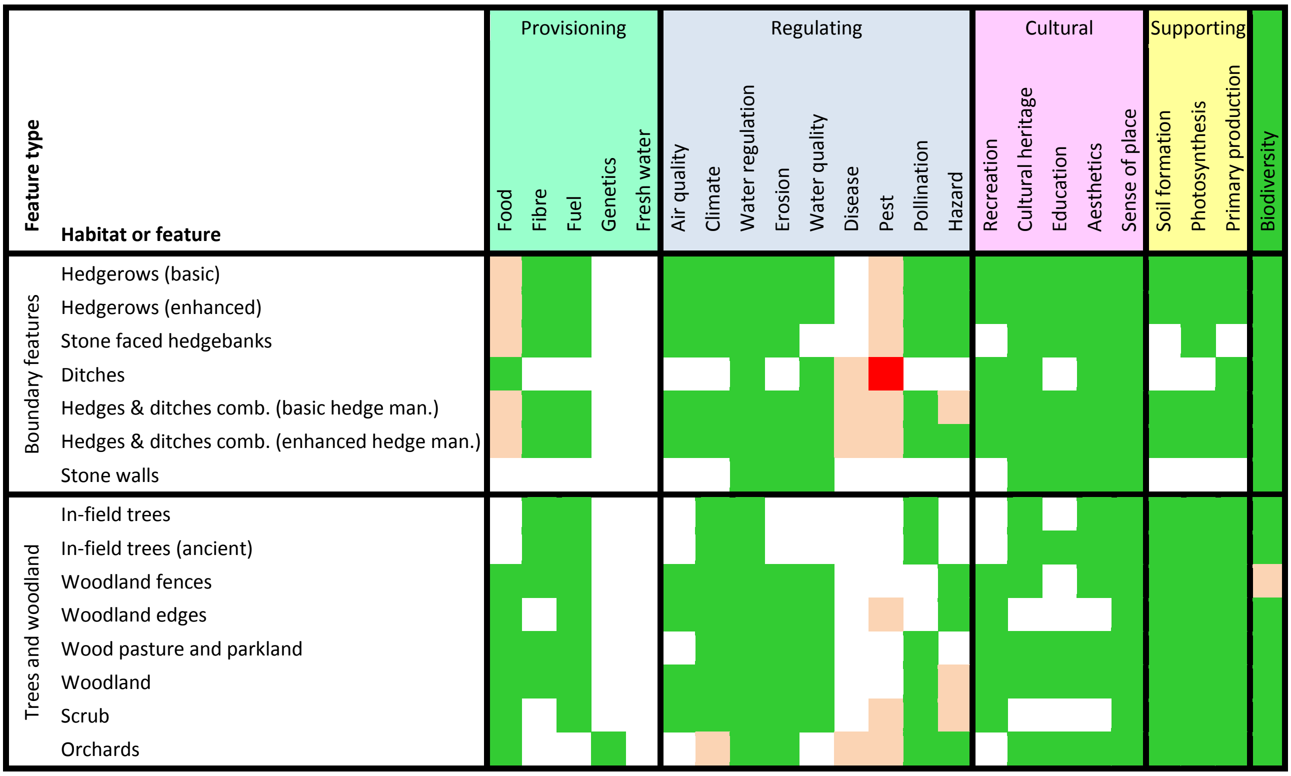


Figure C1: Example matrix of ES impacts on ecosystem service delivery
(Source: Cole *et al*., 2009)

The approach taken by Cole *et al*. (2009) is quite simple, but effective for the purpose it was intended for, i.e. an overview of the potential contribution of a range of features towards a fairly high level classification of ecosystem services (i.e. the MEA classification – see Table D1 in Annex D). However, it is perhaps too simple for the purpose of the EFA calculator. For example:

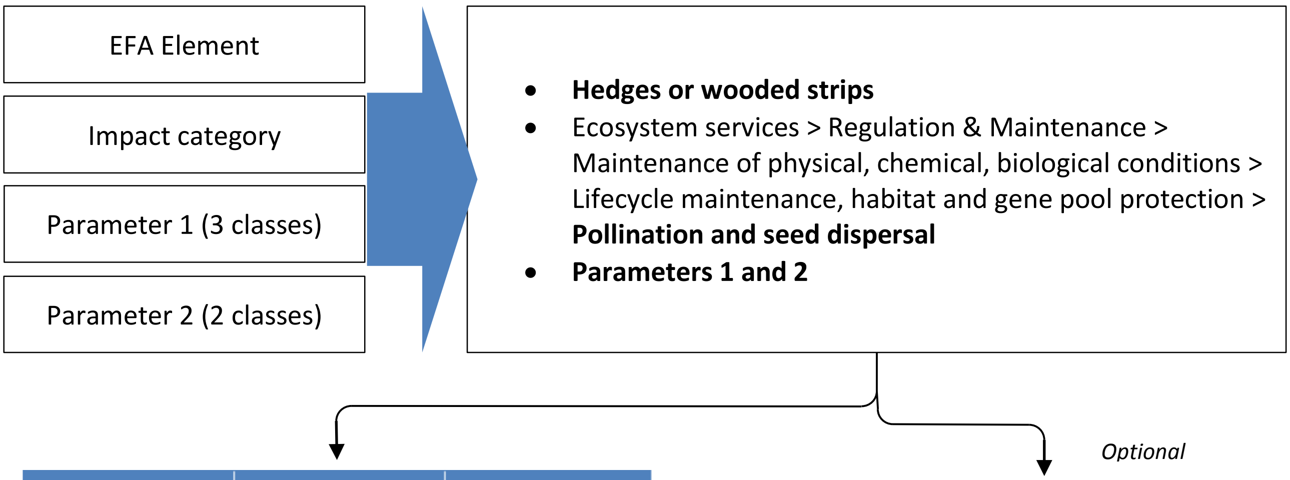
- The evidence gathered in the literature review (Section 2) may be more specific that the resolution offered by the MEA classification;
- The assessment undertaken by Cole *et al*. (2009) was a generic assessment and not a site or farm specific assessment, albeit those features whose benefits were location specific were identified.
- The scoring range of 1 or 2 does not provide the necessary scope to reflect differences in relative functional impact, especially if there are numerous (site-specific) parameters that given rise to that variance, in which case a broader scale would be needed, e.g. 1-100.

There are many more approaches to quantifying ecosystem services (e.g. Bagstad *et al*. (2013) identified 17), some more sophisticated than others. For example, there is the ES matrix model (Burkhard *et al*., 2009; Jacobs *et al*., 2015) which estimates the capacity of a landscape to provide ecosystem services based on land use, land cover, soils, vegetation and biotope data combined with expert estimates. The model consists of a matrix with the ecosystem services as columns and geospatial units as rows. The particular spatial unit's capacity to provide an ecosystem service is estimated at each intersection. This is not dissimilar to the approach of Cole *et al*. (2009), but captured in a model environment and spatially mapped.

More sophisticated approaches include the ARIES (ARtificial Intelligence for Ecosystem Services) model (Balbi *et al*., 2015; Villa *et al*., 2014) that provides a suite of models and applications to map benefits, beneficiaries and ecosystem service flows. However, even these more sophisticated tools tend to rely on indicators (and/or in combination with biophysical models) rather than direct absolute measures. For example, water quality is estimated by combining indicators of nitrate leaching (expressed as average NO_3 concentration in the leachate) and phosphorus losses from the agricultural soil (Balbi *et al*., 2015). It is also acknowledged that the outputs from such tools should be seen as comparative rather than absolute, thus they are also tools for relative impact assessment.

C.3.4. Approach to assessing ecosystem services

A sophisticated modelling approach is beyond the scope and resources of this project. However, an expert-judgement approach, similar to that of Cole *et al*. (2009) or Burkhard *et al*. (2009) and Jacobs *et al*. (2015) is feasible. Such an approach could be applied using the CICES framework and relative function impact scores derived for EFA elements for different variable parameters. There may also be scope (as an option) to calibrate the scoring scale to recognised indicators or absolute values to aid interpretation and transparency, but where this is not possible a simple scoring index can be applied directly. The concept is illustrated in Figure C.2.



Parameter 1	Parameter 2	Impact score
P1C1	P2C1	5
P1C2	P2C1	10
P1C3	P2C1	15
P1C1	P2C2	10
P1C2	P2C2	20
P1C3	P2C2	30

Index value	Absolute value
20	50
40	100
60	150
80	200
100	250

Figure C2: Metrics concept for the relative functional impact on ecosystem services

C.4. Biodiversity

C.4.1. Introduction

The topic of biodiversity, indicators and metrics is huge and has been debated for many decades and there are many different contexts and purposes. It can include: monitoring actual species populations on the ground; the quality and status of habitats; the pressures on species and habitats; metrics at the farm/local level; metrics at landscape or regional level; metrics at national, European or global levels; tools for conservation practitioners; tools for farmers; tools for regulators; and tools for policy makers. For example, Rayment *et al*. (2014) highlight that there are more than 100 metrics used in the USA and over 40 used in

Germany, let alone the rest of the EU. Consequently finding a framework for biodiversity impacts "off the shelf" is more difficult as many may not be fit for purpose for the specified context.

One of the challenges with biodiversity is that it is possible to explore and assess it from multiple perspectives. For example, Duelli and Obrist (2003) state that, in an agricultural context in Europe, the three most important motivations to enhance biodiversity are species conservation; ecological resilience; and biological control of pests. They then explain that depending on the perspective and motivation there are different approaches for selecting indicators and developing indices, i.e. the fitness for purpose will vary on the perspective and motivation and thus no single indicator for biodiversity can be devised. Therefore, the first step is to clarify the context and perspective to be taken within this project with regard to biodiversity, as this will impact upon what tools and techniques may be fit for purpose.

The objective is to assess the relative functional impact of EFA elements with respect to biodiversity. The term biodiversity can have a broad variety of definitions (Kaennel, 1998) ranging from some very strict metrics of biological diversity (such as the Shannon index) through to a very generic term used for any aspect of biological or wildlife conservation. We also need to acknowledge that biodiversity plays an inherently important role in provisioning, regulating and cultural ecosystem services, thus there will be a relationship between the two. However, in this project ecosystem services are being assessed as a separate impact category. Therefore, the main context that this leaves is biodiversity conservation, specifically biodiversity enhancement and maintenance. In the context of biodiversity conservation, EFA elements can be a habitat themselves (e.g. hedgerow); a species (e.g. trees); and/or impact upon the pressure upon species and habitats (e.g. catch crop reducing N loss). However, within the context of biodiversity conservation there is also scope for different interpretations with respect to assessing relative functional impact. For example, the relative functional impact could be in relation to the benefit for specific species or species groups (e.g. birds, mammals, invertebrates, etc.). Alternatively, it could be in terms of biological diversity, i.e. numbers of different species. Although not unconnected, these can be quite different with respect to metrics for assessment.

C.4.2. Biodiversity taxonomy and hierarchy

From a scientific perspective, taxonomies and hierarchies exist for habitats and species. For example, the European Nature Information System (EUNIS) habitat classification (EEA, 2015a; Davies *et al*., 2004) and species groups (EEA, 2015b) and species taxonomic classification (EEA, 2015c). There are also more specific habitat classifications such as those laid out by the JNCC (2010), which are more specific to agro-ecosystems. These do not necessarily provide a hierarchy that can be used for assessing impacts on biodiversity, but they do perhaps provide a common taxonomy.

There are hierarchies that have been developed and used for assessing biodiversity. For example, the Agrobiodiversity Management Yardstick (AMY) developed in the Netherlands (van Amstel *et al*., 2007a & 2007b) and the SOSTARE project (De Paola *et al*., 2011; De Paola, 2012; Paracchini *et al*., 2015). AMY uses a ladder of abstraction to create links between agrobiodiversity policy goals and management measures on a farm. There are four levels of abstraction (see Figure C.3), with the 5th level containing around 140 on-farm management measures that positively affect agrobiodiversity.

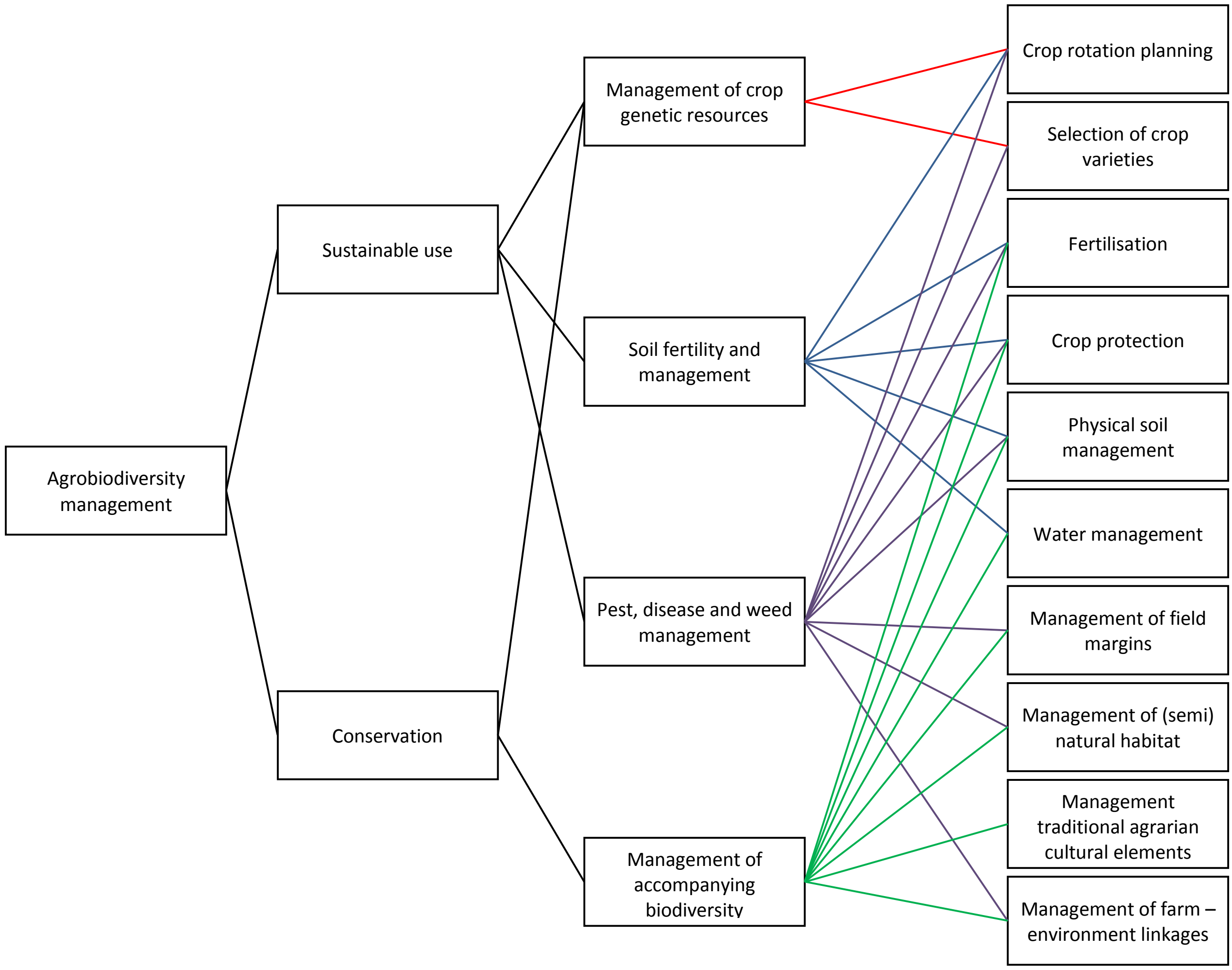


Figure C3: First four levels of abstraction of AMY
(Source: van Amstel *et al*., 2007a)

Similar to AMY, SOSTARE also operates an aggregation process whereby basic indicators are aggregated into pillars, and then into three dimensions (composite indicators) of Agronomy, Economy and Ecology. The indicators for the Ecology dimension, of most relevance to this project, are shown in Table C.1.

Table C1: Ecology indicators in SOSTARE project

Dimension	Sub-dimensions	Basic indicators
Ecology	EL01 Farm natural value	L01 Linear elements
		L02 Patch/area elements
		L03 Spot/point elements
	EL02 Landscape ecology/functional landscape pattern	L04 Indigenous vegetation patches
		L05 Fractal index
		L06 Proximity index

(Derived from De Paola, 2012; Paracchini *et al*., 2015)

Both AMY and SOSTARE where developed for assessing the actual performance of whole farms and not for assessing the potential performance of a single component (such as an EFA element). Consequently their applicability is limited. There is some synergy between the Ecology Pillar in SOSTARE and the EFA elements, e.g. linear, patch and spot elements do relate to EFA elements (e.g. hedges, catch crops and individual trees).

However, other aspects, such as the fractal and proximity indices, do not transpose well as they are reliant on detailed farm survey data and/or GIS and mapping techniques.

Similar to SOSTARE, Quinn *et al*. (2013) use a hierarchy show in Table C.2 to produce a biodiversity score for their Healthy Farm Index (HFI), with the aim that the data needed would be readily available to farmers. However, again the context of this indicator hierarchy is one of whole farm assessment and not a relative functional impact assessment of landscape features or elements.

Table C2: Hierarchy used to generate a biodiversity score for the Healthy Farm Index

Score	Category	Metric
Biodiversity score	Species diversity	Planned vegetation richness
		Livestock richness
		Avian indicator species
		Native/total ratio
	Ecosystem diversity	Richness of landscape elements
		Percent non-crop
		Percent rare landscape elements

Although there are some similarities amongst the tools outlined above, it is clear they are approaching the issue of biodiversity from quite different perspectives. AMY is focused on management measures; SOSTARE on the landscape components; and HFI on diversity. This reflects the different contexts and purposes for which they were developed.

C.4.3. Biodiversity performance metrics

Metrics of performance in relation biodiversity range from the simple to the complex. Quite commonly they involve some degree of subjectivity and expert judgement. For example, AMY used a group of experts to construct 140 on-farm management measures that positively affect agrobiodiversity. These experts also scored each management practice for its efficacy in relation to the positive impact on agrobiodiversity and the extent to which it contributes to conservation and sustainable use of agrobiodiversity.

SOSTARE calculates 'synthetic indicators', from data collected in a farm survey. The synthetic indicators are constructed to allow the evaluation of farm performances through measurable values, which are then converted onto a common index (0-1).

Rayment *et al*. (2014) explored biodiversity metrics in the context of biodiversity offsetting. They identified the main types of metric were species or habitat focused approaches. In relation to the latter, this includes metrics such as area of habitats and then multiplying this value by a standard value and/or the site condition, where a 'standard value' relates to ecological values that typically reflect properties such as their naturalness, species richness and diversity, and rarity; and 'site condition' relates the change in ecological condition.

Some of these 'standard values' could be attributes of EFA elements, e.g. the species richness of hedgerows and thus this could potentially be accounted for in the relative functional impact of that EFA element. However, such attributes are quite generic in nature. Other attributes could be more species specific with respect to their relative functional impact, e.g. large hedges with many trees may favour some bird species, such as thrushes, tits, corvids, and finches, whereas other birds species, such as ground nesting species (red-legged partridge - *Alectoris rufa*, skylark - *Alauda arvensis*, meadow pipit - *Anthus pratensis*) and sparrows may prefer short, treeless hedges (Chamberlain *et al*., 2001).

C.4.4. Approach to assessing biodiversity

It is apparent from the few examples reviewed above, and the broader literature, that assessing biodiversity is highly context specific. As such there is no framework that can be utilised "off the shelf" for this project, as it would not be fit for purpose. It is therefore proposed to derive a relatively simple framework, similar to that used for ecosystem services, but the structure will be driven by the requirements of the EFA calculator and the nature of the evidence gathered in the literature review (Section 2).

There is still a need for a hierarchy to facilitate aggregation. Given that there is no established hierarchy, a structure that facilitates easy interpretation within the EFA calculator would seem the most appropriate approach. Therefore it is proposed to use species groups, such as the EUNIS species groups (EEA, 2015b), as a basis for aggregating data on the relative functional impact of EFA elements (see Figure C.4). There may be scope to have sub-divisions within species groups, but this will be determined by the degree of detail that is interpreted and transformed from the literature review (Section 2).

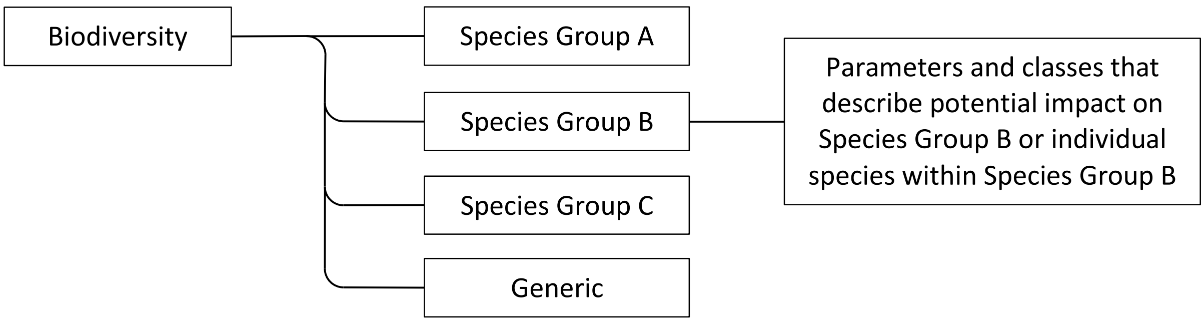


Figure C4: Species group hierarchy concept for biodiversity

Such an approach is outcome focused, i.e. in terms of benefits to the conservation of specific species or species groups. However, in some instances the evidence gathered in the literature review (Section 2) may not be species specific or even species group specific, e.g. the evidence may only relate to specific habitats or it may be generic in nature. Such evidence can be handled in a number of different ways:

- The relative functional impact of the habitat to different species/species groups could be determined
- The relative functional impact could be applied across all species groups
- The relative functional impact could be expressed in a generic category (as shown in Figure C.4)

These options will be explored and tested during the development phase to see which one is the most effective at reflecting relative functional impact.

The process for scoring relative functional impacts would be similar to that for ecosystem services (Figure C.2), i.e. selecting an EFA element, relevant parameters, and deriving a relative performance score based on the evidence gathered in the literature review (Section 2).

This approach does not account for species diversity, other than perhaps the generic category which could account for features and attributes that may support a diverse community species. The possibility for accounting for diversity, e.g. the number of species groups that an EFA impacts upon, was considered. However, it was deemed not very meaningful given the broad-scale nature of the tool and the complex arguments entailed in understanding the benefits of species diversity in different local circumstances.

C.5. Management

C.5.1. Introduction

In some respects the impacts of EFA elements in terms of farm management are simpler. However, on the other hand there is very little, if any, existing scientific literature to draw upon as a basis for assessing impact. The basis of the assessment is more likely to be drawn from management, best practice guides, industry and trade literature, news reports, etc.

With respect to assessing management impacts, the perspective is a slightly different compared to ecosystem services and biodiversity. We are not necessarily assessing the consequential or even functional impact of an EFA element on management, but rather assessing the relative additional burden of managing and maintaining the EFA element as a feature on the farm. This is a subtle difference but an important one (e.g. if an element is protected under GAEC, this element shall not be removed and therefore its presence does not constitute an additional burden to be calculated). However, as with ecosystem services and biodiversity, we are not assessing this impact against a baseline, i.e. we not assessing the cost or effort required to create an EFA feature. The context is one of the feature already exists, and thus the management burden is the effort required to maintain it. With respect to maintenance, this is not just in terms of maintenance to ensure its existence, but to ensure it performs desired functions, and to ensure that it is managed in a way that is compliance with any rules, conditions or restrictions specified by a Member State for that EFA element.

As with ecosystem services and biodiversity, some form of impact taxonomy and hierarchy is required. There is unlikely to be any "of the shelf" frameworks available, but there may be some common categories or terminology that can be utilised. Performance metrics are also required, and this will largely involve using expert judgement to assess the relative burden an EFA element may present within a specific context for the categories identified in the taxonomy and hierarchy.

C.5.2. Management impact taxonomy and hierarchy

The existence of EFA elements on farms will hopefully result in a number of benefits to ecosystem services and biodiversity, as reviewed in Section 2. However, this comes at a cost or burden in terms of management and maintenance. A management impact taxonomy (or impact categories) is required firstly in order to characterise burdens and secondly to facilitate aggregation in the context of the EFA calculator. The following have been identified as potential categories:

- Labour and/or time
- Skills and knowledge
- Frequency
- Economic costs
- Temporal restrictions
- Production

Labour and/or time: This covers the amount of time required in terms of labour (by the farmer and/or farm workers). Some EFA elements will require more time to be invested in the management compared to other EFA elements, thus increasing the burden on the farm.

Skills and knowledge: The level of skills and knowledge required to undertake the tasks required for maintenance (e.g. ranging from basic to expert). Some EFA elements may require a higher level of skills and knowledge compared to other EFA elements. This may mean in some circumstances that specialised skills or knowledge may need to be sought and/or training may be required.

Frequency: How often tasks need to be undertaken (e.g. weekly, monthly, bimonthly, quarterly, annually, every 2 years, etc.). This is connected to labour and time, i.e. it is effectively a multiplier, but there is also the additional burden in tasks that need to be done frequently need to be scheduled into the workload for the farm, thus add to the complexity of scheduling and time management.

Economic costs: This is specifically the capital and annual costs (excluding labour and time) required for maintenance. Labour/time has an economic cost, but this category deals with everything else addition to this, and can be split into capital and annual costs. Capital costs will include investments in any necessary machinery or infrastructure required (e.g. hedge cutting machinery). Annual costs will include the cost of any inputs required for maintenance, e.g. fuel or materials.

Temporal restrictions: This would include date and/or time restriction on activities, e.g. sowing dates, which must be adhered to. These could create a burden on management with respect to scheduling work.

Production: Some EFA elements could potentially impact on production in terms of reduced yields or simply taking land out of production (e.g. fallow land). In this instance the EFA calculator will focus on the amount of land that is taken out of production as a consequence of different EFA elements.

C.5.3. Management impact performance metrics

The categories outlined above will all have their own absolute units of measurement. Labour could be measured in hours, days or months or could be measured in currency, e.g. €10 per hour or per metre; Skills and knowledge may be on a nominal scale (e.g. low, moderate, high or basic through to expert); Frequency may be expressed in time units (e.g. weekly, monthly, bimonthly, quarterly, annually, every 2 years, etc.); Economic costs could expressed in currency or nominally; Temporal restrictions may also be expressed nominally; and Production could be expressed in terms of impact on yield (e.g. tonnes/ha) or nominally. In order to incorporate these into the EFA calculator and allow aggregation they will need to be converted on to a common scale. This could be done using the same approach used for ecosystem services and biodiversity (see Sections C.3 and C.4).

C.5.4. Approach to assessing management burdens

The approach is largely outlined above. Each EFA element will be assessed with respect to the impact categories listed in Section C.5.2 and an impact score assigned accordingly. In some instances the impact score may vary with different parameters, thus as with ecosystem services and biodiversity a range of score will be assigned for the given variable parameters.

With regard to aggregating the scores for the impact categories, each category will be given an equal weighting and the scores aggregated accordingly. However, management burdens may be very farm specific and some of the management impact categories may be more important on one farm compared to another. Additionally, economic costs, for example, could vary significantly across Europe. Therefore it will be important to ensure that users can easily adjust the weights used for the management impact factors so that they appropriately reflect those factors which are of more importance on their farm.

Finally, it should be noted that when assessing burdens this will be viewed as any 'additional' burden that is incurred specifically as a result of EFA. Thus, for example, if a farm is already undertaking management as part of current obligations, e.g. for GAEC or SMR, then this will not be assessed within this framework.

C.6. EFA element combinations and the wider landscape

The framework outlined above has tackled assessing the relative functional impact of individual EFA elements on ecosystem services, biodiversity and management. However, there may be additional benefits if some EFA elements are used in combination, for example if hedgerows or ponds are connected together, as discussed in Sections 2.2 and 2.3. Assessing EFA elements in isolation would not detect such functional benefits and they may end up being overlooked or unaccounted for. To address this, a mechanism and/or set of rules are required to account for the additional functional impact of combinations of EFA elements.

There is limited scope to tackle this issue within the confines of an easy to use EFA calculator. Ideally, EFA elements should be plotted spatially on map and some assessment made of their connectivity and relationship to each other. Spatial mapping is not possible in the EFA calculator thus an alternative approach is required.

One possible approach, which utilises the existing structure of the framework above and the EFA calculator, is for EFA elements to become parameters which affect the relative functional impact of other EFA elements. For example, a hedgerow could be a hedgerow on its own or it could be hedgerow with a buffer strip, i.e. the buffer strip EFA element is a parameter that describes the attributes of the hedgerow EFA element. Similarly, another attribute might be whether the hedgerow is connected to other hedges or habitats such as ponds and woodlands. These are only descriptive attributes, but they offer the opportunity to account for any additional benefits that may arise from combinations and/or connections with other EFA elements and landscape features. Thus, for example, a hedge in isolation may attain a certain score for biodiversity based on its attributes, and then that score may increase if we then extend the attributes to reveal the hedge is connected to other habitats and/or also has a buffer strip.

Annex D. Ecosystem Service Classifications

Table D1: Millennium Ecosystem Assessment ecosystem services classification

Provisioning Services *Products obtained from ecosystems*	**Regulating Services** *Benefits obtained from regulation of ecosystem processes*	**Cultural Services** *Non-material benefits obtained from ecosystems*
• Food • Fresh water • Fuel wood • Fibre • Biochemicals • Genetic resources	• Climate regulation • Disease regulation • Water regulation • Water purification • Pollination	• Spiritual and religious • Recreation & eco-tourism • Aesthetic • Inspirational • Educational • Sense of place • Cultural heritage
Support Services *Services necessary for the production of all other ecosystem services*		
• Soil formation • Nutrient cycling • Primary production		

(Source: MEA, 2003)

Figure D1: Relationship between core ecosystem processes, beneficial processes and benefits
(Source: Balmford *et al*., 2011)

Table D2: CQuEL nested hierarchy of ecosystem services

Service class	Service group	Service type
Provisioning services		
Nutrition	Terrestrial agricultural products	Commercial cropping
		Sustainable cropping
		Commercial animal husbandry
		Sustainable animal husbandry
	Freshwater food production	Commercial aquaculture
		Sustainable freshwater production
	Coastal food production	Commercial aquaculture
		Commercial fisheries
		Sustainable fisheries
	Harvesting from the wild	Non-commercial collection
Fibre/materials	Production of biotic materials	Timber
		Wools and hides
		Natural building materials (thatch/straw)
	Production of abiotic materials	Minerals
Energy	Renewable biotic sources	Biomass/ plant and animal wastes
	Renewable abiotic sources	Wind
		Solar
		Water (hydro)
		Air/ground source
Water	Provision of potable water	Provision of stored water (aquifers/ peats/ reservoirs)
		Provision of river waters
Regulating services		
Regulation of flows	Regulation of erosion	Soil erosion control
		Coastal erosion control
	Regulation of terrestrial water flows	River flood generation control (wider catchment)
		River flood propagation control (within river valleys)
		Aquifer recharge
	Regulation of coastal waters	Coastal flood control
Regulation of physical environment	Climate regulation	Reduction in GHG outputs
		Carbon sequestration
		Carbon storage
		Climate amelioration (modification of local micro-climates)
	Regulation of freshwater quality	Purification of ground water
		Purification of surface water (chemical and ecological quality)
	Regulation of coastal water quality	Purification of estuarine waters
		Purification of coastal waters
	Regulation of air quality	Filtering aerial particulates
	Regulation of soil quality	Build up of soil organic content
Regulation of biotic environment	Pest and disease control	Biological controls
	Maintaining natural lifecycles	Pollination
	Gene pool conservation	Conservation of wild genetic resources
		Conservation of domesticated genetic resources (rare breeds / species)
Cultural services		
Meaningful local places	Sense of place	
	Cultural heritage	
	Education	
	Recreation	
Socially valued landscapes	Aesthetic qualities	
	Inspiration / spiritualism	
	Tranquillity / calm	
	Escapism	

Table D3: CICES Structure

Section	Division	Group	Class	Class type	Examples
Provisioning	Nutrition	Biomass	Cultivated crops	Crops by amount, type	Cereals (e.g. wheat, rye, barely), vegetables, fruits etc.
			Reared animals and their outputs	Animals, products by amount, type	Meat, dairy products (milk, cheese, yoghurt), honey etc.
			Wild plants, algae and their outputs	Plants, algae by amount, type	Wild berries, fruits, mushrooms, water cress, salicornia (saltwort or samphire); seaweed (e.g. Palmaria palmata = dulse, dillisk) for food
			Wild animals and their outputs	Animals by amount, type	Game, freshwater fish (trout, eel etc.), marine fish (plaice, sea bass etc.) and shellfish (i.e. crustaceans, molluscs), as well as equinoderms or honey harvested from wild populations; Includes commercial and subsistence fishing and hunting for food
			Plants and algae from in-situ aquaculture	Plants, algae by amount, type	In situ seaweed farming
			Animals from in-situ aquaculture	Animals by amount, type	In-situ farming of freshwater (e.g. trout) and marine fish (e.g. salmon, tuna) also in floating cages; shellfish aquaculture (e.g. oysters or crustaceans) in e.g. poles
		Water	Surface water for drinking	By amount, type	Collected precipitation, abstracted surface water from rivers, lakes and other open water bodies for drinking
			Ground water for drinking		Freshwater abstracted from (non-fossil) groundwater layers or via ground water desalination for drinking
	Materials	Biomass	Fibres and other materials from plants, algae and animals for direct use or processing	Material by amount, type, use, media (land, soil, freshwater, marine)	Fibres, wood, timber, flowers, skin, bones, sponges and other products, which are not further processed; material for production e.g. industrial products such as cellulose for paper, cotton for clothes, packaging material; chemicals extracted or synthesised from algae, plants and animals such as turpentine, rubber, flax, oil, wax, resin, soap (from bones), natural remedies and medicines (e.g. chondritin from sharks), dyes and colours, ambergris (from sperm whales used in perfumes); Includes consumptive ornamental uses.
			Materials from plants, algae and animals for agricultural use		Plant, algae and animal material (e.g. grass) for fodder and fertilizer in agriculture and aquaculture;
			Genetic materials from all biota		Genetic material (DNA) from wild plants, algae and animals for biochemical industrial and pharmaceutical processes e.g. medicines, fermentation, detoxification; bio-prospecting activities e.g. wild species used in breeding programmes etc.
		Water	Surface water for non-drinking purposes	By amount, type and use	Collected precipitation, abstracted surface water from rivers, lakes and other open water bodies for domestic use (washing, cleaning and other non-drinking use), irrigation, livestock consumption, industrial use (consumption and cooling) etc.
			Ground water for non-drinking purposes		Freshwater abstracted from (non-fossil) groundwater layers or via ground water desalination for domestic use (washing, cleaning and other non-drinking use), irrigation, livestock consumption, industrial use (consumption and cooling) etc.
	Energy	Biomass-based energy sources	Plant-based resources	By amount, type, source	Wood fuel, straw, energy plants, crops and algae for burning and energy production

Section	Division	Group	Class	Class type	Examples
			Animal-based resources		Dung, fat, oils, cadavers from land, water and marine animals for burning and energy production
		Mechanical energy	Animal-based energy	By amount, type, source	Physical labour provided by animals (horses, elephants etc.)
Regulation & Maintenance	Mediation of waste, toxics and other nuisances	Mediation by biota	Bio-remediation by micro-organisms, algae, plants, and animals	By amount, type, use, media (land, soil, freshwater, marine)	Bio-chemical detoxification/decomposition/mineralisation in land/soil, freshwater and marine systems including sediments; decomposition/detoxification of waste and toxic materials e.g. waste water cleaning, degrading oil spills by marine bacteria, (phyto)degradation, (rhizo)degradation etc.
			Filtration/sequestration /storage/accumulation by micro-organisms, algae, plants, and animals	By amount, type, use, media (land, soil, freshwater, marine)	Biological filtration/sequestration/storage/accumulation of pollutants in land/soil, freshwater and marine biota, adsorption and binding of heavy metals and organic compounds in biota
		Mediation by ecosystems	Filtration/sequestration /storage/accumulation by ecosystems	By amount, type, use, media (land, soil, freshwater, marine)	Bio-physicochemical filtration/sequestration/storage/accumulation of pollutants in land/soil, freshwater and marine ecosystems, including sediments; adsorption and binding of heavy metals and organic compounds in ecosystems (combination of biotic and abiotic factors)
			Dilution by atmosphere, freshwater and marine ecosystems		Bio-physico-chemical dilution of gases, fluids and solid waste, wastewater in atmosphere, lakes, rivers, sea and sediments
			Mediation of smell/noise/visual impacts		Visual screening of transport corridors e.g. by trees; Green infrastructure to reduce noise and smells
	Mediation of flows	Mass flows	Mass stabilisation and control of erosion rates	By reduction in risk, area protected	Erosion / landslide / gravity flow protection; vegetation cover protecting/stabilising terrestrial, coastal and marine ecosystems, coastal wetlands, dunes; vegetation on slopes also preventing avalanches (snow, rock), erosion protection of coasts and sediments by mangroves, sea grass, macroalgae, etc.
			Buffering and attenuation of mass flows		Transport and storage of sediment by rivers, lakes, sea
		Liquid flows	Hydrological cycle and water flow maintenance	By depth/volumes	Capacity of maintaining baseline flows for water supply and discharge; e.g. fostering groundwater; recharge by appropriate land coverage that captures effective rainfall; includes drought and water scarcity aspects.
			Flood protection	By reduction in risk, area protected	Flood protection by appropriate land coverage; coastal flood prevention by mangroves, sea grass, macroalgae, etc. (supplementary to coastal protection by wetlands, dunes)
		Gaseous / air flows	Storm protection	By reduction in risk, area protected	Natural or planted vegetation that serves as shelter belts
			Ventilation and transpiration	By change in temperature/humidity	Natural or planted vegetation that enables air ventilation
	Maintenance of physical, chemical, biological conditions	Lifecycle maintenance, habitat and gene pool protection	Pollination and seed dispersal	By amount and source	Pollination by bees and other insects; seed dispersal by insects, birds and other animals
			Maintaining nursery populations and habitats	By amount and source	Habitats for plant and animal nursery and reproduction e.g. seagrasses, microstructures of rivers etc.

Section	Division	Group	Class	Class type	Examples
		Pest and disease control	Pest control	By reduction in incidence, risk, area protected	Pest and disease control including invasive alien species
			Disease control		In cultivated and natural ecosystems and human populations
		Soil formation and composition	Weathering processes	By amount/concentration and source	Maintenance of bio-geochemical conditions of soils including fertility, nutrient storage, or soil structure; includes biological, chemical, physical weathering and pedogenesis
			Decomposition and fixing processes		Maintenance of bio-geochemical conditions of soils by decomposition/mineralisation of dead organic material, nitrification, denitrification etc.), N-fixing and other bio-geochemical processes;
		Water conditions	Chemical condition of freshwaters	By amount/concentration and source	Maintenance / buffering of chemical composition of freshwater column and sediment to ensure favourable living conditions for biota e.g. by denitrification, re-mobilisation/re-mineralisation of phosphorous, etc.
			Chemical condition of salt waters		Maintenance / buffering of chemical composition of seawater column and sediment to ensure favourable living conditions for biota e.g. by denitrification, re-mobilisation/re-mineralisation of phosphorous, etc.
		Atmospheric composition and climate regulation	Global climate regulation by reduction of greenhouse gas concentrations	By amount, concentration or climatic parameter	Global climate regulation by greenhouse gas/carbon sequestration by terrestrial ecosystems, water columns and sediments and their biota; transport of carbon into oceans (DOCs) etc.
			Micro and regional climate regulation		Modifying temperature, humidity, wind fields; maintenance of rural and urban climate and air quality and regional precipitation/temperature patterns
Cultural	Physical and intellectual interactions with biota, ecosystems, and land-/seascapes [environmental settings]	Physical and experiential interactions	Experiential use of plants, animals and land-/seascapes in different environmental settings	By visits/use data, plants, animals, ecosystem type	In-situ whale and bird watching, snorkelling, diving etc.
			Physical use of land-/seascapes in different environmental settings		Walking, hiking, climbing, boating, leisure fishing (angling) and leisure hunting
		Intellectual and representative interactions	Scientific	By use/citation, plants, animals, ecosystem type	Subject matter for research both on location and via other media
			Educational		Subject matter of education both on location and via other media
			Heritage, cultural		Historic records, cultural heritage e.g. preserved in water bodies and soils
			Entertainment		Ex-situ viewing/experience of natural world through different media
			Aesthetic		Sense of place, artistic representations of nature
	Spiritual, symbolic and other interactions with biota, ecosystems, and land-/seascapes [environmental settings]	Spiritual and/or emblematic	Symbolic	By use, plants, animals, ecosystem type	Emblematic plants and animals e.g. national symbols such as American eagle, British rose, Welsh daffodil

Section	Division	Group	Class	Class type	Examples
			Sacred and/or religious		Spiritual, ritual identity e.g. 'dream paths' of native Australians, holy places; sacred plants and animals and their parts
		Other cultural outputs	Existence	By plants, animals, feature/ecosystem type or component	Enjoyment provided by wild species, wilderness, ecosystems, land-/seascapes
			Bequest		Willingness to preserve plants, animals, ecosystems, land-/seascapes for the experience and use of future generations; moral/ethical perspective or belief

Annex E. Parameters and parameter classes

Adjacent trees and woodland

- None
- Some trees and woodland
- Lots of trees and woodland

Adjacent vegetation structure

- Large area (>1ha) of rough grassland, scrub, hedges or woodland
- Small area (<1ha) of rough grassland, scrub, hedges or woodland
- Short closely grazed grassland or arable crops
- Large areas of bare ground

Adjacent water bodies quality

- No adjacent water bodies
- Good (clear water abundant organisms)
- Moderate (clear/partially discoloured, some organisms)
- Poor (Partially discoloured, low number of organisms)
- Very poor (Discoloured/green, negligible organisms)

Adjacent wildlife corridors

- Diverse and complete linear features
- Uniform linear features with gaps
- No linear features

Age of wall (time since construction/repair)

- New (1-5 years)
- Moderate (6-15 years)
- Old (>15 years)

Agroforestry species

- *Abies spp.* (Fir)
- *Acer spp.* (Maple)
- *Aesculus hippocastanum* (Horse chestnut)
- *Alnus spp.* (Alder)
- *Betula spp.* (Birch)
- *Buxus spp.* (Box)
- *Carpinus spp.* (Hornbeam)
- *Castanea sativa* (Sweet chestnut)
- *Cedrus spp.* (Cedar)
- *Corylus spp.* (Hazel)
- *Eucalyptus spp.* (Eucalyptus)
- *Fagus sylvatica* (Beech)
- *Fraxinus spp.* (Ash)
- *Ilex spp.* (Holly)
- *Juglans nigra* (Walnut)
- *Larix spp.* (Larch)
- *Malus sylvestris* (Crab apple)

- *Morus* (Mulberry)
- *Picea spp.* (Spruce)
- *Pinus spp.* (Pine)
- *Platanus* (Plane)
- *Populus spp.* (Poplar)
- *Prunus avium* (Wild cherry)
- *Prunus spinosa* (Blackthorn)
- *Quercus spp.* (Oak)
- *Robinia* (Back locust)
- *Salix spp.* (Willow)
- *Sorbus aucuparia* (Rowan)
- *Taxus baccata* (Yew)
- *Tilia spp.* (Lime)
- *Ulmus spp.* (Elm)

Annual rainfall

- Very high (>765 mm)
- High (646-765 mm)
- Moderate (533-646 mm)
- Low (451-533 mm)
- Very low (<451 mm)

Aquatic vegetation cover

- 0 to 10%
- 10 to 20%
- 20 to 30%
- 30 to 40%
- 40 to 50%
- 50 to 60%
- 60 to 70%
- 70 to 80%
- 80 to 90%
- 90 to 100%

Are sediments removed by dredging

- Yes
- No

Areas of open water

- Yes
- No

Average retention time

- Very long
- Long
- Moderate
- Short
- Very short

Bank vegetation cutting period

- Before seed setting
- After seed setting
- Unknown

Buffer strip adjacent

- Yes
- No

Buffer width

- < 2 m
- 2 to 10 m
- 10 to 25 m
- > 25m

Buffering capacity of soils & rocks

- Very low (e.g. peats)
- Low (acidic soils and/or rocks)
- Moderate (others)
- Moderate to high (e.g. clay rich soils)
- High (e.g. containing considerable calcium carbonate)

Catch/cover crop species 1

- *Medicago* (Alfalfa)
- *Secale cereale* (Rye)
- *Phacelia tanacetifolia* (Phacelia)
- *Hordeum vulgare* (Barley)
- *Brassica juncea* (Leaf mustard)
- *Avena sativa* (Oats)
- *Lolium (perenne, multiflorum)* (Ryegrass)
- *Lupinus spp* (Lupin)
- *Brassica napus* (Rapeseed)
- *Raphanus sativus subsp. Oleiferus* (Fodder radish)
- *Fagopyrum esculentum* (Buckwheat)
- *Festulolium* (Festulolium)
- *Avena strigosa* (Lopsided Oat)
- *Trifolium alexandrinum* (Egyptian clover)
- *Trifolium pratense* (Red clover)
- *Trifolium spp.* (Clover species)
- *Borago officinalis* (Borage)
- *Sinapis alba* (White mustard)
- *Brassica rapa* (Turnip Rape)
- *Raphanus sativus subsp. Niger* (Black radish)
- *Sorghum bicolor* (Sorghum)
- *Tagetes spp.* (Tagetes)
- *Vicia sativa* (Common vetch)
- *Eruca sativa* (Salad rocket)
- *Vicia faba* (Faba bean)
- *Viccia spp.* (Vetch)
- *Triticum aestivum* (Common wheat)

- *Triticosecale* (Triticale)
- *Lathyrus sativus* (Grass pea)
- *Pisum spp* (Pea)
- *Trifolium incarnatum* (Crimson clover)
- *Trifolium resupinatum* (Persian clover)
- *Camelina sativa* (Camelina)
- *Linum usitatissimum* (Linseed)
- *Guizotia abyssinica* (Niger)
- *Trifolium repens* (White clover)
- *Sorghum sudanense* (Sudan grass)
- *Festuca spp.* (Fescue)
- *Poa spp.* (Meadow grass)
- *Brassica nigra* (Black mustard)
- *Setaria italica* (Foxtail millet)
- *Coriandrum sativum* (Coriander)
- *Festuca rubra* (Red fescue)
- *Crambe abyssinica* (Abyssinian kale)
- *Dactylis glomerata* (Cock's foot)
- *Phalaris canariensis* (Canary grass)
- *Lupinus arboreus* (Yellow lupin)
- *Helianthus annuus* (Sunflower)
- *Hyacinthoides non-scripta* (Bluebell)
- *Carthamus tinctorius* (Safflower)
- *Vicia pannonica* (Pannonian vetch)
- *Bromus spp.* (Brome)
- *Lepidium sativum* (Garden cress)
- *Phleum pratense* (Timothy grass)
- *Zea spp.* (Maize)
- *Poa trivialis* (Rough meadow-grass)
- *Brassica oleracea* (Kale)
- *Trigonella foenum-graecum* (Fenugreek)
- *Lotus spp.* (Birds foot-trefoil)
- *Lens spp* (Lentil)
- *Cicer spp* (Chickpea)
- *Onobrychis spp* (Sainfoin)
- *Glycine spp* (Soybean)
- *Melilotus spp* (Sweet Clover)
- *Lolium x boucheanum* (Hybrid ryegrass)
- *Sorghum bicolor x Sorghum sudanese* (Hybrid sorghum)
- *Crotalaria juncea* (Sunn hemp)
- *Lathyrus latifolius* (Everlasting pea)
- *Lupinus albus* (White lupin)
- *Lupinus angustifolius* (Blue lupin)
- *Lupinus luteus* (Annual yellow-lupin)
- *Medicago lupulina* (Black medick)
- *Medicago scutellata* (Snail medick)
- *Ornithopus sativus* (Serradella)
- *Trifolium hybridum* (Alsike clover)
- *Trifolium squarrosum* (Squarrose clover)
- *Trifolium subterraneum* (Subterranean clover)
- *Trifolium michelianum* (Balansa clover)
- *Trifolium vesiculosum* (Arrowleaf clover)
- *Trigonella caerula* (Blue fenugreek)
- *Vicia villosa* (Hairy vetch)
- *Beta vulgaris* (Beet)
- *Brassica carinata* (Ethiopian mustard)
- *Centaurea cyanus* (Cornflower)
- *Crepis spp.* (Hawksbeard)

- *Daucus carota* (Wild carrot)
- *Dipsacus spp.* (Teasel)
- *Echium vulgare* (Viper's Bugloss)
- *Foeniculum vulgare* (Fennel)
- *Galium verum* (Lady's Bedstraw)
- *Hypericum perforatum* (Perforate St John's-wort)
- *Lamium spp.* (Deadnettle)
- *Leucanthemum vulgare* (Ox-eye daisy)
- *Malva spp.* (Mallow)
- *Oenothera spp.* (Evening primrose)
- *Origanum spp.* (Marjoram and oregano)
- *Papaver rhoeas* (Common poppy)
- *Petroselinum crispum* (Parsley)
- *Plantago lanceolata* (English plantain)
- *Prunella spp.* (Selfheal)
- *Reseda spp.* (Dyers Rocket)
- *Salvia pratensis* (Meadow clary)
- *Sanguisorba spp.* (Burnet)
- *Silene spp.* (Campion)
- *Silybum marianum* (Milk thistle)
- *Tanacetum vulgare* (Tansy)
- *Verbascum spp.* (Mullein)
- *Agrostemma githago* (Common corn-cockle)
- *Anethum graveolens* (Dill)
- *Calendula officinalis* (Pot marigold)
- *Carum carvi* (Caraway)
- *Nigella spp.* (Nigella)
- *Spinacia spp.* (Spinach)
- *Festuca pratensis* (Meadow fescue)
- *Malva silvestris* (Common mallow)
- *Onobrychis viciifolia* (Common sainfoin)
- *Poa pratensis* (Smooth meadow-grass)
- *Festuca arundinacea* (Tall fescue)
- *Spergula arvensis* (Corn spurrey)
- *Festuca ovina* (Sheep's fescue)
- *Agrostis stolonifera* (Creeping bentgrass)
- *Agrostis capillaris* (Common bent)
- *Poa palustris* (Fowl meadowgrass)
- *Anthyllis vulneraria* (Common kidneyvetch)
- *Galega orientalis* (Fodder galega)
- *Medicago falcata* (Blue alfalfa)
- *Cichorium intybus* (Chicory)
- *Grass* (undersown in previous crop)
- *Cruciferae* (Cruciferous crops)S

Catch/cover crop species 2

As above

CC species groups 1

- Amaranthaceae
- Apiaceae (Umbelliferae)
- Other
- Boraginaceae
- Brassicaceae
- Caprifoliaceae (honeysuckle)

- Fabaceae - Vicia fabae
- Fabaceae - other
- Lamiaceae
- Plantaginaceae
- Poaceae (grass)
- Poaceae (grass) - cereal
- Zea spp. (Maize)

CC species groups 2

As above

Clearing ditch vegetation frequency

- Very frequent
- Frequent
- Moderately frequent
- Infrequent
- Very infrequent

Condition of wall

- Good
- Moderate (some repair needed)
- Poor (derelict)

Deadwood present

- Yes
- No

Density of hedgerow trees

- None
- Low
- Moderate
- High

Depth of impermeable layer beneath buffer strip

- Very deep
- Deep
- Moderate
- Shallow
- Very shallow

Disposal of cut weeds

- Left on the ditch margins
- Removed from the immediate ditch area
- Fully removed

Disposal of dredged sediment

- Left on the ditch margins
- Removed from immediate ditch area
- Fully removed

Distance to closest source of wild plants

- >25m
- <25m

Distribution density of adjacent water bodies

- >1.3 per km^2
- 1 per km^2
- 0.5 per km^2
- 0.1 per km^2
- None

Ditch vegetation clearance equipment

- Mowing-drum
- Ditch-scoop
- Mowing-basket
- Unknown

Ditches are a traditional feature of local area

- Yes
- No

Diversity of tree species

- Strict monoculture
- Limited mixture
- Moderate mixture
- Diverse mixture
- Very diverse mixture

Dredging machine

- Pull-shovel
- Punched pull-shovel
- Suction pipe
- Unknown

Dredging of ditch sediments

- Not dredged
- Infrequent dredging
- Intermittent dredging
- Regular dredging
- Very regular dredging

Ducks present

- Yes
- No

Ecological zone

- Temperate oceanic forest
- Temperate continental forest
- Temperate mountain
- Boreal coniferous forest
- Boreal mountain
- Sub-tropical dry forest
- Sub-tropical mountain
- Temperate steppe

Erosion risk in catchment

- Low
- Moderate
- High

Fallow baseline

- Arable
- Vineyard

Feature has infrastructure for visitors

- Yes
- No

Feature is a significant component in the local landscape

- Yes
- No

Feature is on, or adjacent to, arable land

- Yes
- No

Field managed to reduce erosion

- Yes
- No

Field size

- <10ha
- >=10ha

Floral diversity

- Low
- Moderate
- High

Form of the bank

- Very steep
- Steep
- Moderate
- Shallow
- Very shallow

General flow rate in ditch

- Very low
- Low
- Moderate
- High
- Very high

General nutrient status

- High
- Moderate
- Low

Gradient

- <=4% (effectively flat)
- 5-10%
- 10 to 20%
- 20 to 30%
- 30 to 40%
- 40 to 50%
- >50%

Ground cover

- None (bare soil)
- Natural regeneration
- Sown wildflower
- Sown bird seed mix
- Sown grass only
- Arable crop

Ground cover (fallow)

- None (bare soil)
- Natural regeneration
- Sown bird seed mix
- Sown wildflower
- Sown grass only

Ground cover (in woods)

- Very sparse
- Sparse
- Moderate
- Good
- Very good

Ground cover at base of hedge

- Poor (bare)
- Moderate (partial)
- High

Ground under canopy is cultivated

- Yes
- No

Hedge height

- Tall
- Moderate
- Short

Hedgerow adjacent

- Yes
- No

Hedgerow cutting frequency

- Every year
- Every 2 years
- Every 3 years (or more)

Hedgerow cutting season

- Winter
- Spring
- Summer
- Autumn

Hedgerow is part of a green lane

- Yes
- No

Hedges are a traditional feature of local area

- Yes
- No

Herbaceous vegetation in woodland edge

- Herbaceous vegetation limited
- Moderate herbaceous vegetation
- Considerable herbaceous vegetation

High sulphate soil additions

- Yes
- No

Hydraulic conductivity of the soil

- Very high
- High
- Moderate
- Low
- Very low

Intermittent periods of ditch drying

- Yes
- No

Level of grazing

- Low
- Moderate
- High
- Very high

Level of shading by bank vegetation

- 0 to 10%
- 10 to 20%
- 20 to 30%
- 30 to 40%
- 40 to 50%
- 50 to 60%
- 60 to 70%
- 70 to 80%
- 80 to 90%
- 90 to 100%

Level of structural variability

- Highly varied structure
- Moderate to highly varied structure
- Moderately varied structure
- Some structural variability
- Limited structural variability

Lichens present

- Yes
- No

Livestock access to ditch bank

- Direct access
- No access/No livestock

Local area context

- Local area largely forested
- Local area largely unforested
- Other

Low-grade weirs/small dams in ditch

- Yes (and sediments periodically removed)
- Yes (sediments not removed)
- No

Mature trees with basal hollows

- Yes
- No

Mean annual precipitation

- <1000 mm
- 1000-1250 mm
- 1250-1500 mm
- >1500 mm

Mean annual temperature

- <-10 °C
- -10 to -5 °C
- -5 to 0 °C
- 0 to 5 °C
- 5 to 10 °C
- 10 to 15 °C
- 15 to 20 °C
- >20 °C

Natural water table and hydroperiod maintained

- Yes
- No

Nitrogen fixing crop species

- *Medicago* (Alfalfa)
- *Phaseolus spp.* (Bean)
- *Vigna spp.* (Bean)
- *Ornithopus spp* (Bird's-foot)
- *Lotus spp.* (Birds foot-trefoil)
- *Cicer spp* (Chickpea)
- *Trifolium spp.* (Clover species)
- *Coronilla varia* (Crown vetch)
- *Dolichos lala* (Dolichos)
- *Vicia faba* (Faba bean)
- *Trigonella foenum-graecum* (Fenugreek)
- *Hedysarum coronarium* (French honeysuckler)
- *Galega* (Galega (Goat's rue))
- *Anthyllis* (Kidney vetch)
- *Lens spp* (Lentil)
- *Glycyrrhiza glabra* (Liquorice)
- *Lupinus spp* (Lupin)
- *Pisum spp* (Pea)
- *Arachis* (Pinut)
- *Onobrychis spp* (Sainfoin)
- *Glycine spp* (Soybean)
- *Melilotus spp* (Sweet Clover)
- *Viccia spp.* (Vetch)
- *Lathyrus* (Vetchlings)

Number of connected aquatic habitats

- None
- One
- Two
- Three to five
- Six or more

Number of connected terrestrial linear habitats

- None
- One
- Two
- Three to five
- Six or more

Number of other habitats connected to hedge

- None
- One
- Two
- Three
- Four or more

Number of ponds present

- One
- Two to three

- Four to five
- Six to seven
- More than seven

Number of visitors

- None
- Low
- Moderate
- High

Old trees or buildings present within 1 km²

- Yes
- No

Overhanging vegetation on the bank

- Yes
- No

Pesticides sprayed on adjacent field

- Yes
- No

Pond catchment land use

- Extensive grassland
- Intensive grassland
- Extensive arable
- Intensive arable

Pond catchment proportion agriculture

- 0 to 10%
- 10 to 20%
- 20 to 30%
- 30 to 40%
- 40 to 50%
- 50 to 60%
- 60 to 70%
- 70 to 80%
- 80 to 90%
- 90 to 100%

Pond is part of a series

- Not in a series (isolated)
- First in series
- Second in series
- Third in series
- Fourth or more in series

Pond shape

- Very regular
- Regular
- Moderately irregular
- Irregular
- Very irregular

Pond size

- Very large
- Large
- Moderate
- Small
- Very small

Pond stocked with fish

- Yes
- No

Pond substrate

- Natural
- Concrete or plastic

Pond water source

- Groundwater
- River or stream
- Surface flow (intensive agriculture)
- Surface flow (extensive agriculture)
- Unknown

Porosity

- High porosity
- Moderate porosity
- Low porosity

Presence of fruit bearing plants

- High
- Moderate
- Low

Presence of in-ditch vegetation

- Very high
- High
- Moderate
- Low
- Very low

Presence of open spaces

- Low
- Moderate
- High

Presence of pollen bearing plants

- High
- Moderate
- Low

Previous land use

- Arable
- Grassland

Proximity to other aquatic habitats

- Low
- Moderate
- High

Proximity to other woodland/forest areas

- Low
- Moderate
- High

Regional water stress

- None
- Low
- Moderate
- High
- Very high

Regulatory context

- GAEC1, SMR1 or SMR10
- Other

Removal of accumulated pollutants

- Yes
- No

Risk of acid deposition

- High
- Moderately high
- Moderate
- Low

- Very low
- None
- Unknown

Risk of N deposition

- High
- Moderately high
- Moderate
- Low
- Very low
- None
- Unknown

Risk of overland flow becoming concentrated

- Low
- Moderate
- High

Sensitive features downwind

- Yes
- No

Shelterbelt height

- Tall
- Moderate
- Short

Short rotation coppice species

- *Alnus spp.* (Alder)
- *Fraxinus spp.* (Ash)
- *Robinia* (Back locust)
- *Betula spp.* (Birch)
- *Ulmus spp.* (Elm)
- *Eucalyptus spp.* (Eucalyptus)
- *Corylus spp.* (Hazel)
- *Carpinus spp.* (Hornbeam)
- *Tilia spp.* (Lime)
- *Acer spp.* (Maple)
- *Morus* (Mulberry)
- *Quercus spp.* (Oak)
- *Platanus* (Plane)
- *Populus spp.* (Poplar)
- *Sorbus aucuparia* (Rowan)
- *Castanea sativa* (Sweet chestnut)
- *Juglans nigra* (Walnut)
- *Prunus avium* (Wild cherry)
- *Salix spp.* (Willow)

Slope

- Flat
- Moderate
- Steep

Soil texture

- Coarse
- Medium
- Medium fine
- Fine
- Very fine

South aspect

- >75% faces south
- 50-75% faces south
- 25-50% faces south
- <25% faces south

Stonewall has a north-facing side

- Yes
- No

Stonewall material

- Limestone
- Other

Stonewalls are a traditional feature of local area

- Yes
- No

Sub-surface drains under buffer strip

- Yes
- No

Terraces are a traditional feature of local area

- Yes
- No

Terraces are regularly maintained

- Yes
- No

Time of dredging

- Summer
- Other

Topography

- Banks, ridges, hollows or hummocks
- Mostly uniform

Tree maintenance period

- Jan-Mar
- Apr-Jun
- Jul-Sep
- Oct-Dec

Tree species

- All native species
- Mainly native species
- Mix of native and exotic species
- Mainly exotic species
- All exotic species

Typical stone wall maintenance period

- Aug to Oct
- Nov to Jan
- Feb to Apr
- May to Jul

Variety of neighbouring ponds

- No neighbouring ponds
- All similar
- Limited variety
- Moderately varied
- Varied
- Very varied

Vegetation clearance period

- Spring
- Summer
- Autumn
- Winter
- Unknown

Vegetation density

- None
- Low
- Moderate

- High

Vegetation height

- Low
- Moderate
- High

Veteran/ancient trees

- Yes
- No

Water bodies downwind

- Yes
- No

Water status

- Wet except under drought conditions
- Periodically dry

Waterbody depth

- Mainly deep water
- Mainly shallow water
- Variety of depths
- Large variety of depths

Woodland age (years)

- 1 to 5
- 6 to 10
- 11 to 15
- 16 to 20
- 21 to 25
- >26

Woodland commercially harvested

- Yes
- No

Woodland edge profile

- 1 step edges
- 2 step edges
- 3 step edges

Woodland edge shape

- Straight and uniform

- Straight and variable
- Curvy and uniform
- Curvy and variable

Woodland edge vegetation density

- Sparse
- Intermediate
- Dense

Woodland edge width

- None
- Narrow (<10m)
- Wide (>10m)

Woodland location

- Field edge
- Within field

Woodland type

- Coniferous
- Eucalypts
- Broadleaved
- Broadleaved-coniferous mix

Years since dredging

- 1 year
- 2 years
- 3 years
- 4+ years

Annex F. Detailed hypothetical farm scenarios

Case study 01

Description: A large flat arable farm in south of Croatia, near the coast, characterised by a number of ditches and lines and trees and hedgerows.

Parameter	Value
Member state:	Croatia
Farm size (ha):	585
Arable area (ha)	565.2
Soil texture	Medium
Annual rainfall	1250-1500 mm
Risk of acid deposition	None
Risk of N deposition	Low
Ecological zone	Sub-tropical dry forest
Mean annual temperature	10 to 15 °C
Regional water stress	Moderate
Contribution of existing features to EFA:	1.3%

Existing features:

- Hedges or wooded strips (3)
- Trees in line (2)
- Ponds (1)
- Ditches (6)

Impact assessment:

Ecosystem services: The positive impacts are relatively moderate. The majority of the positive impacts come from:

- Water conditions
- Liquid flows
- Intellectual and representative interactions
- Lifecycle maintenance, habitat and gene pool protection

Biodiversity: The positive impacts are relatively moderate. The majority of the positive impacts come from:

- Birds: All
- Invertebrates: All
- Mammals: All
- Amphibians

Management: There are some negative impacts, which are relatively very low. The majority of the negative impacts come from:

- Labour

Suggested EFA options (default criteria):

1. Short rotation coppice

2. Nitrogen fixing crops
3. Catch crops or green cover
4. Land strips (other)
5. Woodland
6. Isolated trees
7. Ponds
8. Fallow land
9. Trees in line
10. Hedges or wooded strips
11. Land strips (adjacent/parallel to water)
12. Ditches
13. Traditional stone walls

Suggested features (all):

1. Agroforestry
2. Short rotation coppice
3. Nitrogen fixing crops
4. Catch crops or green cover
5. Land strips (other)
6. Woodland
7. Isolated trees
8. Ponds
9. Fallow land
10. Trees in line
11. Hedges or wooded strips
12. Land strips (adjacent/parallel to water)
13. Ditches
14. Traditional stone walls
15. Terraces

Notes: All hedges are two wide for EFA, Pond is too big for EFA, one ditch is two wide for EFA.

Case study 02

Description: A small arable farm in a valley with a moderate slope on the western side of Cyprus, with no water bodies on or adjacent to the farm.

Parameter	Value
Member state:	Cyprus
Farm size (ha):	67.3
Arable area (ha)	64.3
Soil texture	Fine
Annual rainfall	<451 mm
Risk of acid deposition	None
Risk of N deposition	Very low
Ecological zone	Sub-tropical dry forest
Mean annual temperature	>20 °C
Regional water stress	Very high
Contribution of existing features to EFA:	5.3%

Existing features:

- Trees in a line (6)
- Agroforestry (2)
- Garrigue (1)

Impact assessment:

Ecosystem services: The positive impacts are relatively low. The majority of the positive impacts come from:

- Lifecycle maintenance, habitat and gene pool protection

There are also some negative impacts, which are relatively low. The majority of the negative impacts come from:

- Water conditions

Biodiversity: The positive impacts are relatively low. The majority of the positive impacts come from:

- Invertebrates: All
- Mammals: All
- Birds: All

Suggested EFA options (default criteria):

1. Nitrogen fixing crops
2. Agroforestry
3. Woodland
4. Fallow land
5. Land strips (adjacent/parallel to water)

Suggested features (all):

1. Short rotation coppice
2. Nitrogen fixing crops

3. Terraces
4. Catch crops or green cover
5. Land strips (other)
6. Agroforestry
7. Woodland
8. Isolated trees
9. Hedges or wooded strips
10. Ponds
11. Ditches
12. Trees in line
13. Fallow land
14. Land strips (adjacent/parallel to water)
15. Traditional stone walls

Notes: None

Case study 03

Description: A moderately sized flat arable farm in the east of Denmark. A few minor water bodies on the farm and located next to a fjord.

Parameter	Value
Member state:	Denmark
Farm size (ha):	585
Arable area (ha)	569.8
Soil texture	Coarse
Annual rainfall	533-646 mm
Risk of acid deposition	Low
Risk of N deposition	Moderate
Ecological zone	Temperate oceanic forest
Mean annual temperature	5 to 10 °C
Regional water stress	Very high
Contribution of existing features to EFA:	0.4%

Existing features:

- Hedges or wooded strips (5)
- Woodland (5)
- Ponds (2)
- Land strips (adjacent/parallel to water) (2)

Impact assessment:

Ecosystem services: The positive impacts are relatively moderate. The majority of the positive impacts come from:

- Atmospheric composition and climate regulation
- Intellectual and representative interactions
- Lifecycle maintenance, habitat and gene pool protection

There are also some negative impacts, which are relatively moderate. The majority of the negative impacts come from:

- Provision of water for as a material
- Provision of water for nutrition

Biodiversity: The positive impacts are relatively moderate. The majority of the positive impacts come from:

- Terrestrial plants: All
- Fungi
- Biodiversity (general)
- Birds: All
- Invertebrates: All

Management: There are some negative impacts, which are relatively very low. The majority of the negative impacts come from:

- Labour

Suggested EFA options (default criteria):

1. Short rotation coppice
2. Catch crops or green cover
3. Ponds
4. Fallow land
5. Land strips (adjacent/parallel to water)

Suggested features (all):

1. Agroforestry
2. Short rotation coppice
3. Nitrogen fixing crops
4. Catch crops or green cover
5. Land strips (other)
6. Isolated trees
7. Ditches
8. Trees in line
9. Ponds
10. Fallow land
11. Hedges or wooded strips
12. Woodland
13. Traditional stone walls
14. Land strips (adjacent/parallel to water)
15. Terraces

Notes: None

Case study 04

Description: An arable farm in the central region of France. A largely flat area with a few minor water bodies on the farm and some larger water bodies (lakes) in the surrounding area.

Parameter	Value
Member state:	France
Farm size (ha):	229
Arable area (ha)	207.6
Soil texture	Fine
Annual rainfall	646-765 mm
Risk of acid deposition	None
Risk of N deposition	Moderate
Ecological zone	Temperate oceanic forest
Mean annual temperature	10 to 15 °C
Regional water stress	Moderate
Contribution of existing features to EFA:	4.3%

Existing features:

- Hedges or wooded strips (9)
- Woodland (4)
- Ponds (1)
- Land strips (other) (5)

Impact assessment:

Ecosystem services: The positive impacts are relatively moderate. The majority of the positive impacts come from:

- Atmospheric composition and climate regulation
- Lifecycle maintenance, habitat and gene pool protection
- Liquid flows

There are also some negative impacts, which are relatively moderate. The majority of the negative impacts come from:

- Water conditions
- Mass flows

Biodiversity: The positive impacts are relatively moderate. The majority of the positive impacts come from:

- Terrestrial plants: All
- Invertebrates: All
- Fungi
- Biodiversity (general)

Management: There are some negative impacts, which are relatively very low. The majority of the negative impacts come from:

- Labour

Suggested EFA options (default criteria):

1. Agroforestry
2. Short rotation coppice
3. Nitrogen fixing crops
4. Catch crops or green cover
5. Traditional stone walls
6. Isolated trees
7. Land strips (other)
8. Hedges or wooded strips
9. Ponds
10. Trees in line
11. Ditches
12. Fallow land
13. Land strips (adjacent/parallel to water)
14. Woodland
15. Terraces

Suggested features (all):

1. Agroforestry
2. Short rotation coppice
3. Nitrogen fixing crops
4. Catch crops or green cover
5. Traditional stone walls
6. Isolated trees
7. Land strips (other)
8. Hedges or wooded strips
9. Ponds
10. Trees in line
11. Ditches
12. Fallow land
13. Land strips (adjacent/parallel to water)
14. Woodland
15. Terraces

Notes: None

Case study 05

Description: A large flat arable farm in south-east Germany with a few minor water bodies on or adjacent to the farm.

Parameter	Value
Member state:	Germany
Farm size (ha):	844
Arable area (ha)	811
Soil texture	Medium
Annual rainfall	451-533 mm
Risk of acid deposition	Low
Risk of N deposition	Moderate
Ecological zone	Temperate continental forest
Mean annual temperature	5 to 10 °C
Regional water stress	Moderate
Contribution of existing features to EFA:	3.7%

Existing features:

- Hedges or wooded strips (2)
- Woodland (3)
- Ditches (1)

Impact assessment:

Ecosystem services: The positive impacts are relatively moderate. The majority of the positive impacts come from:

- Intellectual and representative interactions
- Atmospheric composition and climate regulation
- Liquid flows

There are also some negative impacts, which are relatively moderate. The majority of the negative impacts come from:

- Water conditions
- Mass flows

Biodiversity: The positive impacts are relatively moderate. The majority of the positive impacts come from:

- Fungi
- Biodiversity (general)
- Birds: All
- Terrestrial plants: All

Management: There are some negative impacts, which are relatively very low. The majority of the negative impacts come from:

- Labour

Suggested EFA options (default criteria):

1. Agroforestry
2. Short rotation coppice
3. Nitrogen fixing crops
4. Catch crops or green cover
5. Land strips (other)
6. Traditional stone walls
7. Isolated trees
8. Hedges or wooded strips
9. Ponds
10. Trees in line
11. Ditches
12. Fallow land
13. Land strips (adjacent/parallel to water)
14. Woodland
15. Terraces

Suggested features (all):

1. Agroforestry
2. Short rotation coppice
3. Nitrogen fixing crops
4. Catch crops or green cover
5. Land strips (other)
6. Traditional stone walls
7. Isolated trees
8. Hedges or wooded strips
9. Ponds
10. Trees in line
11. Ditches
12. Fallow land
13. Land strips (adjacent/parallel to water)
14. Woodland
15. Terraces

Notes: Dominated by a large block of woodland.

Case study 06

Description: A large flat arable farm in north-east Germany with a few minor water bodies on or adjacent to the farm, including a few ditches.

Parameter	Value
Member state:	Germany
Farm size (ha):	1033
Arable area (ha)	999
Soil texture	Coarse
Annual rainfall	533-646 mm
Risk of acid deposition	Low
Risk of N deposition	Low
Ecological zone	Temperate oceanic forest
Mean annual temperature	5 to 10 °C
Regional water stress	Very high
Contribution of existing features to EFA:	2.3%

Existing features:

- Hedges or wooded strips (3)
- Isolated trees (3)
- Trees in line (2)
- Woodland (6)
- Ponds (2)
- Ditches (10)
- Land strips (adjacent/parallel to water) (2)

Impact assessment:

Ecosystem services: The positive impacts are relatively moderate. The majority of the positive impacts come from:

- Atmospheric composition and climate regulation
- Intellectual and representative interactions
- Lifecycle maintenance, habitat and gene pool protection
- Liquid flows

There are also some negative impacts, which are relatively moderate. The majority of the negative impacts come from:

- Provision of water for as a material
- Provision of water for nutrition

Biodiversity: The positive impacts are relatively moderate. The majority of the positive impacts come from:

- Birds: All
- Terrestrial plants: All
- Invertebrates: All
- Fungi

There are also some negative impacts, which are relatively moderate. The majority of the negative impacts come from:

- Biodiversity (general)

Management: There are some negative impacts, which are relatively very low. The majority of the negative impacts come from:

- Labour

Suggested EFA options (default criteria):

1. Agroforestry
2. Short rotation coppice
3. Nitrogen fixing crops
4. Catch crops or green cover
5. Land strips (other)
6. Isolated trees
7. Ponds
8. Hedges or wooded strips
9. Fallow land
10. Ditches
11. Trees in line
12. Woodland
13. Land strips (adjacent/parallel to water)
14. Traditional stone walls
15. Terraces

Suggested features (all):

1. Agroforestry
2. Short rotation coppice
3. Nitrogen fixing crops
4. Catch crops or green cover
5. Land strips (other)
6. Isolated trees
7. Ponds
8. Hedges or wooded strips
9. Fallow land
10. Ditches
11. Trees in line
12. Woodland
13. Land strips (adjacent/parallel to water)
14. Traditional stone walls
15. Terraces

Notes: Woodland, hedges and trees in a line dominate the impact.

Case study 07

Description: A small arable farm on moderately sloping land in southern Germany. There are no water bodies on or adjacent to the farm and it is surrounded by woodland.

Parameter	Value
Member state:	Germany
Farm size (ha):	85.1
Arable area (ha)	83
Soil texture	Medium fine
Annual rainfall	646-765 mm
Risk of acid deposition	Low
Risk of N deposition	Low
Ecological zone	Temperate mountain
Mean annual temperature	5 to 10 °C
Regional water stress	High
Contribution of existing features to EFA:	1.3

Existing features:

- Trees in line (1)
- Woodland (4)

Impact assessment:

Ecosystem services: The positive impacts are relatively moderate. The majority of the positive impacts come from:

- Liquid flows
- Atmospheric composition and climate regulation
- Lifecycle maintenance, habitat and gene pool protection

There are also some negative impacts, which are relatively moderate. The majority of the negative impacts come from:

- Mass flows
- Provision of water for as a material

Biodiversity: The positive impacts are relatively moderate. The majority of the positive impacts come from:

- Fungi
- Terrestrial plants: All
- Birds: All
- Lichens

There are also some negative impacts, which are relatively moderate. The majority of the negative impacts come from:

- Biodiversity (general)

Suggested EFA options (default criteria):

1. Agroforestry

2. Short rotation coppice
3. Nitrogen fixing crops
4. Terraces
5. Catch crops or green cover
6. Land strips (other)
7. Isolated trees
8. Ponds
9. Ditches
10. Trees in line
11. Fallow land
12. Hedges or wooded strips
13. Land strips (adjacent/parallel to water)
14. Traditional stone walls
15. Woodland

Suggested features (all):

1. Agroforestry
2. Short rotation coppice
3. Nitrogen fixing crops
4. Terraces
5. Catch crops or green cover
6. Land strips (other)
7. Isolated trees
8. Ponds
9. Ditches
10. Trees in line
11. Fallow land
12. Hedges or wooded strips
13. Land strips (adjacent/parallel to water)
14. Traditional stone walls
15. Woodland

Notes: None

Case study 08

Description: A small arable farm at the western end of the island of Crete. The farm is flat and has not water bodies on or adjacent to the farm.

Parameter	Value
Member state:	Greece
Farm size (ha):	36.8
Arable area (ha)	36.2
Soil texture	Medium
Annual rainfall	533-646 mm
Risk of acid deposition	None
Risk of N deposition	Low
Ecological zone	Sub-tropical dry forest
Mean annual temperature	15 to 20 °C
Regional water stress	High
Contribution of existing features to EFA:	10.7

Existing features:

- Fallow land (4)
- Isolated trees (1)
- Woodland (2)
- Agroforestry (2)

Impact assessment:

Ecosystem services: The positive impacts are relatively very low. The majority of the positive impacts come from:

- Lifecycle maintenance, habitat and gene pool protection

There are also some negative impacts, which are relatively very low. The majority of the negative impacts come from:

- Water conditions

Biodiversity: The positive impacts are relatively low. The majority of the positive impacts come from:

- Reptiles
- Mammals: All
- Birds: All
- Terrestrial plants: All

There are also some negative impacts, which are relatively low. The majority of the negative impacts come from:

- Terrestrial plants: All

Suggested EFA options (default criteria):

1. Nitrogen fixing crops
2. Woodland
3. Ditches
4. Trees in line
5. Land strips (adjacent/parallel to water)
6. Fallow land

Suggested features (all):

1. Short rotation coppice
2. Nitrogen fixing crops
3. Agroforestry
4. Catch crops or green cover
5. Land strips (other)
6. Isolated trees
7. Hedges or wooded strips
8. Woodland
9. Ponds
10. Ditches
11. Trees in line

12. Traditional stone walls
13. Land strips (adjacent/parallel to water)
14. Fallow land
15. Terraces

Notes: Woodland is more scrubland, but no option for that. Agroforestry has been declared for some of the orchard areas.

Case study 09

Description: A large flat arable farm in the centre of the north of Hungary, with just one water body passing through the western side of the farm.

Parameter	Value
Member state:	Hungary
Farm size (ha):	1690
Arable area (ha)	1645
Soil texture	Coarse
Annual rainfall	533-646 mm
Risk of acid deposition	Low
Risk of N deposition	Moderately high
Ecological zone	Temperate continental forest
Mean annual temperature	5 to 10 °C
Regional water stress	Very high
Contribution of existing features to EFA:	2.7%

Existing features:

- Hedges or wooded strips (2)
- Trees in a line (1)
- Woodland (10)
- Ditches (1)

Impact assessment:

Ecosystem services: The positive impacts are relatively low. The majority of the positive impacts come from:

- Atmospheric composition and climate regulation
- Liquid flows
- Intellectual and representative interactions

There are also some negative impacts, which are relatively low. The majority of the negative impacts come from:

- Provision of water for as a material
- Provision of water for nutrition

Biodiversity: The positive impacts are relatively moderate. The majority of the positive impacts come from:

- Biodiversity (general)
- Terrestrial plants: All
- Invertebrates: All

- Fungi

Management: There are some negative impacts, which are relatively very low. The majority of the negative impacts come from:

- Labour

Suggested EFA options (default criteria):

1. Agroforestry
2. Short rotation coppice
3. Nitrogen fixing crops
4. Catch crops or green cover
5. Land strips (other)
6. Isolated trees
7. Ponds
8. Hedges or wooded strips
9. Trees in line
10. Ditches
11. Fallow land
12. Land strips (adjacent/parallel to water)
13. Woodland
14. Terraces

Suggested features (all):

1. Agroforestry
2. Short rotation coppice
3. Nitrogen fixing crops
4. Catch crops or green cover
5. Land strips (other)
6. Traditional stone walls
7. Isolated trees
8. Ponds
9. Hedges or wooded strips
10. Trees in line
11. Ditches
12. Fallow land
13. Land strips (adjacent/parallel to water)
14. Woodland
15. Terraces

Notes: None

Case study 10

Description: A small farm in the south-west of Ireland, largely flat with a few minor hills and undulations and one minor water body on the farm.

Parameter	Value
Member state:	Ireland
Farm size (ha):	20
Arable area (ha)	20
Soil texture	Medium
Annual rainfall	1250-1500 mm
Risk of acid deposition	Very low
Risk of N deposition	Moderate
Ecological zone	Temperate oceanic forest
Mean annual temperature	5 to 10 °C
Regional water stress	Moderate
Contribution of existing features to EFA:	0.4%

Existing features:

- Ditches (1)
- Traditional stone walls (8)

Impact assessment:

Ecosystem services: The positive impacts are relatively high. The majority of the positive impacts come from:

- Intellectual and representative interactions

Biodiversity: The positive impacts are relatively moderate. The majority of the positive impacts come from:

- Mammals: All
- Lichens
- Birds: All
- Fungi

Management: There are some negative impacts, which are relatively very low. The majority of the negative impacts come from:

- Labour

Suggested EFA options (default criteria):

1. Short rotation coppice
2. Nitrogen fixing crops
3. Catch crops or green cover
4. Woodland
5. Trees in line
6. Fallow land
7. Ditches
8. Hedges or wooded strips
9. Land strips (adjacent/parallel to water)

Suggested features (all):

1. Agroforestry
2. Short rotation coppice
3. Nitrogen fixing crops
4. Catch crops or green cover
5. Land strips (other)
6. Woodland
7. Isolated trees
8. Ponds
9. Trees in line
10. Fallow land
11. Ditches
12. Hedges or wooded strips
13. Land strips (adjacent/parallel to water)
14. Terraces
15. Traditional stone walls

Notes: None

Case study 11

Description: An arable farm in central northern Italy. The area is flat and there is very few water bodies on or adjacent to the farm.

Parameter	Value
Member state:	Italy
Farm size (ha):	92.7
Arable area (ha)	85.5
Soil texture	Coarse
Annual rainfall	765-1000 mm
Risk of acid deposition	None
Risk of N deposition	Moderately high
Ecological zone	Temperate oceanic forest
Mean annual temperature	10 to 15 °C
Regional water stress	High
Contribution of existing features to EFA:	0.4%

Existing features:

- Hedges or wooded strips (1)
- Isolated trees (1)
- Trees in a line (1)

Impact assessment:

Ecosystem services: The positive impacts are relatively moderate. The majority of the positive impacts come from:

- Mediation by flora and fauna
- Water conditions
- Mediation by ecosystems

Biodiversity: The positive impacts are relatively moderate. The majority of the positive impacts come from:

- Birds: All
- Terrestrial plants: All

There are also some negative impacts, which are relatively moderate. The majority of the negative impacts come from:

- Terrestrial plants: All

Management: There are some negative impacts, which are relatively very low. The majority of the negative impacts come from:

- Labour

Suggested EFA options (default criteria):

1. Agroforestry
2. Short rotation coppice
3. Nitrogen fixing crops
4. Land strips (other)
5. Woodland
6. Isolated trees
7. Ponds
8. Ditches
9. Fallow land
10. Trees in line
11. Traditional stone walls
12. Land strips (adjacent/parallel to water)
13. Hedges or wooded strips
14. Terraces

Suggested features (all):

1. Agroforestry
2. Short rotation coppice
3. Nitrogen fixing crops
4. Catch crops or green cover
5. Land strips (other)
6. Woodland
7. Isolated trees
8. Ponds
9. Ditches
10. Fallow land
11. Trees in line
12. Traditional stone walls
13. Land strips (adjacent/parallel to water)
14. Hedges or wooded strips
15. Terraces

Notes: None

Case study 12

Description: A small arable farm on the north side of Sicily, Italy. Moderate slopes with no water bodies on or adjacent to the farm.

Parameter	Value
Member state:	Italy
Farm size (ha):	44.9
Arable area (ha)	31.9
Soil texture	Medium fine
Annual rainfall	451-533 mm
Risk of acid deposition	None
Risk of N deposition	Very low
Ecological zone	Sub-tropical dry forest
Mean annual temperature	15 to 20 °C
Regional water stress	Very high
Contribution of existing features to EFA:	2.5

Existing features:

- Hedges or wooded strips (2)
- Woodland (3)
- Land strips (other) (1)

Impact assessment:

Ecosystem services: The positive impacts are relatively moderate. The majority of the positive impacts come from:

- Intellectual and representative interactions
- Atmospheric composition and climate regulation
- Liquid flows

There are also some negative impacts, which are relatively moderate. The majority of the negative impacts come from:

- Mass flows
- Provision of water for as a material

Biodiversity: The positive impacts are relatively moderate. The majority of the positive impacts come from:

- Terrestrial plants: All
- Biodiversity (general)
- Fungi
- Birds: All

Management: There are some negative impacts, which are relatively very low. The majority of the negative impacts come from:

- Labour

Suggested EFA options (default criteria):

1. Agroforestry
2. Terraces
3. Short rotation coppice
4. Nitrogen fixing crops
5. Isolated trees
6. Ponds
7. Land strips (other)
8. Ditches
9. Trees in line
10. Fallow land
11. Hedges or wooded strips
12. Traditional stone walls
13. Land strips (adjacent/parallel to water)
14. Woodland

Suggested features (all):

1. Agroforestry
2. Terraces
3. Short rotation coppice
4. Nitrogen fixing crops
5. Catch crops or green cover
6. Isolated trees
7. Ponds
8. Land strips (other)
9. Ditches
10. Trees in line
11. Fallow land
12. Hedges or wooded strips
13. Traditional stone walls
14. Land strips (adjacent/parallel to water)
15. Woodland

Notes: None

Case study 13

Description: An arable farm in the centre of the Netherlands. Flat and no water bodies on or adjacent to the farm.

Parameter	Value
Member state:	Netherlands
Farm size (ha):	109
Arable area (ha)	105.8
Soil texture	Coarse
Annual rainfall	646-765 mm
Risk of acid deposition	High
Risk of N deposition	High
Ecological zone	Temperate oceanic forest
Mean annual temperature	5 to 10 °C
Regional water stress	High
Contribution of existing features to EFA:	0%

Existing features:

- Hedges or wooded strips (4)
- Trees in line (2)
- Woodland (3)

Impact assessment:

Ecosystem services: The positive impacts are relatively moderate. The majority of the positive impacts come from:

- Atmospheric composition and climate regulation
- Liquid flows
- Intellectual and representative interactions

There are also some negative impacts, which are relatively moderate. The majority of the negative impacts come from:

- Water conditions
- Provision of water for as a material

Biodiversity: The positive impacts are relatively moderate. The majority of the positive impacts come from:

- Fungi
- Birds: All
- Terrestrial plants: All
- Invertebrates: All

There are also some negative impacts, which are relatively moderate. The majority of the negative impacts come from:

- Biodiversity (general)

Management: There are some negative impacts, which are relatively very low. The majority of the negative impacts come from:

- Labour

Suggested EFA options (default criteria):

1. Short rotation coppice
2. Nitrogen fixing crops
3. Catch crops or green cover
4. Land strips (adjacent/parallel to water)

Suggested features (all):

1. Agroforestry
2. Short rotation coppice
3. Nitrogen fixing crops
4. Catch crops or green cover
5. Land strips (other)
6. Isolated trees

7. Ponds
8. Ditches
9. Trees in line
10. Fallow land
11. Hedges or wooded strips
12. Land strips (adjacent/parallel to water)
13. Woodland
14. Traditional stone walls
15. Terraces

Notes: None

Case study 14

Description: A small arable farm in the south-east of Poland. The land is flat and there are no water bodies on or adjacent to the farm

Parameter	Value
Member state:	Poland
Farm size (ha):	66
Arable area (ha)	60.7
Soil texture	Medium fine
Annual rainfall	451-533 mm
Risk of acid deposition	Moderate
Risk of N deposition	Moderate
Ecological zone	Temperate continental forest
Mean annual temperature	5 to 10 °C
Regional water stress	Very high
Contribution of existing features to EFA:	8.6%

Existing features:

- Woodland (1)
- Land strips (other (3)

Impact assessment:

Ecosystem services: The positive impacts are relatively moderate. The majority of the positive impacts come from:

- Lifecycle maintenance, habitat and gene pool protection
- Intellectual and representative interactions
- Atmospheric composition and climate regulation

There are also some negative impacts, which are relatively moderate. The majority of the negative impacts come from:

- Provision of water for nutrition
- Provision of water for as a material

Biodiversity: The positive impacts are relatively high. The majority of the positive impacts come from:

- Fungi

- Invertebrates: All
- Birds: All
- Mammals: All

Suggested EFA options (default criteria):

1. Short rotation coppice
2. Nitrogen fixing crops
3. Catch crops or green cover
4. Hedges or wooded strips
5. Isolated trees
6. Land strips (other)
7. Ponds
8. Trees in line
9. Ditches
10. Fallow land
11. Land strips (adjacent/parallel to water)
12. Woodland

Suggested features (all):

1. Agroforestry
2. Short rotation coppice
3. Nitrogen fixing crops
4. Catch crops or green cover
5. Hedges or wooded strips
6. Traditional stone walls
7. Isolated trees
8. Land strips (other)
9. Ponds
10. Trees in line
11. Ditches
12. Fallow land
13. Land strips (adjacent/parallel to water)
14. Woodland
15. Terraces

Notes: None

Case study 15

Description: A large arable farm in the north-east of Romania. It is flat, with very few features, just a ditch down the western border and some lines of trees down the eastern border.

Parameter	Value
Member state:	Romania
Farm size (ha):	1490
Arable area (ha)	1487.1
Soil texture	Medium fine
Annual rainfall	451-533 mm
Risk of acid deposition	None
Risk of N deposition	Low
Ecological zone	Temperate steppe
Mean annual temperature	10 to 15 °C
Regional water stress	Low
Contribution of existing features to EFA:	0.2%

Existing features:

- Trees in line (2)
- Ditches (1)

Impact assessment:

Ecosystem services: The positive impacts are relatively low. The majority of the positive impacts come from:

- Liquid flows
- Water conditions
- Intellectual and representative interactions

Biodiversity: The positive impacts are relatively moderate. The majority of the positive impacts come from:

- Birds: All
- Aquatic plants: All
- Invertebrates: All
- Amphibians

Management: There are some negative impacts, which are relatively very low. The majority of the negative impacts come from:

- Labour

Suggested EFA options (default criteria):

1. Short rotation coppice
2. Nitrogen fixing crops
3. Catch crops or green cover
4. Land strips (other)
5. Woodland
6. Hedges or wooded strips
7. Isolated trees

8. Ponds
9. Trees in line
10. Land strips (adjacent/parallel to water)
11. Ditches
12. Terraces

Suggested features (all):

1. Agroforestry
2. Short rotation coppice
3. Nitrogen fixing crops
4. Catch crops or green cover
5. Land strips (other)
6. Woodland
7. Hedges or wooded strips
8. Isolated trees
9. Ponds
10. Fallow land
11. Trees in line
12. Land strips (adjacent/parallel to water)
13. Ditches
14. Traditional stone walls
15. Terraces

Notes: None

Case study 16

Description: A largely flat arable farm in a valley in the east of Slovenia, with some minor water bodies on or adjacent to the farm, including a small river that forms the southern boundary of the farm.

Parameter	Value
Member state:	Slovenia
Farm size (ha):	357
Arable area (ha)	302
Soil texture	Medium
Annual rainfall	1000-1250 mm
Risk of acid deposition	Low
Risk of N deposition	Low
Ecological zone	Temperate continental forest
Mean annual temperature	5 to 10 °C
Regional water stress	High
Contribution of existing features to EFA:	0%

Existing features:

- Hedges or wooded strips (7)
- Woodland (4)
- Ditches (1)

Impact assessment:

Ecosystem services: The positive impacts are relatively moderate. The majority of the positive impacts come from:

- Intellectual and representative interactions
- Lifecycle maintenance, habitat and gene pool protection
- Atmospheric composition and climate regulation
- Liquid flows

There are also some negative impacts, which are relatively moderate. The majority of the negative impacts come from:

- Mass flows
- Provision of water for as a material

Biodiversity: The positive impacts are relatively moderate. The majority of the positive impacts come from:

- Terrestrial plants: All
- Invertebrates: All
- Birds: All
- Fungi

Management: There are some negative impacts, which are relatively very low. The majority of the negative impacts come from:

- Labour

Suggested EFA options (default criteria):

1. Nitrogen fixing crops
2. Catch crops or green cover
3. Fallow land

Suggested features (all):

1. Agroforestry
2. Short rotation coppice
3. Nitrogen fixing crops
4. Catch crops or green cover
5. Land strips (other)
6. Traditional stone walls
7. Isolated trees
8. Ponds
9. Trees in line
10. Ditches
11. Fallow land
12. Land strips (adjacent/parallel to water)
13. Hedges or wooded strips
14. Woodland
15. Terraces

Notes: None

Case study 17

Description: An arable farm, slightly to the north of the centre of Spain. The farm is flat, with no water bodies on or adjacent to the farm, and is surrounded by forest to the east.

Parameter	Value
Member state:	Spain
Farm size (ha):	753
Arable area (ha)	647.9
Soil texture	Fine
Annual rainfall	451-533 mm
Risk of acid deposition	None
Risk of N deposition	Moderate
Ecological zone	Sub-tropical dry forest
Mean annual temperature	10 to 15 °C
Regional water stress	High
Contribution of existing features to EFA:	14.6

Existing features:

- Woodland (12)

Impact assessment:

Ecosystem services: The positive impacts are relatively moderate. The majority of the positive impacts come from:

- Intellectual and representative interactions
- Atmospheric composition and climate regulation
- Liquid flows

There are also some negative impacts, which are relatively moderate. The majority of the negative impacts come from:

- Mass flows
- Provision of water for nutrition

Biodiversity: The positive impacts are relatively high. The majority of the positive impacts come from:

- Terrestrial plants: All
- Lichens
- Fungi

There are also some negative impacts, which are relatively high. The majority of the negative impacts come from:

- Biodiversity (general)

Suggested EFA options (default criteria):

1. Agroforestry
2. Nitrogen fixing crops
3. Fallow land

4. Woodland

Suggested features (all):

1. Agroforestry
2. Short rotation coppice
3. Nitrogen fixing crops
4. Catch crops or green cover
5. Land strips (other)
6. Isolated trees
7. Hedges or wooded strips
8. Ponds
9. Ditches
10. Trees in line
11. Fallow land
12. Land strips (adjacent/parallel to water)
13. Traditional stone walls
14. Woodland
15. Terraces

Notes: None

Case study 18

Description: An arable farm in the central east of Sweden. Flat with a few minor water bodies on or adjacent to the farm.

Parameter	Value
Member state:	Sweden
Farm size (ha):	373
Arable area (ha)	351.6
Soil texture	Medium
Annual rainfall	533-646 mm
Risk of acid deposition	Low
Risk of N deposition	Low
Ecological zone	Temperate continental forest
Mean annual temperature	0 to 5 °C
Regional water stress	High
Contribution of existing features to EFA:	0.7%

Existing features:

- Woodland (1)
- Ditches (2)
- Land strips (adjacent/parallel to water) (4)
- Land strips (other) (1)

Impact assessment:

Ecosystem services: The positive impacts are relatively low. The majority of the positive impacts come from:

- Atmospheric composition and climate regulation

- Liquid flows

There are also some negative impacts, which are relatively low. The majority of the negative impacts come from:

- Mass flows
- Water conditions

Biodiversity: The positive impacts are relatively low. The majority of the positive impacts come from:

- Biodiversity (general)
- Invertebrates: All
- Fungi

Management: There are some negative impacts, which are relatively very low. The majority of the negative impacts come from:

- Labour

Suggested EFA options (default criteria):

1. Agroforestry
2. Short rotation coppice
3. Nitrogen fixing crops
4. Catch crops or green cover
5. Land strips (other)
6. Fallow land
7. Land strips (adjacent/parallel to water)

Suggested features (all):

1. Agroforestry
2. Short rotation coppice
3. Nitrogen fixing crops
4. Catch crops or green cover
5. Land strips (other)
6. Isolated trees
7. Ponds
8. Trees in line
9. Ditches
10. Fallow land
11. Hedges or wooded strips
12. Land strips (adjacent/parallel to water)
13. Woodland
14. Traditional stone walls
15. Terraces

Notes: Woodland looks like willow, so possibly SRC, but has been classified as woodland.

Case study 19

A relatively flat area, just to the north of London, with a few minor hills and changes in elevation, with some minor waterbodies on or adjacent to the farm.

Parameter	Value
Member state:	England, UK
Farm size (ha):	77.3
Arable area (ha)	66.6
Soil texture	Fine
Annual rainfall	533-646 mm
Risk of acid deposition	Very low
Risk of N deposition	Moderate
Ecological zone	Temperate oceanic forest
Mean annual temperature	5 to 10 °C
Regional water stress	Very high
Contribution of existing features to EFA:	5.1%

Existing features:

- Hedges or wooded strips (16)
- Isolated trees (1)
- Ponds (2)
- Woodland (5)

Impact assessment:

Ecosystem services: The positive impacts are relatively moderate. The majority of the positive impacts come from:

- Lifecycle maintenance, habitat and gene pool protection
- Atmospheric composition and climate regulation
- Intellectual and representative interactions

There are also some negative impacts, which are relatively moderate. The majority of the negative impacts come from:

- Mass flows
- Provision of water for as a material

Biodiversity: The positive impacts are relatively moderate. The majority of the positive impacts come from:

- Terrestrial plants: All
- Mammals: All
- Birds: All
- Biodiversity (general)

There are also some negative impacts, which are relatively moderate. The majority of the negative impacts come from:

- Terrestrial plants: All

Management: There are some negative impacts, which are relatively low. The majority of the negative impacts come from:

- Labour

Suggested EFA options (default criteria):

1. Short rotation coppice
2. Nitrogen fixing crops
3. Catch crops or green cover
4. Fallow land
5. Land strips (adjacent/parallel to water)
6. Hedges or wooded strips

Suggested features (all):

1. Agroforestry
2. Terraces
3. Short rotation coppice
4. Nitrogen fixing crops
5. Catch crops or green cover
6. Land strips (other)
7. Isolated trees
8. Ponds
9. Ditches
10. Trees in line
11. Fallow land
12. Land strips (adjacent/parallel to water)
13. Hedges or wooded strips
14. Woodland
15. Traditional stone walls

Notes: Due to the relative size of Woodland 4 (2.3 ha), the bulk of the impacts are associated with this feature.

Case study 20

A country estate in Bedfordshire, with some arable land. It is a largely flat area, with a few minor hills and changes in elevation, especially on the west side of the estate, and some minor waterbodies on or adjacent to the farm.

Parameter	Value
Member state:	England, UK
Farm size (ha):	288
Arable area (ha)	90.7
Soil texture	Fine
Annual rainfall	533-646 mm
Risk of acid deposition	Low
Risk of N deposition	Low
Ecological zone	Temperate oceanic forest
Mean annual temperature	5 to 10 °C
Regional water stress	Very high
Contribution of existing features to EFA:	2.3%

Existing features:

- Hedges or wooded strips (7)
- Isolated trees (2)
- Trees in a line (2)
- Ponds (1)

Impact assessment:

Ecosystem services: The positive impacts are relatively moderate. The majority of the positive impacts come from:

- Mediation by ecosystems
- Intellectual and representative interactions
- Mediation by flora and fauna

Biodiversity: The positive impacts are relatively moderate. The majority of the positive impacts come from:

- Birds: All
- Invertebrates: All
- Mammals: All

There are also some negative impacts, which are relatively moderate. The majority of the negative impacts come from:

- Terrestrial plants: All

Management: There are some negative impacts, which are relatively low. The majority of the negative impacts come from:

- Labour

Suggested EFA options (default criteria):

1. Short rotation coppice
2. Nitrogen fixing crops
3. Catch crops or green cover
4. Fallow land
5. Land strips (adjacent/parallel to water)
6. Hedges or wooded strips

Suggested features (all):

1. Agroforestry
2. Short rotation coppice
3. Nitrogen fixing crops
4. Catch crops or green cover
5. Land strips (other)
6. Woodland
7. Isolated trees
8. Ponds
9. Ditches
10. Fallow land

11. Trees in line
12. Land strips (adjacent/parallel to water)
13. Hedges or wooded strips
14. Traditional stone walls
15. Terraces

Notes: None

Case study 21

An arable farm, in Kent, that is also a nature reserve. The arable land is surrounded by a considerable area of woodland. The majority of the farm is flat with undulating topography, with some moderate to steep slopes in the south-east. There are no waterbodies on the farm.

Parameter	Value
Member state:	England, UK
Farm size (ha):	266
Arable area (ha)	94.4
Soil texture	Medium
Annual rainfall	646-765 mm
Risk of acid deposition	Low
Risk of N deposition	Moderate
Ecological zone	Temperate oceanic forest
Mean annual temperature	5 to 10 °C
Regional water stress	Very high
Contribution of existing features to EFA:	0.2%

Existing features:

- Hedges or wooded strips (1)
- Woodland (10)
- Field margins (land strips (other)) (6)

Impact assessment:

Ecosystem services: The positive impacts are relatively high. The majority of the positive impacts come from:

- Intellectual and representative interactions
- Atmospheric composition and climate regulation
- Liquid flows

There are also some negative impacts, which are relatively high. The majority of the negative impacts come from:

- Provision of water for as a material
- Provision of water for nutrition

Biodiversity: The positive impacts are relatively high. The majority of the positive impacts come from:

- Terrestrial plants: All
- Fungi
- Lichens

- Birds: All

There are also some negative impacts, which are relatively high. The majority of the negative impacts come from:

- Biodiversity (general)

Management: There are some negative impacts, which are relatively very low. The majority of the negative impacts come from:

- Labour

Suggested EFA options (default criteria):

1. Short rotation coppice
2. Nitrogen fixing crops
3. Catch crops or green cover
4. Fallow land
5. Hedges or wooded strips
6. Land strips (adjacent/parallel to water)

Suggested features (all):

1. Terraces
2. Agroforestry
3. Short rotation coppice
4. Nitrogen fixing crops
5. Catch crops or green cover
6. Land strips (other)
7. Isolated trees
8. Ponds
9. Ditches
10. Trees in line
11. Fallow land
12. Hedges or wooded strips
13. Land strips (adjacent/parallel to water)
14. Traditional stone walls
15. Woodland

Notes: The woodland on the estate dominates the impacts of the farm due to its size and its quality.

Case study 22

Description: An arable farm in Eastern Scotland, partly hilly and partly flat, with waterbodies on and adjacent to the farm, including watercourses forming the south and east borders of the farm.

Parameter	Value
Member state:	Scotland, UK
Farm size (ha):	93.2
Arable area (ha)	80.9
Soil texture	Coarse
Annual rainfall	1000-1250 mm
Risk of acid deposition	None
Risk of N deposition	Very low
Ecological zone	Temperate oceanic forest
Mean annual temperature	0 to 5 °C
Regional water stress	Low
Contribution of existing features to EFA:	0.8

Existing features:

- Hedges or wooded strips (6)
- Woodland (1)
- Ponds (1)

Impact assessment:

Ecosystem services: The positive impacts are relatively moderate. The majority of the positive impacts come from:

- Atmospheric composition and climate regulation
- Intellectual and representative interactions
- Liquid flows

There are also some negative impacts, which are relatively moderate. The majority of the negative impacts come from:

- Mass flows
- Water conditions

Biodiversity: The positive impacts are relatively moderate. The majority of the positive impacts come from:

- Fungi
- Lichens
- Terrestrial plants: All
- Biodiversity (general)

Management: There are some negative impacts, which are relatively very low. The majority of the negative impacts come from:

- Labour

Suggested EFA options (default criteria):

1. Nitrogen fixing crops
2. Catch crops or green cover
3. Land strips (other)
4. Hedges or wooded strips
5. Ditches
6. Fallow land
7. Land strips (adjacent/parallel to water)

Suggested features (all):

1. Agroforestry
2. Terraces
3. Short rotation coppice
4. Nitrogen fixing crops
5. Catch crops or green cover
6. Land strips (other)
7. Traditional stone walls
8. Isolated trees
9. Hedges or wooded strips
10. Ponds
11. Trees in line
12. Ditches
13. Fallow land
14. Land strips (adjacent/parallel to water)
15. Woodland

Notes: Due to the relative size of the Woodland, the bulk of the impacts are associated with this feature.

Case study 23

Description: An arable farm in a coastal location in the south-east of Scotland, largely flat and a few minor water bodies.

Parameter	Value
Member state:	Scotland, UK
Farm size (ha):	112
Arable area (ha)	105.4
Soil texture	Fine
Annual rainfall	1000-1250 mm
Risk of acid deposition	Low
Risk of N deposition	Low
Ecological zone	Temperate oceanic forest
Mean annual temperature	5 to 10 °C
Regional water stress	Moderate
Contribution of existing features to EFA:	1.9%

Existing features:

- Hedges or wooded strips (13)
- Woodland (1)
- Archaeological sites (1)

Impact assessment:

Ecosystem services: The positive impacts are relatively low. The majority of the positive impacts come from:

- Intellectual and representative interactions

There are also some negative impacts, which are relatively low. The majority of the negative impacts come from:

- Water conditions
- Mass flows

Biodiversity: The positive impacts are relatively very low. The majority of the positive impacts come from:

- Terrestrial plants: All
- Birds: All
- Mammals: All
- Fungi

Management: There are some negative impacts, which are relatively very low. The majority of the negative impacts come from:

- Labour

Suggested EFA options (default criteria):

1. Nitrogen fixing crops
2. Catch crops or green cover
3. Land strips (other)
4. Hedges or wooded strips
5. Ditches
6. Fallow land
7. Land strips (adjacent/parallel to water)

Suggested features (all):

1. Agroforestry
2. Short rotation coppice
3. Nitrogen fixing crops
4. Catch crops or green cover
5. Land strips (other)
6. Traditional stone walls
7. Isolated trees
8. Woodland
9. Ponds
10. Hedges or wooded strips
11. Trees in line
12. Ditches
13. Fallow land
14. Land strips (adjacent/parallel to water)
15. Terraces

Notes: None

Case study 24

Description: An arable farm in the south-east of Scotland, largely flat with a gentle slope towards the south, with field segregated with stonewalls.

Parameter	Value
Member state:	Scotland, UK
Farm size (ha):	113
Arable area (ha)	101
Soil texture	Coarse
Annual rainfall	1000-1250 mm
Risk of acid deposition	Low
Risk of N deposition	Low
Ecological zone	Temperate oceanic forest
Mean annual temperature	5 to 10 °C
Regional water stress	Moderate
Contribution of existing features to EFA:	0%

Existing features:

- Woodland (2)
- Traditional stone walls (17)

Impact assessment:

Ecosystem services: The positive impacts are relatively high. The majority of the positive impacts come from:

- Intellectual and representative interactions
- Atmospheric composition and climate regulation
- Liquid flows

There are also some negative impacts, which are relatively high. The majority of the negative impacts come from:

- Water conditions
- Provision of water for nutrition

Biodiversity: The positive impacts are relatively high. The majority of the positive impacts come from:

- Fungi
- Lichens
- Invertebrates: All
- Birds: All

Suggested EFA options (default criteria):

1. Nitrogen fixing crops
2. Catch crops or green cover
3. Land strips (other)
4. Hedges or wooded strips
5. Ditches
6. Fallow land

7. Land strips (adjacent/parallel to water)

Suggested features (all):

1. Agroforestry
2. Terraces
3. Short rotation coppice
4. Nitrogen fixing crops
5. Catch crops or green cover
6. Land strips (other)
7. Hedges or wooded strips
8. Isolated trees
9. Ponds
10. Trees in line
11. Ditches
12. Fallow land
13. Land strips (adjacent/parallel to water)
14. Traditional stone walls
15. Woodland

Notes: None

Case study 25

Description: A country estate with arable land in a coastal location in the south-east of Scotland, largely flat with a few minor undulations, and water body forming the eastern boundary of the estate.

Parameter	Value
Member state:	Scotland, UK
Farm size (ha):	488
Arable area (ha)	284
Soil texture	Coarse, medium and medium fine
Annual rainfall	1000-1250 mm
Risk of acid deposition	Low
Risk of N deposition	Low
Ecological zone	Temperate oceanic forest
Mean annual temperature	5 to 10 °C
Regional water stress	Moderate
Contribution of existing features to EFA:	0.4%

Existing features:

- Hedges or wooded strips (8)
- Woodland (11)
- Stonewalls (8)

Impact assessment:

Ecosystem services: The positive impacts are relatively moderate. The majority of the positive impacts come from:

- Atmospheric composition and climate regulation

- Liquid flows

There are also some negative impacts, which are relatively moderate. The majority of the negative impacts come from:

- Water conditions
- Mass flows

Biodiversity: The positive impacts are relatively moderate. The majority of the positive impacts come from:

- Biodiversity (general)
- Fungi
- Mammals: All
- Birds: All

Management: There are some negative impacts, which are relatively very low. The majority of the negative impacts come from:

- Labour

Suggested EFA options (default criteria):

1. Nitrogen fixing crops
2. Land strips (other)
3. Catch crops or green cover
4. Hedges or wooded strips
5. Ditches
6. Fallow land
7. Land strips (adjacent/parallel to water)

Suggested features (all):

1. Agroforestry
2. Short rotation coppice
3. Nitrogen fixing crops
4. Land strips (other)
5. Catch crops or green cover
6. Traditional stone walls
7. Hedges or wooded strips
8. Isolated trees
9. Ponds
10. Trees in line
11. Ditches
12. Fallow land
13. Land strips (adjacent/parallel to water)
14. Woodland
15. Terraces

Notes: None

References

Acreman, M.C., Harding, R.J., Lloyd, C., McNamara, N.P., Mountford, J.O., Mould, D.J., Purse, B.V., Heard, M.S., Stratford, C.J. and Dury, S.J. (2011) Trade-off in ecosystem services of the Somerset Levels and Moors wetlands. *Hydrological Sciences Journal*, **56(8)**, 1543-1565

Allen, A. and Chapman, D. (2001) Impacts of afforestation on groundwater resources and quality. *Hydrogeology Journal*, **9(4)**, 390-400

Alrababah, M.A., Alhamad, M.A., Suwaileh, A. and Al-Gharaibeh, M. (2007) Biodiversity of semi-arid Mediterranean grasslands: Impact of grazing and afforestation. *Applied Vegetation Science*, **10(2)**, 257-264

Anderson, G.Q.A., Haskins, L.R. and Nelson, S.H. (2004) *The effects of bioenergy crops on farmland birds in the United Kingdom: A review of current knowledge and future predictions*. In: Biomass and Agriculture, Sustainability, markets and policies. Proceedings of an OECD workshop on biomass and agriculture. OECD Publications, France, Vienna

Antonopoulos, I-S., Canfora, P., Gaudillat, M.D.P., Styles, D., Williamson, J., Jewer, A., Haddaway, N. and Price, M. (2015) *Best environmental management practice for the agriculture sector - crop and animal production. Final draft*. Joint Research Centre, European Commission, June 2015.

ARG (2010) *Advice Note 5: Great Crested Newt Habitat Suitability Index*. Amphibian and Reptile Groups (ARG) of the United Kingdom

Armitage, P.D., Szoszkiewicz, K., Blackburn, J.H. and Nesbitt, I. (2003) Ditch communities: a major contributor to floodplain biodiversity. *Aquatic Conservation: Marine and Freshwater Ecosystems*, **13(2)**, 165-185

Armstrong, A. (1999) *Establishment of Short Rotation Coppice*. Forestry Commission Practice Note No. 7. Forestry Commission, Edinburgh.

Aronsson, P.G., Bergstrom, L.F. and Elowson, S.N.E. (2000) Long term influence of intensively cultured short-rotation willow coppice on nitrogen concentrations in groundwater. *Journal of Environmental Management*, **58**, 135-145

Askegaard, M. (2011) Nitrate leaching from organic arable crop rotations is mostly determined by autumn field management. *Agriculture Ecosystems and Environment*, **142**, 149-160

Aufhammer, W. (1992) Interplanting of non-legumes into faba bean (Vicia faba L.) to reduce the risk of nitrate contamination of the ground water. *European Journal of Agronomy*, **1**, 59-69

Bagstad, K.J., Semmens, D.J., Waage, S. and Winthrop, R. (2013) A comparative assessment of decision-support tools for ecosystem services quantification and valuation. *Ecosystem Services*, **5**, 27-39

Bailey, S. (2007) Increasing connectivity in fragmented landscapes: an investigation of evidence for biodiversity gain in woodlands. *Forest Ecology and Management*, **238(1)**, 7-23

Baker, J., Beebee T., Buckley, J., Gent, A. and Orchard, D. (2011) *Amphibian Habitat Management Handbook*. Amphibian and Reptile Conservation, Bournemouth

Balbi, S., del Prado, A., Gallejones, P., Geevan, C.P., Pardo, G., Pérez-Miñanaa, E., Manrique, R., Hernandez-Santiago, C. and Villa, F. (2015) Modeling trade-offs among ecosystem services in agricultural production systems. *Environmental Modelling & Software*, In Press, 1-13

Balestrini, R., Arese, C., Delconte, C.A., Lotti, A. and Salerno, F. (2011) Nitrogen removal in subsurface water by narrow buffer strips in the intensive farming landscape of the Po River watershed, Italy. *Ecological Engineering*, **37(2)**, 148-157

Balmford, A., Fisher, B., Green, R.E., Naidoo, R., Strassburg, B., Turner, R.K. and Rodrigues, A.S.L. (2011) Bringing ecosystem services into the real world: an operational framework for assessing the economic consequences of losing wild nature. *Environmental and Resource Economics*, **48**, 161-175

Barling, R.D. and Moore, I.D. (1994) Role of buffer strips in management of waterway pollution: A review. *Environmental Management*, **18(4)**, 513-558

Baron, B. (2007) A look at the Chiropteran Fauna of the Maltese Islands: Towards an effective Action Plan for their conservation. *Xjenza – Journal of the Malta Chamber of Scientists*, **12**, 1-9

Bastrup-Birk, A. and Gundersen, P. (2004) Water quality improvements from afforestation in an agricultural catchment in Denmark illustrated with the INCA model. *Hydrology and Earth System Sciences*, **8(4)**, 764-777

Baudry, J., Bunce, R.G.H. and Burel, F. (2000) Hedgerows: an international perspective on their origin, function and management. *Journal of Environmental Management*, **60(1)**, 7-22

Baum, S., Weih, M., Busch, G., Kroiher, F. and Bolte, A. (2009) The impact of Short Rotation Coppice plantations on phytodiversity. *Landbauforschung - vTI Agriculture and Forestry Research*, **3(59)**, 163–170

Baur, B. and Baur, A. (2006) Habitat related dispersal in the rock-dwelling land snail *Chondrina clienta*. *Ecography*, **18(2)**, 123-130

Baur, B., Fröberg, L. and Baur, A. (1995) Species diversity and grazing damage in a calcicolous lichen community on top of stone walls in Öland, Sweden. In: Annales Botanici Fennici (January, pp. 239-250). Finnish Zoological and Botanical Publishing Board

BCT (2013) *Encouraging bats. A guide for bat-friendly gardening and living*. Bat Conservation Trust (BCT)

Benton, T.G., Vickery, J. A. and Wilson, J.D. (2003) Farmland biodiversity: is habitat heterogeneity the key? *Trends in Ecology & Evolution*, **18(4)**, 182-188

Berg, A. (2002) Breeding birds in short-rotation coppices on farmland in central Sweden - the importance of Salix height and adjacent habitats. *Agriculture, Ecosystems and Environment*, **90**, 265-276

Bevan, A. and Conolly, J. (2012) Terraced fields and Mediterranean landscape structure: An analytical case study from Antikythera, Greece. *Ecological Modelling*, **222(7)**, 1303-1314

Bevan, A., Conolly, J., Colledge, S., Frederick, C., Palmer, C., Siddall, R. and Stellatou, A. (2013) The long-term ecology of agricultural terraces and enclosed fields from Antikythera, Greece. *Human Ecology*, **41(2)**, 255-272

Bhattarai, R., Kalita, P.K. and Patel, M.K. (2009) Nutrient transport through a vegetative filter strip with subsurface drainage. *Journal of Environmental Management*, **90(5)**, 1868-1876

Bicknell, D. (1991) In Proceedings from A National Australian Conference on The Role of Trees in Sustainable Agriculture held at Albury, Victoria, Australia, in October 1991

Bienes, R., Moscoso del prado, J., Del Olmo, A. and Rodríguez, C. (1996) Soil loss by water erosion on agricultural land in the central region of Spain caused by short duration storms. *Ecología*, **10**, 71-77

Biggs, J. (2007) *Small-scale Solutions for Big Water Problems.* Pond Conservation: The Water habitats Trust, Oxford

Biggs, J., Corfield, A., Walker, D., Whitfield, M. and Williams, P. (1994) New approaches to the management of ponds. *British Wildlife*, **5(5)**, 273-287

Biggs, J., Fox, G., Nicolet, P., Whitfield, M. and Williams, P. (2001) Dangers and opportunities in managing temporary ponds. *Freshwater Forum*, **17(1)**, 71-80

Biggs, J., Williams, P., Whitfield, M., Nicolet, P. and Weatherby, A. (2005) 15 years of pond assessment in Britain: results and lessons learned from the work of Pond Conservation. *Aquatic Conservation: Marine and Freshwater Ecosystems*, **15(6)**, 693-714

Biggs, J., Williams, P., Whitfield. M, Fox, G. and Nicolet, P. (2000) *Ponds, pools and lochans: Guidance on good practice in the management and creation of small waterbodies in Scotland.* SEPA, Stirling, UK

Blackwell, M.S.A., Hogan, D.V. and Maltby, E. (1999) The use of conventionally and alternatively located buffer zones for the removal of nitrate from diffuse agricultural run-off. *Water Science and Technology*, **39(12)**, 157-164

Blakesley, D. and Buckley, G.P. (2010) *Managing Your Woodland for Wildlife*. Pisces Publications, Newbury

Blomqvist, M.M., Vos, P., Klinkhamer, P.G.L. and ter Keurs, W.J. (2003) Declining plant species richness of grassland ditch banks - a problem of colonisation or extinction? *Biological Conservation*, **109(3)**, 391-406

Boone, G.C. and Tinklin, R. (1988) Importance of hedgerow structure in determining the occurrence and density of small mammals. *Aspects of Applied Biology,* **16**, 73-78

Boughey, K.L., Lake, I.R., Haysom, K.A. and Dolman, P.M. (2011) Improving the biodiversity benefits of hedgerows: how physical characteristics and the proximity of foraging habitat affect the use of linear features by bats. *Biological Conservation*, **144(6)**, 1790-1798

Brady, L.D. and Phillips, M. (2012) *Developing a 'Habitat Suitability Index' for Reptiles*. ARC Research Report 12/06. Report to Amphibian and Reptile Conservation Trust

Braskerud, B.C. (2002a) Factors affecting nitrogen retention in small constructed wetlands treating agricultural non-point source pollution. *Ecological Engineering*, **18(3)**, 351-370

Braskerud, B.C. (2002b) Factors affecting phosphorus retention in small constructed wetlands treating agricultural non-point source pollution. *Ecological Engineering*, **19(1)**, 41-61

Bredemeier, M. and Dohrenbusch, A. (2004) 'Afforestation and Reforestation', in Biodiversity: Structure and Function, edited by W. Barthlott, K.E. Linsenmair & S. Porembski, in *Encyclopedia of Life Support Systems (EOLSS)*, Developed under the Auspices of the UNESCO, Eolss Publishers, Paris, France

Broadmeadow, M. and Matthews, R. (2003) *Forests, Carbon and Climate Change: the UK Contribution.* Forestry Commission, Edinburgh

Brockerhoff, E.G., Jactel, H., Parrotta, J.A., Quine, C.P. and Sayer, J. (2008) Plantation forests and biodiversity: oxymoron or opportunity? *Biodiversity and Conservation*, **17(5)**, 925-951

Burgess, P.J. (1999) Effects of agroforestry on farm biodiversity in the UK. *Scottish Forestry*, **53(1)**, 24-27

Burgess, S.S., Adams, M.A., Turner, N.C., White, D.A., and Ong, C.K. (2001) Tree roots: conduits for deep recharge of soil water. *Oecologia*, **126(2)**, 158-165

Burkhard, B., Kroll, F., Müller, F. and Windhorst, W. (2009) Landscapes' capacities to provide ecosystem services – a concept for land-cover based assessments. *Landscape Online*, **15**, 1–22

Buscardo, E., Smith, G.F., Kelly, D.L., Freitas, H., Iremonger, S., Mitchell, F.J.G., O'Donoghue, S. and McKee, A.-M. (2008) The early effects of afforestation on biodiversity of grasslands in Ireland. *Biodiversity and Conservation*, **17(5)**, 1057-1072

Busch, G. (2009) The impact of short rotation coppice cultivation on groundwater recharge - a spatial (planning) perspective. *Landbauforschung - vTI Agriculture and Forestry Research*, **3(59)**, 207-222

Calder I.R., Reid, I., Nisbet, T.R., Armstrong, A., Green, J.C. and Parkin, G. (2002) *Study of the potential impacts on water resources of proposed afforestation. Trees and Drought Project on Lowland England – TaDPoLE.* Loughborough University report to the Department for environment, food and rural affairs (Defra). Loughborough University, Loughborough

CALU (2007) *Managing Energy and Carbon. The farmers guide to energy audits*. Centre for Alternative Land Use (CALU), University of Bangor, Wales

Caparrós, A. and Jacquemont, F. (2003) Conflicts between biodiversity and carbon sequestration programs: economic and legal implications. *Ecological Economics*, **46(1)**, 143-157

Carroll, Z.L., Bird, S.B., Emmett, B.A., Reynolds, B. and Sinclair, F.L. (2004) Can tree shelterbelts on agricultural land reduce flood risk? *Soil Use and Management*, **20(3)**, 357-359

Carvell, C., Meek, W.R., Pywell, R.F., Goulson, D. and Nowakowski M. (2007) Comparing the efficacy of agri-environment schemes to enhance bumble bee abundance and diversity on arable field margins. *Journal of Applied Ecology*, **44**, 29-40

Casalí, J., López, J.J. and Giráldez, J.V. (1999) Ephemeral gully erosion in southern Navarra (Spain). *Catena*, **36**, 65-84

Céréghino, R., Biggs, J., Oertli, B. and Declerck, S. (2008) The ecology of European ponds: defining the characteristics of a neglected freshwater habitat. *Hydrobiologia*, **597(1)**, 1-6

Céréghino, R., Boix, D., Cauchie, H.-M., Martens, K. and Oertli, B. (2014) The ecological role of ponds in a changing world. *Hydrobiologia*, **723(1)**, 1-6

Chamberlain, D.E., Vickery, J.A. and Marshall, E.J.P. (2001) *The effect of hedgerow characteristics, adjacent habitat and landscape on the winter hedgerow bird community*. Final report for Defra project BD2106, prepared by IACR - Long Ashton Research Station, University of Bristol and British Trust for Ornithology

Chambers, B.J. and Garwood, T.W.D. (2000) Monitoring of water erosion on arable farms in England and Wales. 1990-94. *Soil Use and Management*, **16(2)**, 93-99

Chow, T.L., Rees, H.W. and Daigle, J.L. (1999) Effectiveness of terraces/grassed waterway systems for soil and water conservation: A field evaluation. *Journal of Soil and Water conservation*, **54(3)**, 577-583

Chung, I.M. and Miller, D.A. (1995) Natural Herbicide Potential of Alfalfa Residue on Selected Weed Species. *Agronomy Journal*, **87**, 920-925

Clarke, S.A., Green, D.G., Bourn, N.A. and Hoare, D.J. (2011) *Woodland Management for Butterflies and Moths: A Best Practice Guide*. Butterfly Conservation, Wareham, Dorset, UK

Clarke, S.J. (2014) Conserving freshwater biodiversity: The value, status and management of high quality ditch systems. *Journal for Nature Conservation*, DOI: 10.1016/j.jnc.2014.10.003

CLM (2015) *GAIA biodiversity yardstick*. Website: http://www.gaia-biodiversity-yardstick.eu/ (Last accessed: 07/10/15)

Coates, A. and Say, A. (1999) *Ecological assessment of short rotation coppice*. Report ETSU B/W5/00216/00/REPORT/1-3. A report for the Department of Trade and Industry

Cole, L.J., Brocklehurst, S., McCracken, D.I., Harrison, W. and Robertson, D. (2012) Riparian field margins: their potential to enhance biodiversity in intensively managed grasslands. *Insect Conservation and Diversity*, **5(1)**, 86-94

Colley, M.R. and Luna, J.M. (2000) Relative Attractiveness of Potential Beneficial Insectary Plants to Aphidophagous Hoverflies (Diptera: Syrphidae). *Environmental Entomology*, **29(5)**, 1054-1059

Collier, M.J. (2013) Field boundary stone walls as exemplars of 'novel' ecosystems. *Landscape Research*, **38(1)**, 141-150

Conklin, A.E., Erich, M.S., Liebman, M., Lambert, D., Gallandt, E.R. and Halteman, W.A. (2002) Effects of red clover (Trifolium pratense) green manure and compost soil amendments on wild mustard (Brassica kaber) growth and incidence of disease. *Plant and Soil*, **238**, 245-256

Cool Farm Alliance (2015) *Cool Farm Tool*. Website: http://www.coolfarmtool.org/ (Last accessed: 07/10/15)

Cooper, R.J., Gilliam, J., Daniels, R.B. and Robarge, W.P. (1987) Riparian areas as filters for agricultural sediment. *Soil Science Society of America Journal*, **51**, 416-420

Cranmer, L., McCollin, D., and Ollerton, J. (2012) Landscape structure influences pollinator movements and directly affects plant reproductive success. *Oikos*, **121(4)**, 562-568

Croxton, P.J., Carvell, C., Mountford, J.O. and Sparks, T.H. (2002) A comparison of green lanes and field margins as bumblebee habitat in an arable landscape. *Biological Conservation*, **107(3)**, 365-374

Croxton, P.J., Hann, J.P., Greatorex-Davies, J.N. and Sparks, T.H. (2005) Linear hotspots? The floral and butterfly diversity of green lanes. *Biological Conservation*, **121(4)**, 579-584

Cuttle, S.P., Hallard, R.J., Speir, T.W. and Williams, P.H. (1992) Nitrate leaching from sheep-grazed grass/clover and fertilized pastures. *Journal of Agricultural Science*, **119**, 335-343

Dabney, S.M., Delgado, J.A. and Reeves, D. (2001) Using winter cover crops to improve soil and water quality. *Communications in Soil Science and Plant Analysis*, **32**, 1221-1250

DARD (n.d.) *Trees - On the Farm*. Department of Agriculture and Rural Development (DARD), Belfast

Davies, B., Biggs, J., Williams, P. and Thompson, S. (2009) Making agricultural landscapes more sustainable for freshwater biodiversity: a case study from southern England. *Aquatic Conservation: Marine and Freshwater Ecosystems*, **19(4)**, 439-447

Davies, B.R., Biggs, J., Williams, P.J., Lee, J.T. and Thompson, S. (2008) A comparison of the catchment sizes of rivers, streams, ponds, ditches and lakes: implications for protecting aquatic biodiversity in an agricultural landscape. *Hydrobiologia*, **597(1)**, 7-17

Davies, C.E., Moss, D. and Hill, M.O. (2004) *EUNIS Habitat Classification Revised 2004*. Report to the European Environment Agency (EEA) by the Centre for Hydrology and Ecology, UK

de Groot, R.S., Wilson, M.A. and Boumans, R.M.J. (2002) A typology for the classification, description and valuation of ecosystem functions, goods and services. *Ecological Economics*, **41**, 393-408

De Snoo, G.R. (1999) Unsprayed field margins: effects on environment, biodiversity and agricultural practice. *Landscape and Urban Planning*, **46(1)**, 151-160

Defra (2010) *Fertiliser Manual (RB209). 8th Edition*. Department for Environment, Food and Rural Affairs (Defra), The Stationery Office, London

Defra (n.d.) *Woodland: Tailored Advice on Managing Land for Pollinators*. Defra, London

DeMars, C.A., Rosenberg, D.K. and Fontaine, J.B. (2010) Multi-scale factors affecting bird use of isolated remnant oak trees in agro-ecosystems. *Biological Conservation*, **143(6)**, 1485-1492

Dimitriou, E., Karaouzas, I., Skoulikidis, N. and Zacharias, I. (2006) Assessing the environmental status of Mediterranean temporary ponds in Greece. *Annales de Limnologie - International Journal of Limnology*, **42(1)**, 33-41

Dimitriou, I., Busch, G., Jacobs, S., Schmidt-Walter, P. and Lamersdorf, N. (2009) A review of the impacts of Short Rotation Coppice cultivation on water issues. *Landbauforschung – vTI Agriculture and Forestry Research*, **59(3)**, 197-206

Dimitriou, I., Mola-Yudego, B., Aronsson, P. and Eriksson, J. (2012) Changes in some soil parameters in short-rotation coppice plantations on agricultural land in Sweden. *Bioenergy Research*, **5(3)**, 563-572

Dix M.E., Leatherman D., Brandle J.R., Hintz D. L. (1988) Insect management in windbreaks Proceedings of a symposium on windbreak technology, Lincoln, Nebraska, 23–27 June, 1986. *Agriculture, Ecosystems and Environment*, 22-23, 513-537

Dix, M.E., Johnson, R.J., Harrell, M.O., Case, R.M., Wright, R.J. (1995) Influences of Trees on Abundance of Natural Enemies of Insect Pests: A Review. *Agroforestry Systems*, **29**, 303-311

Djurhuus, J. and Olsen, P. (1997) Nitrate leaching after cut grass/clover ley affected by time of ploughing. *Soil Use and Management*, **13**, 61-67

Douglas, D.J., Vickery, J.A. and Benton, T.G. (2009) Improving the value of field margins as foraging habitat for farmland birds. *Journal of Applied Ecology*, **46(2)**, 353-362

Dover, J., Sparks, T., Clarke, S., Gobbett, K. and Glossop, S. (2000) Linear features and butterflies: the importance of green lanes. *Agriculture, Ecosystems and Environment*, **80(3)**, 227-242

DSWA – Dry Stone Walling Association (2007) Dry Stone Walls and Wildlife, Dry Stone Walling Association, Great Britain

Dudgeon, D., Arthington, A.H., Gessner, M.O., Kawabata, Z., Knowler, D.J., Lévêque, C., Naiman, R.J., Prieur-Richard, A.H., Soto, D., Stiassny, M.L. and Sullivan, C.A. (2006) Freshwater biodiversity: importance, threats, status and conservation challenges. *Biological reviews of the Cambridge Philosophical Society*, **81(2)**, 163-182

Duelli, P. and Obrist, M.K. (2003) Biodiversity indicators: the choice of values and measures. *Agriculture, Ecosystems and Environment*, **98**, 87-98

Dunning, N.P., Beach, T. (1994) Soil Erosion, Slope Management, and Ancient Terracing in the Maya Lowlands. *Latin American Antiquity*, **5**, 51-69

Dyda, J., Symes, N. and Lamacraft, D. (2009) *Woodland management for birds: a guide to managing woodland for priority birds in Wales*. The RSPB, Sandy and Forestry Commission Wales, Aberystwyth

EC (2009) Regulation (EC) No 1221/2009 of the European Parliament and of the Council of 25 November 2009 on the voluntary participation by organisations in a Community eco-management and audit scheme (EMAS). *Official Journal of the European Union*, **L 342**, 0001-0045, 22.12.2009

EC (2011) *Science for Environment Policy: Soil water repellency could change soil's ability to sequester carbon*. European Commission (EC) DG ENV News Alert Issue 267, Brussels

EC (2012) *The biodiversity value of stone field boundaries in Scilly*. Report under the European Agricultural Fund for Rural Development: Europe Investing in Rural Areas, European Commission (EC)

EC (2013) Regulation (EU) No 1307/2013 of the European Parliament and of the Council of 17 December 2013 establishing rules for direct payments to farmers under support schemes within the framework of the Common Agricultural Policy and repealing Council Regulation (EC) No 637/2008 and Council Regulation (EC) No 73/2009. *Official Journal of the European Union*, **L 347**: 608-670

EC (2014) Commission Delegated Regulation (EU) No 639/2014 of 11 March 2014 Supplementing Regulation (EU) No 1307/2013 of the European Parliament and of the Council Establishing Rules for Direct Payments to Farmers Under Support Schemes Within the Framework of the Common Agricultural Policy and Amending Annex X to that Regulation. European Commission (EC). *Official Journal of the European Union*, **L 181**: 1-47

Edgar, P., Foster, J., and Baker, J. (2010) *Reptile Habitat Management Handbook*. Amphibian and Reptile Conservation, Bournemouth, UK

EEA (2014) *Corine biotopes*. European Environment Agency (EEA). http://www.eea.europa.eu/data-and-maps/data/corine-biotopes (Last accessed: 26/02/2015)

EEA (2015a) *EUNIS habitat type hierarchical view*. European Environment Agency (EEA). http://eunis.eea.europa.eu/habitats-code-browser.jsp (Last accessed: 12/02/2015)

EEA (2015b) *EUNIS Groups*. European Environment Agency (EEA). http://eunis.eea.europa.eu/species-groups.jsp (Last accessed: 12/02/2015)

EEA (2015c) *EUNIS Species taxonomic classification*. European Environment Agency (EEA). http://eunis.eea.europa.eu/species-taxonomic-browser.jsp (Last accessed: 12/02/2015)

Eldridge, D.J. and Freudenberger, D. (2005) Ecosystem wicks: woodland trees enhance water infiltration in a fragmented agricultural landscape in eastern Australia. *Austral Ecology*, **30(3)**, 336-347

Elmarsdottir, A., Fjellberg, A., Halldorsson, G., Ingimarsdottir, M., Nielsen, O.K., Nygaard, P., Oddsdottir, E.S. and Sigurdsson, B.D. (2008) *Effects of afforestation on biodiversity*. In: Halldorsson, G., Oddsdottir, E.S. & Sigurdsson, B.D. (eds.): AFFORNORD. Effects of afforestation on ecosystems, landscape and rural development. *TemaNord*, 562, 37-47

Entrup, N.L. and Stemann, G. (199) Field beans: undersowing solves nitrate problems. *DLG-Mitteilungen*, **105(7)**, 276-277

European Pond Conservation Network. (2008) *The Pond Manifesto.* European Pond Conservation Network, Seville

Eurostat (2013) *The structure of agriculture in the EU - agricultural census 2010*. Chapter 2 in: Agriculture, forestry and fishery statistics. 2013 edition. Eurostat, Luxembourg

Evans, S.T. (1990) The productivity of Maguey terrace agriculture in Central Mexico during the Aztec period. *Latin American Antiquity*, **1**, 117-32

Ewald, N., Kalettka, T. and Brendonck, L. (2012) Eyes of the landscape - value, conservation and management of European ponds. *Limnologica*, **42(4)**, 251-253

Falloon, P., Powlson D. and Smith, P. (2004) Managing field margins for biodiversity and carbon sequestration: a Great Britain case study. *Soil Use and Management*, **20**, 240-247.

Fang, C.F. and Ling, D.L. (2003) Investigation of the noise reduction provided by tree belts. *Landscape and Urban Planning*, **63(4)**, 187-195

Farley, K.A, Jobbágy, E.G. and Jackson, R.B. (2005) Effects of afforestation on water yield: a global synthesis with implications for policy. *Global Change Biology*, **11(10)**, 1565-1576

Ferreira, M. and Beja, P. (2013) Mediterranean amphibians and the loss of temporary ponds: Are there alternative breeding habitats? *Biological Conservation*, **165**, 179-186

Finn, J. A., Kirwan, L. and Connolly, J. (2013) Ecosystem function enhanced by combining four functional types of plant species in intensively managed grassland mixtures: a 3-year continental-scale field experiment. *Journal of Applied Ecology*, **50**, 365-375

Fischer, J., Stott, J. and Law, B.S. (2010) The disproportionate value of scattered trees. *Biological Conservation*, **143(6)**, 1564-1567

Fisher, B., Turner, R.K. and Morling, P. (2009) Defining and classifying ecosystem services for decision making. *Ecological Economics*, **68**,643-653

Fitzgibbon, C.D. (1993) The distribution of grey squirrel dreys in farm woodland: the influence of wood area, isolation and management. *Journal of Applied Ecology*, **30(4)**, 736-742

Forestry Commission (2003) *The Forests & Water Guidelines, Fourth Edition*. Forestry Commission, Edinburgh, UK

Forestry Commission (2005) *Woodland management for bats*. Forestry Commission, Edinburgh, UK

Forman, R.T. and Baudry, J. (1984) Hedgerows and hedgerow networks in landscape ecology. *Environmental management*, **8(6)**, 495-510

Francis, R.A. (2010) Wall ecology: A frontier for urban biodiversity and ecological engineering. *Progress in Physical Geography*, **35(1)**, 43-63

Franzluebbers, A.J., Langdale, G.W., Schomberg, H.H. (1999) Soil carbon, nitrogen, and aggregation in response to type and frequency of tillage. *Soil Science Society of America Journal*, **63**, 349-355

Fry, G. and Sarlöv-Herlin, I. (1997) The ecological and amenity functions of woodland edges in the agricultural landscape; a basis for design and management. *Landscape and Urban Planning*, **37(1-2)**, 45-55

Fuentes-Montemayor, E., Goulson, D. and Park, K.J. (2011) Pipistrelle bats and their prey do not benefit from four widely applied agri-environment management prescriptions. *Biological Conservation*, **144(9)**, 2233-2246

Funtowicz, S., Munda, G. and Paruccini, M. (1990) The aggregation of environmental data using multicriteria methods. *Environmetrics*, **1(4)**, 353-368

Fussell, M and Corbet, S.A. (1992) The nesting places of some British bumble bees. *Journal of Apicultural Research*, **31**, 32-41

Gange A.C. and Llewellyn M. (1989) Factors affecting orchard colonisation by the black-kneed capsid (*Blepharidopterus angulatus* (Hemiptera: Miridae) from alder windbreaks), *Annals of Applied Biology*, **2**, 221-230

García-Ruiz, J.M. (2010) The effects of land uses on soil erosion in Spain: A review. *Catena*, **81**, 1-11

García-Ruiz, J.M., Lasanta, T., Ortigosa, L., Ruiz-Flaño, P., Martí, C. and González, C. (1995) Sediment yield under different land uses in the Spanish Pyrenees. *Mountain Research and Development*, **15(3)**, 229-240

Gee, J.H.R., Smith, B.D., Lee, K.M. and Griffiths, S.W. (1997) The ecological basis of freshwater pond management for biodiversity. *Aquatic Conservation: Marine and Freshwater Ecosystems*, **7(2)**, 91-104

Geertsema, W. and Sprangers, J.T.C.M. (2002) Plant distribution patterns related to species characteristics and spatial and temporal habitat heterogeneity in a network of ditch banks. *Plant Ecology*, **162(1)**, 91-108

Gibbons, P., Lindenmayer, D.B., Fischer, J., Manning, A D., Weinberg, A., Seddon, J., Ryan, P. and Barrett, G. (2008) The future of scattered trees in agricultural landscapes. *Conservation Biology*, **22(5)**, 1309-1319

Girardin, P., Bockstaller, C. and Van der Werf, H. (1999) Indicators: Tools to Evaluate the Environmental Impacts of Farming Systems. *Journal of Sustainable Agriculture*, **13(4)**, 5-21

Goulson, D., Lye, G.C. and Darvill, B. (2005) Decline and Conservation of Bumble Bees. *Annual Review of Entomology*, **53**, 191-208

Graham, S., Wilson, B.R., Reid, N. and Jones, H. (2003) Scattered paddock trees, litter chemistry and surface soil properties in pastures of the New England Tablelands, New South Wales. *Australian Journal of Soil Research,* **42**, 905-912

Greenhalgh, T. and Peacock, R. (2005) Effectiveness and efficiency of search methods in systematic reviews of complex evidence: audit of primary sources. *British Medical Journal*, **331(7524)**,1064-1065

Gyssels, G., Poesen, J., Bochet, E. and Li, Y. (2005) Impact of plant roots on the resistance of soils to erosion by water: a review. *Progress in Physical Geography*, **29(2)**, 189-217

Hagen, L.J. and Skidmore, E.L. (1971) Turbulent Velocity Fluctuations and Vertical Flow as Affected by Windbreak Porosity. *Transactions of the ASAE*, **14(4)**, 634-637

Haines-Young, R. and Potschin, M. (2010) *Proposal for a Common International Classification of Ecosystem Goods and Services (CICES) for Integrated Environmental and Economic Accounting (V1).* Report prepared by Centre for Environmental Management, University of Nottingham, United Kingdom for the European Environment Agency, Contract No: No. EEA/BSS/07/007 21 March 2010

Haines-Young, R. and Potschin, M. (2013) *Common International Classification of Ecosystem Services (CICES): Consultation on Version 4, August-December 2012*. EEA Framework Contract No EEA/IEA/09/003

Hall, R.L., Allen, S.J., Rosier, P.T.W., Smith, D.M., Hodnett, M.G., Roberts, J.M., Hopkins, R., Davies, H.N., Kinniburgh, D.G. and Goody, D.C. (1996) *Hydrological effects of short rotation coppice*. Institute of Hydrology report to the Energy Technology Support Unit, ETSU.

Hanley, M.E., Franco, M., Dean, C.E., Franklin, E.L., Harris, H.R., Haynes, A.G., Rapson, S.R. and Knight, M.E. (2011) Increased bumblebee abundance along the margins of a mass flowering crop: evidence for pollinator spill-over. *Oikos*, **120(11)**, 1618-1624

Hannon, L.E. and Sisk, T.D. (2009) Hedgerows in an agri-natural landscape: potential habitat value for native bees. *Biological conservation*, **142(10)**, 2140-2154

Hanowski, J.M., Niemi, G.J. and Christian, D.C. (1997) Influence of within plantation heterogeneity and surrounding landscape composition on avian communities in hybrid poplar plantations. *Conservation Biology*, **11(4)**, 936-944

Hanson, C.G. and Mason, J.L. (1985) Bird seed aliens in Britain. *Walsonia*, **15**,237-252

Harris, R.A. and Cohn, L.F. (1985) Use of vegetation for abatement of highway traffic noise. *Journal of urban planning and development*, **111(1)**, 34-48

Hauggaard-Nielsen, H., Ambus, P. and Jensen, E.S. (2003) The comparison of nitrogen use and leaching in sole cropped versus intercropped pea and barley. *Nutrient Cycling in Agroecosystems*, **65**, 289-300

HCT (2007) *National Amphibian and Reptile Recording Scheme (NARRS). Reptile Habitat Guide*. The Herpetological Conservation Trust (HCT), with financial support from Natural England, UK

Heard, M.S., Carvell, C., Carreck, N.L., Rothery, P., Osborne, J.L. and Bourke, A.F.G. (2007) Landscape context not patch size determines bumble-bee density on flower mixtures sown for agri-environment schemes. *Biology Letters*, **3**, 638-641

Heilman, P. and Norby, R.J. (1998) Nutrient cycling and fertility management in temperate short rotation forest systems. *Biomass and Bioenergy*, **14(4)**, 361-370

Helliwell, D.R. (1975) The distribution of woodland plant species in some Shropshire Hedgerows. *Biological Conservation,* **7**, 61-71

Hernández-Morcillo, M., Plieninger, T. and Bieling, C. (2013) An empirical review of cultural ecosystem service indicators. *Ecological Indicators*, **29**, 434-444

Herzon, I. and Helenius, J. (2008) Agricultural drainage ditches, their biological importance and functioning. *Biological Conservation*, **141(5)**, 1171-1183

Hill, A.R. (1996) Nitrate Removal in Stream Riparian Zones. *Journal of Environmental Quality*, **25(4)**, 743-755

Hill, C.R. and Robinson, J.S. (2012) Phosphorus flux from wetland ditch sediments. *Science of the Total Environment*, **437**, 315-322

Hilty, J.A., Lidicker Jr., W.Z. and Merenlender, A.M. (eds.) (2006) *Corridor Ecology. The Science and Practice of Linking Landscapes for Biodiversity Conservation*. Island Press, London, UK

Hinden, H., Oertli, B., Menetrey, N., Sager, L. and Lachavanne, J.-B. (2005) Alpine pond biodiversity: what are the related environmental variables? *Aquatic Conservation: Marine and Freshwater Ecosystems*, **15(6)**, 613-624

Hinsley, S.A. and Bellamy, P.E. (2000) The influence of hedge structure, management and landscape context on the value of hedgerows to birds: a review. *Journal of Environmental Management*, **60(1)**, 33-49

Holland, J.M. and Luff, M.L. (2000) The effects of agricultural practices on Carabidae in temperate agroecosystems. *Integrated Pest Management Reviews*, **5(2)**, 109-129

Holland, J.M., Perry, J.N. and Winder, L. (1999) The within-field spatial and temporal distribution of arthropods in winter wheat. *Bulletin of Entomological Research*, **89**, 499-513

Holland, J.M., Thomas, C.F.G., Birkett, T., Southway, S. and Oaten, H. (2005) Farm-scale spatiotemporal dynamics of predatory beetles in arable crops. *Journal of Applied Ecology*, **42(6)**, 1140-1152

Holland, P.G. (1972) The pattern of species density of old stone walls in western Ireland. *The Journal of Ecology*, **60(3)**, 799-805

Hubbard, V.C., Jordan, D. and Stecker, J.A. (1999) Earthworm response to rotation and tillage in a Missouri claypan soil. *Biology and Fertility of Soils*, **29**, 343-347

Huhta, V. (1976) Effects of clear-cutting on numbers, biomass and community respiration of soil invertebrates. *Annales of Zoologici fennici,* **13**, 63-80

Humphrey, J. Ferris, R., Jukes, M. and Peace, A. (2002) *Biodiversity in Planted Forests*. In Forest Research (Ed.) *Annual Report and Accounts 2000-2001.* (pp. 24-33). The Stationery Office, Edinburgh

Hunter, M.D. (2002) Landscape structure, habitat fragmentation, and the ecology of insects. *Agricultural and Forest Entomology*, **4(3)**, 159-166

IGER (2002) *Scoping the potential of farm ponds to provide environmental benefits – Final Project Report, Defra project ES0109.* Defra, London

IPCC (2006) *2006 Guidelines for National Greenhouse Gas Inventories. Intergovernmental Panel on Climate Change*. Prepared by the National Greenhouse Gas Inventories Programme, Eggleston H.S., Buendia L., Miwa

Jacobs, S., Burkhard, B., Van Daele, T., Staes, J. and Schneiders, A. (2015) 'The Matrix Reloaded': A review of expert knowledge use for mapping ecosystem services. *Ecological Modelling*, **295**, 21-30

Jeffries, M. (2005) Small ponds and big landscapes: the challenge of invertebrate spatial and temporal dynamics for European pond conservation. *Aquatic Conservation: Marine and Freshwater Ecosystems*, **15(6)**, 541-547

Jensen, E.S., Peoples, M.B. and Hauggaard-Nielsen, H. (2010) Faba bean in cropping systems. *Field Crops Research*, **115**, 203-216

Jerzy, K.A.R.G. (2004) Importance of midfield shelterbelts for over-wintering entomofauna (Turew area, West Poland). *Polish Journal of Ecology*, **52(4)**, 421-431

JNCC (2001) *Habitat management for bats. A guide for land managers, land owners and their advisors*. Joint Nature Conservation Committee (JNCC), UK

JNCC (2010) *Handbook for Phase 1 habitat survey. A technique for environmental audit*. Joint Nature Conservation Committee (JNCC), UK. ISBN : 978-0-86139-636-8

Jobin, B., Boutin, C. and DesGranges, J.-L. (1997) Effects of agricultural practices on the flora of hedgerows and woodland edges in southern Quebec. *Canadian Journal of Plant Science*, **77(2)**, 293-299

Johnston, A.E. and Dawson, C.J. (2005) *Phosphorus in agriculture and in relation to water quality*. Peterborough, UK, Agricultural Industries Confederation. 72 pp.

Jose, S. (2009) Agroforestry for ecosystem services and environmental benefits: an overview. *Agroforestry systems*, **76(1)**, 1-10

Josefsson, J., Berg, Å, Hiron, M., Pärta, T. and Eggers, S. (2013) Grass buffer strips benefit invertebrate and breeding skylark numbers in a heterogeneous agricultural landscape. *Agriculture, Ecosystems and Environment*, **181**, 101-107

Joshi, J., Matthies, D. and Schmid, B. (2000) Root hemiparasites and plant diversity in experimental grassland communities. *Journal of Ecology*, **88**, 634-644

Justus, M. and Köpke, U. (1995) Strategies to reduce nitrogen losses via leaching and to increase precrop effects when growing faba beans. *Biological Agriculture and Horticulture*, **11(1-4)**, 145-155

Kaennel, M. (1998) *Biodiversity: a diversity in definition*. In: Bachmann, P., Köhl, M. and Päivinen, R. (Eds.) Assessment of Biodiversity for Improved Forest Planning. Kluwer Academic Publishers, Dordrecht

Kahle, P., Hildebrand, E., Baum, C. and Boelcke, B. (2007) Long-term effects of short rotation forestry with willows and poplar on soil properties. *Archives of Agronomy and Soil Science*, **53(6)**, 673-682

Kalda, O., Kalda, R. and Liira, J. (2015) Multi-scale ecology of insectivorous bats in agricultural landscapes. *Agriculture, Ecosystems and Environment*, **199(1)**, 105-113

Kaspar, T.C., Kladivko, E.J., Singer, J.W., Morse, S. and Mutch, D.R. (2008) *Potential and limitations of cover crops, living mulches, and perennials to reduce nutrient losses to water sources from agricultural fields*. In UMRSHNC (Upper Mississippi River Sub-basin Hypoxia Nutrient Committee). Final Report: Gulf Hypoxia and Local Water Quality Concerns Workshop. St. Joseph, Michigan: ASABE. American Society of Agricultural and Biological Engineers. pp. 127-148

Kavdır, Y., Rasse, D.P. and Smucker, A.J.M. (2005) Specific contributions of decaying alfalfa roots to nitrate leaching in a Kalamazoo loam soil. *Agriculture, Ecosystems and Environment*, **109**, 97-106

Kay, P., Edwards, A.C. and Foulger, M (2009) A review of the efficacy of contemporary agricultural stewardship measures for ameliorating water pollution problems of key concern to the UK water industry. *Agricultural Systems*, **99(2-3)**, 67-75

Kells, A.R. and Goulson, D. (2003) Preferred nesting sites of bumblebee queens (*Hymenoptera: Apidae*) in agroecosystems in the UK. *Biological Conservation*, **109**, 165-174

Kirby, K.J. (1993) *The effects of plantation management on wildlife in Great Britain: lessons from ancient woodland for the development of afforestation sites*. In: Ecological Effects of Afforestation (ed. C. Watkins). CAB International, Melksham

Kirk, W.D.J. and Howes, F.N. (2012) *Plants for bees*. International Bee Research Association. Cardiff, UK

Koike, S.T., Smith, R., Jackson, L.E., Wyland, L.J., Chaney, W.E. and Inman, J.I. (1997) Cover crops can increase lettuce drop. *California Agriculture*, **51**, 15-18

Köpke, U. and Nemecek, T. (2010) Ecological services of faba bean. *Field Crops Research*, **115(3)**, 217-233

Korpela, E.L., Hyvönen, T., Lindgren, S. and Kuussaari, M. (2013) Can pollination services, species diversity and conservation be simultaneously promoted by sown wildflower strips on farmland? *Agriculture, Ecosystems & Environment*, **179**, 18-24

Kort, J., Collins, M. and Ditsch, D. (1998) A review of soil erosion potential associated with biomass crops. *Biomass and Bioenergy*, **14**, 351-359

Kröger, R., Scott, J.T. and Czarnecki, J.M.P. (2014) Denitrification potential of low-grade weirs and agricultural drainage ditch sediments in the Lower Mississippi Alluvial Valley. *Ecological Engineering*, **73**, 168-175

Kromp, B. (1999) Carabid beetles in sustainable agriculture: a review on pest control efficacy, cultivation impacts and enhancement. *Agriculture, Ecosystems and Environment*, **74**, 187-228

Kruidhof, H.M., Bastiaans, L. and Kropff, M.J. (2008) Ecological weed management by cover cropping: effects on weed growth in autumn and weed establishment in spring. *Weed Research*, **48**, 492-502

Krutz, L.J., Senseman, S.A., Zablotowicz, R.M. and Matocha, M.A. (2005) Reducing herbicide runoff from agricultural fields with vegetative filter strips: a review. *Weed Science*, **53(3)**, 353-367

Kuwano, S., Namba, S., Komatsu, M., Kato, T. and Hayashi, Y. (2001) Auditory and visual interaction in the aesthetic evaluation of environment. *Empirical Studies of the Arts*, **19(2)**, 191-200

Lagerlöf, J., Stark, J. and Svensson, B. (1992. Margins of agricultural fields as habitats for pollinating insects. *Agriculture, Ecosystems & Environment*, **40(1)**, 117-124

Langeveld, H., Quist-Wessel, F., Dimitriou, I., Aronsson, P., Baum, C., Schulz, U., Bolte, A., Baum, S., Köhn, J., Weih, M., Gruss, H., Leinweber, P., Lamersdorf, N., Schmidt-Walter, P. and Berndes, G. (2012). Assessing Environmental Impacts of Short Rotation Coppice (SRC) Expansion: Model Definition and Preliminary Results. *Bioenergy Research*, **5(3)**, 621-635

Lasanta, T., Beguería, S. and García-Ruiz, J.M. (2006a) Geomorphic and hydrological effects of traditional shifting agriculture in a Mediterranean mountain, Central Spanish Pyrenees. *Mountain Research and Development*, **26(2)**, 146-152

Lasanta, T., González-Hidalgo, J.C., Vicente-Serrano, S.M. and Sferi, E. (2006b) Using landscape ecology to evaluate an alternative management scenario in abandoned Mediterranean mountain areas. *Landscape and Urban Planning*, **78**, 101-114

Lazdinis, M., Roberge, J.-M., Kurlavičius, P., Mozgeris, G. and Angelstam, P. (2005) Afforestation Planning and Biodiversity Conservation: Predicting Effects on Habitat Functionality in Lithuania. *Journal of Environmental Planning and Management*, **48(3)**, 331-348

Le Coeur, D., Baudry, J., Burel, F. and Thenail, C. (2002) Why and how we should study field boundary biodiversity in an agrarian landscape context. *Agriculture, Ecosystems & Environment*, **89(1)**, 23-40

Le Féon, V., Burel, F., Chifflet, R., Henry, M., Ricroch, A., Vaissière, B.E. and Baudry, J. (2013) Solitary bee abundance and species richness in dynamic agricultural landscapes. *Agriculture, Ecosystems & Environment*, **166**, 94-101

Le Houérou, H.N. (1993) Land degradation in Mediterranean Europe: can agroforestry be a part of the solution? A prospective review. *Agroforestry Systems*, **21(1)**, 43-61

Leeds-Harrison, P.B., Quinton, J.N., Walker, M.J., Sanders, C.L. and Harrod, T. (1999) Grassed buffer strips for the control of nitrate leaching to surface waters in headwater catchments. *Ecological Engineering*, **12(3-4)**, 299-313

Leng, W., Musters, C.J.M. and de Snoo, G.R. (2011) Effects of mowing date on the opportunities of seed dispersal of ditch bank plant species under different management regimes. *Journal for Nature Conservation*, **19(3)**, 166-174

Lesschen, J.P., Kok, K., Verburg, P.H. and Cammeraat, L.H. (2007) Identification of vulnerable areas for gully erosion under different scenarios of land abandonment in Southeast Spain. *Catena*, **71**, 110-121

Lewis, T. (1969) The distribution of flying insects near a low hedgerow. *Journal of Applied Ecology*, **6(3)**, 443-452

Liu, X., He, B., Li, Z., Zhang, J., Wang, L. and Wang, Z. (2011) Influence of land terracing on agricultural and ecological environment in the loess plateau regions of China. *Environmental Earth Sciences*, **62(4)**, 797-807

López, M.V., Gracia, R., Arrúe, J.L., 2000. Effects of reduced tillage on soil surface properties affecting wind erosion in semiarid fallow lands of Central Aragón. *European Journal of Agronomy*, **12(3)**, 191-199

Lord, E., Shepherd, M., Silgram, M., Goodlass, G., Gooday, R., Anthony, A., Davison, P. and Hodgkinson, R. (2007) *Investigating the effectiveness of NVZ Action Programme measures: development of a strategy for England*. Final report for Defra project NIT18. 116pp + 11 Appendices

Lovei, G.L., Hodgeson, D.J., Macleod, A. and Wratten, S.D. (1993) *Attractiveness of some novel crops for fower-visiting hoverfies (Diptera: Syrphidae): comparisons from two continents*. In S. Corey (ed.), Pest control and sustainable agriculture. CSIRO, Canberra, Australia.

Lovell, S.T. and Sullivan, W.C. (2006) Environmental benefits of conservation buffers in the United States: Evidence, promise, and open questions. *Agriculture, Ecosystems and Environment*, **112(4)**, 249-260

Lowrance, R., Todd, R., Fail, J., Hendrickson, O., Leonard, R. and Asmussen, L. (1984) Riparian Forests as Nutrient Filters in Agricultural Watersheds. *BioScience*, **34**, 374-377

Luff, M.L. (1994) *Starvation capacities of some carabid larvae*. In: Dufréne, M., Loreau, M., Luff, M.L., Maelfait, J.-P. (Eds.), Carabid Beetles, Ecology and Evolution, Kluwer Academic Publishers, Series Entomologica 51, 171–175.

Lye, G., Park, K., Osborne, J., Holland, J. and Goulson, D. (2009) Assessing the value of Rural Stewardship schemes for providing foraging resources and nesting habitat for bumblebee queens (*Hymenoptera: Apidae*). *Biological Conservation*, **142**, 2023-2032

Macdonald, A.J., Powlson, D.S., Poulton, P.R. and Jenkinson, J.S. (1989) Unused fertiliser nitrogen in arable soils—its contribution to nitrate leaching. *Journal of the Science of Food and Agriculture*, **46(4)**, 407-419

Machefert, S.E., Dise, N.B., Goulding, K.W.T. and Whitehead, P.G. (2002) Nitrous oxide emission from a range of land uses across Europe. *Hydrology and Earth System Sciences*, **6**, 325-337

Maes, J., Teller, A., Erhard, M., Murphy, P., Paracchini, M.L., Barredo, J.I., Grizzetti, B, Cardoso, A., Somma, F., Petersen, J.E., Meiner, A., Gelabert, E.R., Zal, N., Kristensen, P., Bastrup-Birk, A., Biala, K., Romao, C., Piroddi, C., Egoh, B., Fiorina, C., Santos, F., Naruševičius, V., Verboven, J., Pereira, H., Bengtsson, J., Gocheva, K., Marta-Pedroso, C., Snäll, T., Estreguil, C., San Miguel, J., Braat, L., Grêt-Regamey, A., Perez-Soba, M., Degeorges, P., Beaufaron, G., Lillebø, A., Abdul Malak, D., Liquete, C., Condé, S., Moen, J., Östergård, H. Czúcz, B., Drakou, E.G., Zulian, G. and Lavalle, C. (2014) *Mapping and Assessment of Ecosystems and their Services. Indicators for ecosystem assessments under Action 5 of the EU Biodiversity Strategy to 2020*. Technical Report - 2014 – 080. 2nd Report – Final, February 2014, ISBN 978-92-79-36161-6, doi: 10.2779/75203, European Union

Maisonneuve, C. and Rioux, S. (2001) Importance of riparian habitats for small mammal and herpetofaunal communities in agricultural landscapes of southern Québec. *Agriculture, Ecosystems and Environment*, **83(1-2)**, 165-175

Manning, A.D., Fischer, J. and Lindenmayer, D.B. (2006) Scattered trees are keystone structures–implications for conservation. *Biological Conservation*, **132(3)**, 311-321

Marques, M.J., García-Muñoz, S., Muñoz-Organero, G. and Bienes, R. (2010) Soil conservation beneath grass cover in hillside vineyards under Mediterranean climatic conditions (Madrid, Spain). *Land Degradation and Development*, **21**,122–131

Marshall, E.J.P. and Moonen, A.C. (2002) Field margins in northern Europe: their functions and interactions with agriculture. *Agriculture, Ecosystems & Environment*, **89(1)**, 5-21

Mathers, A.C., Stewart, B.A. and Blair, B. (1975) Nitrate-nitrogen removal from soil profiles by alfalfa. *Journal of Environmental Quality*, **4**, 403-405

Matthews, S., O'Connor, R. and Plantinga, A.J. (2002) Quantifying the impacts on biodiversity of policies for carbon sequestration in forests. *Ecological Economics*, **40(1)**, 71-87

Mazurek, M. J. and Zielinski, W. J. (2004) Individual legacy trees influence vertebrate wildlife diversity in commercial forests. *Forest Ecology and Management*, **193(3)**, 321-334

McCollin, D., Jackson, J.I., Bunce, R.G.H., Barr, C.J. and Stuart, R. (2000) Hedgerows as habitat for woodland plants. *Journal of Environmental Management*, **60(1)**, 77-90

McCormack, C., Dicks, L., Kloen, H., van Tonder, C., Heathcote, R. and Hillier, J. (2014) *An evidence-based online tool for assessing farm-scale biodiversity*. Poster presented at Biodiversity and Food Security – From Trade-offs to Synergies, 3rd International Conference on Biodiversity and the UN Millennium Development Goals, October 29-31, 2014, Aix-en-Provence, France

McInnes, R.J., Crane, M., Rodda, H.J.E., Danks, P.W., Hogan, D.V. and Field, A.I. (2008) *Management of the Otmoor protected area (Oxfordshire) (Multifunctional wetlands in agricultural landscapes: An evaluation of values, impacts and the application of the ecosystem-based approach)*. WWT Report to Defra. Project Reference: NR0112. WWT, Slimbridge, UK

McKay, H. (ed.) (2011) *Short Rotation Forestry: review of growth and environmental impacts*. Forest Research Monograph, 2, Forest Research, Surrey, 212pp.

McLenaghen, R.D., Cameron, K.C., Lampkin, N.H., Daly, M.L. and Deo, B. (1996) Nitrate leaching from ploughed pasture and the effectiveness of winter catch crops in reducing leaching losses. *New Zealand Journal of Agricultural Research*, **39(3)**, 413-420

McNaughton, K.G., Unsworth, M.H. and Raupach, M.R. (1989) Micrometeorology of Shelter Belts and Forest Edges. *Philosophical Transactions of the Royal Society B: Biological Sciences*, **324(1223)**, 351-368

MEA (2003) *Ecosystems and Human Well-Being.* A Framework for Assessment. Millennium Ecosystem Assessment (MEA), Island Press, Washington DC, USA

MEA (2005) Ecosystems and Human Well-Being. Synthesis. Millennium Ecosystem Assessment (MEA), Island Press, Washington DC, USA

Meddings, A., Taylor, S., Batty, L., Green, R., Knowles, M. and Latham, D. (2011) Managing competition between birds and bats for roost boxes in small woodlands, north-east England. *Conservation Evidence*, **8**, 74-80

Meek, B., Loxton, D., Sparks, T., Pywell, R., Pickett, H. and Nowakowski, M. (2002) The effect of arable field margin composition on invertebrate biodiversity. *Biological Conservation*, **106(2)**, 259-271

Menz, M.H., Phillips, R.D., Winfree, R., Kremen, C., Aizen, M.A., Johnson, S.D. and Dixon, K.W. (2011) Reconnecting plants and pollinators: challenges in the restoration of pollination mutualisms. *Trends in Plant Science*, **16(1)**, 4-12

MEPA (2015) Terrestrial Habitats. Malta Environment and Planning Authority. http://www.mepa.org.mt/biodiversity-habitats-terrestrial (Last accessed: 26/02/2015)

Merckx, T., Feber, R.E., Riordan, P., Townsend, M.C., Bourn, N.A., Parsons, M.S. and Macdonald, D.W. (2009) Optimizing the biodiversity gain from agri-environment schemes. *Agriculture, Ecosystems & Environment*, **130(3)**, 177-182

Miracle, M.R., Oertli, B., Céréghino, R. and Hull, A. (2010) Preface: conservation of European ponds-current knowledge and future needs. *Limnetica*, **29(1)**, 1-8

Moller-Hansen, E. and Djurhuus, J. (1997) Nitrate leaching as influenced by soil tillage and catch crop. *Soil and Tillage Research*, **41(3-4)**, 203-219

Moore, M.T., Kröger, R., Locke, M.A., Cullum, R.F., Steinriede, Jr., R.W., Testa, III, S., Lizotte, Jr., R.E., Bryant, C.T. and Cooper, C.M. (2010) Nutrient mitigation capacity in Mississippi Delta, USA drainage ditches. *Environmental Pollution*, **158(1)**, 175-184

Morandin, L.A. and Kremen, C. (2013) Hedgerow restoration promotes pollinator populations and exports native bees to adjacent fields. *Ecological Applications*, **23(4)**, 829-839

Mountford, J.O., Parish, T and Sparks, T. H. (1994) *The flora of field margins in relation to land use and boundary features. Field Margins: Integrating Agriculture and Conservation*. Monograph No. 58. British Crop Protection Council, pp. 105–110

Muñoz-Carpena, R., Fox, G.A and Sabbagh, G.J. (2010) Parameter importance and uncertainty in predicting runoff pesticide reduction with filter strips. *J. Environ. Qual.*, **39(2)**, 630-641

Musters, C.J.M., Van Alebeek, F., Geers, R.H.E.M., Korevaar, H., Visser, A. and De Snoo, G.R. (2009) Development of biodiversity in field margins recently taken out of production and adjacent ditch banks in arable areas. *Agriculture, Ecosystems & Environment*, **129(1)**, 131-139

Nabuurs, G.J., Masera, O., Andrasko, K., Benitez-Ponce, P., Boer, R., Dutschke, M., Elsiddig, E., Ford-Robertson, J., Frumhoff, P., Karjalainen, T., Krankina, O., Kurz, W.A., Matsumoto, M., Oyhantcabal, W., Ravindranath, N.H., Sanz Sanchez, M.J. and Zhang, X. (2007) Forestry. In: B. Metz, O.R. Davidson, P.R. Bosch, R. Dave & L.A. Meyer (eds.) *Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.* Cambridge University Press, Cambridge & New York

Nair, P.K. (2011) Agroforestry Systems and Environmental Quality: Introduction. *Journal of Environmental Quality*, **40(3)**, 784-790

Nair, V.D. and Graetz, D.A. (2004) Agroforestry as an approach to minimizing nutrient loss from heavily fertilized soils: The Florida experience. *Agroforestry Systems*, **61-62(1-3)**, 269-279

Natural England (2010) *Technical Information Note TIN079: Illustrated Guide to Ponds and Scrapes.* Natural England, Worcester, UK

Natural England (2013) Entry Level Stewardship (ELS) Handbook 4th edition NE349. Natural England, UK

NBSAP (2012) *Country Study (2010) & Proposed National Biodiversity Strategy and Action Plan for Malta (2012-2020)*. Malta's National Biodiversity Strategy and Action Plan (NBASP)

Needelman, B.A., Ruppert, D.E. and Vaughan, R.E. (2007) The role of ditch soil formation and redox biogeochemistry in mitigating nutrient and pollutant losses from agriculture. *Journal of Soil and Water Conservation*, **70(1)**, 207-215

Nicolet, P., Biggs, J., Fox, G., Hodson, M.J., Reynolds, C., Whitfield, M. and Williams, P. (2004) The wetland plant and macroinvertebrate assemblages of temporary ponds in England and Wales. *Biological Conservation*, **120(2)**, 261-278

Nicolet, P., Ruggiero, A. and Biggs, J. (2007) Second European Pond Workshop: Conservation of pond biodiversity in a changing European landscape. *Annales de Limnologie - International Journal of Limnology*, **43(2)**, 77-80

Niemeijer, D. (2002) Developing indicators for environmental policy: data-driven and theory-driven approaches examined by example. *Environmental Science & Policy*, **5(2)**, 91-103

Nisbet, T., Thomas, H. and Shah, N. (2011). *Short Rotation Forestry and Water*. In McKay, H. (ed.) (2011) Short Rotation Forestry: review of growth and environmental impacts. Forest Research Monograph, 2, Forest Research, Surrey, 212pp.

Novara, A., Gristina, L., Saladino, S.S., Santoro, A., and Cerdà, A. (2011) Soil erosion assessment on tillage and alternative soil managements in a Sicilian vineyard. *Soil & Tillage Research*, **117**, 140-147

Nyakatawa, E.Z., Maysa, D.A., Tolbert, V.R., Green, T.H. and Bingham, L. (2006) Runoff, sediment, nitrogen, and phosphorus losses from agricultural land converted to sweetgum and switchgrass bioenergy feedstock production in north Alabama. *Biomass and Bioenergy*, **30**, 655-664

Ochiai, N., Powelson, M.L., Crowe, F.J. and Dick, R.P. (2008) Green manure effects on soil quality in relation to suppression of Verticillium wilt of potatoes. *Biology and Fertility of Soils*, **44(8)**, 1013-1023

Ockenden, M.C., Deasy, C., Quinton, J.N., Surridge, B. and Stoate, C. (2014) Keeping agricultural soil out of rivers: Evidence of sediment and nutrient accumulation within field wetlands in the UK. *Journal of Environmental Management*, **135**, 54-62

O'Connor, R.J. (1987) *Environmental interests of field margins for birds*. In: J.M. Way and P.W. Greig-Smith (Editors), Field Margins. BCPC, Thornton Heath, pp. 35-48

O'Driscoll, E. (ed). (2013) *An Overview of the Irish Forestry and Forest Products Sector 2013*. Irish Forestry and Forest Products Association, Dublin

Oertli, B., Biggs, J., Céréghino, R., Grillas, P., Joly, P. and Lachavanne¸ J-B. (2005) Conservation and monitoring of pond biodiversity : introduction. *Aquatic Conservation: Marine and Freshwater Ecosystems*, **15(6)**, 535-540

Oertli, B., Joye, D.A., Castella, E., Juge, R., Cambin, D. and Lachavanne, J.-B. (2002) Does size matter? The relationship between pond area and biodiversity. *Biological Conservation*, **104(1)**, 59-70

Oldham, R.S., Keeble, J., Swan, M.J.S. and Jeffcote, M. (2000) Evaluating the suitability of habitat for the great crested newt (*Triturus cristatus*). *Herpetological Journal*, **10**, 143-155

Oliver, I., Pearce, S., Greenslade, P.J. and Britton, D.R. (2006) Contribution of paddock trees to the conservation of terrestrial invertebrate biodiversity within grazed native pastures. *Austral Ecology*, **31(1)**, 1-12

Olson, D.M. and Wäckers, F.L. (2007) Management of field margins to maximize multiple ecological services. *Journal of Applied Ecology*, **44(1)**, 13-21

Ouin, A., Cabanettes, A., Andrieu, E., Deconchat, M., Roume, A., Vigan, M. and Larrieu, L. (2015) Comparison of tree microhabitat abundance and diversity in the edges and interior of small temperate woodlands. *Forest Ecology and Management*, **340**, 31-39

Oxbrough, A., Irwin, S., Kelly, T.C. and O'Halloran, J. (2010) Ground-dwelling invertebrates in reforested conifer plantations. *Forest Ecology and Management*, **259**, 2111-2121

Paoletti M.G. (2002) Biodiversity in agroecosystems and bio-indicators of environmental health (In: Structure and Function in Agroecosystems Designing and management. *Advances in Agroecology, Eds: M. Shiyomi and H. Koizumi*) – CRC Press, Boca Raton, Fl.: 11–44

Paoletti, M.G. and Lorenzoni, G.G. (1989) Agroecology patterns in northeastern Italy. *Agriculture, Ecosystems & Environment*, **27(1)**, 139-154

Paracchini, M.L., Bulgheroni, C., Borreani, G., Tabacco, E., Banterle, A., Bertoni, D., Rossi, G., Parolo, G., Origgi, R. and De Paola, C. (2015) A diagnostic system to assess sustainability at a farm level: The SOSTARE model. *Agricultural Systems*, **133**, 35-53

Parish, T., Lakhani, K.H. and Sparks, T.H. (1995) Modelling the relationship between bird population variables and hedgerow and other field margin attributes. I. Species richness of winter, summer and breeding birds. *Journal of Applied Ecology*, **31(4)**, 764-775

Parish, T., Sparks, T.H. and Lakhani, K. H. (1994) Models relating bird species diversity and abundance to field boundary characteristics. *Hedgerow management and nature conservation*, Report on behalf of the FAO, 58-79

Passy, P., Garnier, J., Billen, G., Fesneau, C. and Tournebize, J. (2012) Restoration of ponds in rural landscapes: Modelling the effect on nitrate contamination of surface water (the Seine River Basin, France). *Science of the Total Environment*, **430**, 280-290

Pennington, D. W., Potting, J., Finnveden, G., Lindeijer, E., Jolliet, O., Rydberg, T. and Rebitzer, G. (2004) Life cycle assessment Part 2: Current impact assessment practice. *Environment International*, **30**, 721-739

Persson, T., Svensson, R. and Ingelog, T. (1989) Floristic changes on farm land following afforestation. *Svensk Botanisk Tidskrift*, **83**, 325-344

Pfiffner, L. and Luka, H. (2000) Overwintering of arthropods in soils of arable fields and adjacent semi-natural habitats. *Agriculture, Ecosystems & Environment*, **78(3)**, 215-222

Phillips, J.D. (1989) Non-forest source pollution control effectiveness of riparian forests along a coastal plain river. *Journal of Hydrology*, **110**, 221-237

Pimentel, D., Stachow, U., Takacs, D.A., Brubaker, H.W., Dumas, A.R., Meaney, J.J. and Corzilius, D.B. (1992) Conserving biological diversity in agricultural/forestry systems. *BioScience*, **267(5201)**, 354-362

Pitcairn, C.E.R., Leith, I.D., Sheppard, L.J., Sutton, M.A., Fowler, D., Munro, R.C., Tang, S. and Wilson, D. (1998) The relationship between nitrogen deposition, species composition and foliar nitrogen concentrations in woodland flora in the vicinity of livestock farms. *Environmental Pollution*, **102(1)**, 41-48

Pitcairn, C.E.R., Skiba, U.M., Sutton, M.A., Fowler, D., Munro, R. and Kennedy, V. (2002) Defining the spatial impacts of poultry farm ammonia emissions on species composition of adjacent woodland groundflora using Ellenberg Nitrogen Index, nitrous oxide and nitric oxide emissions and foliar nitrogen as marker variables. *Environmental Pollution*, **119(1)**, 9-21

Plantinga, A.J. and Wu, J.J. (2003) Co-Benefits from Carbon Sequestration in Forests: Evaluating Reductions in Agricultural Externalities from an Afforestation Policy in Wisconsin. *Land Economics*, **79(1)**, 74-85

Plantlife (2000) *Managing your land for ground pine*. Back from the Brink Management Series. Plantlife - The Wild-Plant Conservation Charity. UK

Pond Conservation. (n.d.) *Pond Creation Toolkit.* Pond Conservation, Oxford

Portelli, P. (2010) *Garigue*. Maltese Nature. 3 September 2010. http://naturalmalta.blogspot.co.uk/2010/09/garigue.html (Last accessed: 26/02/2015)

Prevost Y.H. and West R.J. (1990) Environmental architecture – preventing loss of seed production to insects in black and withe spruce seed orchards. Proceedings: Cone and seed pest workshop, 4 October 1989, St. John's, Newfoundland, Canada. Information Report of Newfoundland and Labrador Region Forestry, Canada. 1990: 100–117

Pugnaire, F., Luque, M.T., Armas, C. and Gutiérrez, L. (2006) Colonization processes in semi-arid Mediterranean old-fields. *Journal of Arid Environments*, **65**, 591-603

Püttsepp, U.A., Rosling, A. and Taylor, A.F.S. (2004) Ectomycorrhizal fungal communities associated with Salix viminalis L. and S. dasyclados Wimm. clones in a short-rotation forestry plantation. *Forest Ecology and Management*, **196(2-3)**, 413-424

Pywell, R.F., Meek, W.R., Loxton, R.G., Nowakowski, M., Carvell, C. and Woodcock, B.A. (2011) Ecological restoration on farmland can drive beneficial functional responses in plant and invertebrate communities. *Agriculture, Ecosystems and Environment*, **140**, 62-67

Quinn, J.E., Brandle, J.R. and Johnson, R.J. (2013) A farm-scale biodiversity and ecosystem services assessment tool: the healthy farm index. *International Journal of Agricultural Sustainability*, **11(2)**, 176-192

Quinton, J.A., Catt, J.A. and Hess, T.M. (1999) The Selective Removal of Phosphorus from Soil. *American Society of Agronomy*, **30**, 538-545

Raebel. E.M., Merckx, T., Feber, R.E., Riordan, P., Thompson, D.J., Macdonald, D.W. (2012) Multi-scale effects of farmland management on dragonfly and damselfly assemblages of farmland ponds. *Agriculture, Ecosystems and Environment*, **161**, 80-87

Rannap, R., Lõhmus, A. and Briggs, L. (2009) Restoring ponds for amphibians: a success story. *Hydrobiologia*, **634(1)**, 87-95

Rayment, M., Haines, R., McNeil, D., Conway, M., Tucker, G. and Underwood, E. (2014) *Study on specific design elements of biodiversity offsets: Biodiversity metrics and mechanisms for securing long term conservation benefits*. Final report for DG Environment project: ENV.B.2/ETU/2013/0060r. Prepared by ICF Consulting Services in association with IEEP and associated experts, 15 December 2014

Read, D.J. Freer-Smith, P.H., Morison, J.I.L., Hanley, N., West, C.C. and Snowdon, P. (eds.) (2009) *Combating Climate Change - A Role for UK Forests. An assessment of the Potential of the UK's Trees and Woodlands to Mitigate and Adapt to Climate Change.* The Stationery Office, Edinburgh

Reganold, J.P., Elliott, L.F. and Unger, Y.L. (1987) Long-term effects of organic and conventional farming on soil erosion. *Nature*, **330**, 370-372

Reichenberger, S., Bach, M., Skitschak, A. and Frede, H.-G. (2007) Mitigation strategies to reduce pesticide inputs into ground- and surface water and their effectiveness: a review. *Science of the Total Environment*, **384(1-3)**, 1-35

Ribeiro, R., Carretero, M.A., Sillero, N., Alarcos, G. Ortiz-Santaliestra, M., Lizana, M. and Llorente, G.A. (2011) The pond network: can structural connectivity reflect on (amphibian) biodiversity patterns? *Landscape Ecology*, **26(5)**, 673-682

Richards, L.A. (1928) The usefulness of capillary potential to soil moisture and plant investigators. *Journal of Agricultural Research*, **37(12)**, 719-742

Richards, P.M.W. (1928) Ecological Notes on the Bryophytes of Middlesex, *Journal of Ecology*, **16(2)**, 269-300

Riddle, M.U. and Bergstrőm, L. (2013) Phosphorus Leaching from Two Soils with Catch Crops Exposed to Freeze-Thaw Cycles. *Agronomy Journal*, **105**, 803-811

Rider, N.E. (1952) The effect of a hedge on the flow of air. *Quarterly Journal of the Royal Meteorological Society*, **78(335)**, 97-101

Romero-Díaz, A., Marín-Sanleandro, P., Sánchez-Soriano, A., Belmonte-Serrato, F. and Faulkner, H. (2007) The causes of piping in a set of abandoned agricultural terraces in Southeast Spain. *Catena*, **69**, 282-293

Roulston, T.H. and Goodell, K. (2011) The role of resources and risks in regulating wild bee populations. *Annual Review of Entomology*, **56**, 293-312

Rowley, H.V., Peters, G.M., Lundie, S. and Moore, S.J. (2012) Aggregating sustainability indicators: Beyond the weighted sum. *Journal of Environmental Management*, **111**, 24-33

Ruiz, E. (2008) *Management of Natura 2000 habitats. 3170 *Mediterranean temporary ponds.* European Commission, Brussels

Ruiz-Colmenero, M. (2013) Vegetation cover reduces erosion and enhances soil organic carbon in a vineyard in the central Spain. *Catena*, **104**, 153-160

Ruiz-Colmenero, M., Bienes, R. and Marques, M.J. (2011) Soil and water conservation dilemmas associated with the use of green cover in steep vineyards. *Soil & Tillage Research*, **117**, 211-223

Ruiz-Flaño, P., García-Ruiz, J.M. and Ortigosa, L. (1992) Geomorphological evolution of abandoned fields. A case study in the Central Pyrenees. *Catena*, **19**, 301-308

Ryszkowski L., Karg J., Kujawa K., Goldyn H., Arczyfska-Chudy E. (2002) Influence of landscape mosaic structure on diversity of wild plant and animal communities in agricultural landscape of Poland (In: Landscape ecology in agroecosystems management, Ed. L. Ryszkowski) – CRC Press, Boca Raton, New York, Washington D.C.: 185-217

Ryszkowski, L., Baroszewicz, A. and Kędziora, A. (1999) Management of matter fluxes by biogeochemical barriers at the agricultural landscape level. *Landscape Ecology*, **14**, 479-492

Sage, R., Cunningham, M. and Boatman, N. (2006) Birds in willow short rotation coppice compared to other arable crops in central England and a review of bird census data from energy crops in the UK. *Ibis,* **148(1)**, 184-197

Sahin, V. and Hall, M.J. (1996) The effects of afforestation and deforestation on water yields. *Journal of Hydrology*, **178**, 293-309

Sarlöv Herlin, I. (2001) Approaches to forest edges as dynamic structures and functional concepts. *Landscape Research*, **26(1)**, 27-43

Sarlöv Herlin, I.J. and Fry, G.L.A. (2000) Dispersal of woody plants in forest edges and hedgerows in a Southern Swedish agricultural area: the role of site and landscape structure. *Landscape Ecology*, **15(3)**, 229-242

Schembri, P.J. (1993) *Physical geography and ecology of the Maltese Islands: A brief overview*. In: Busuttil, S., Lerin, F. and Mizzi, L. (Eds.) Malta: Food, agriculture, fisheries and the environment. Options Méditerranéennes: Série B. Etudes et Recherches; n. 7

Schmidt-Walter, P. and Lamersdorf, N. (2012) Biomass production with willow and poplar short rotation coppices on sensitive areas—the impact on nitrate leaching and groundwater recharge in a drinking water catchment near Hanover, Germany. *BioEnergy Research*, **5(3)**, 546-562

Schnitter, P.H. (1994) *The development of carabid communities from uncultivated fields and meadows in the first years of a succession*. In: Dufréne, M., Loreau, M., Luff, M.L., Maelfait, J.-P. (Eds.), Carabid Beetles: Ecology and Evolution, Kluwer Academic Publishers, Dordrecht/Boston/London, pp. 361-366

Schroth, G. and McNeely, J.A. (2011) Biodiversity conservation, ecosystem services and livelihoods in tropical landscapes: Towards a common agenda. *Environmental Management*, **48**, 229-236

Schultz, R.C., Collettil, J.P., Isenhart, T.M., Simpkins, W.W., Mize, C.W. and Thompson, M.L. (1995) Design and placement of a multi-species riparian buffer strip system. *Agroforestry Systems*, **29(3)**, 201-226

Schultz, R.C., Isenhart, T.M., Colletti, J.P., Simpkins, W.W., Udawatta, R.P. and Schultz, P.L. (2009) *Riparian and upland buffer practices*. In Garret, H.E. (ed.) North American agroforestry: An integrated science and practice. 2nd ed. ASA, Madison, WI, 163-218

Schwartz, R.C., Fryrear, D.W., Harris, B.L., Bilbro, J.D. and Juo, A.S.R. (1995) Mean flow and shear stress distributions as influenced by vegetative windbreak structure. *Agricultural and Forest Meteorology,* **75(1)**, 1-22

Scottish Government (2014) *Greening - Frequently Asked Questions*. 07/10/2014. http://www.gov.scot/Topics/farmingrural/Agriculture/CAP/GreeningFAQs (Last accessed: 14 September 2015)

Sebastián-González, E., Sánchez-Zapata, J.A. and Botella, F. (2010) Agricultural ponds as alternative habitat for waterbirds: spatial and temporal patterns of abundance and management strategies. *European Journal of Wildlife Research*, **56(1)**, 11-20

Seddon, J., Doyle, S., Bourne, M., Maccallum, R. and Briggs, S. (2009) Biodiversity benefits of alley farming with old man saltbush in central western New South Wales. *Animal Production Science*, **49(10)**, 860-868

Shackelford, G., Steward, P.R., Benton, T.G., Kunin, W.E., Potts, S.G., Biesmeijer, J.C. and Sait, S.M. (2013) Comparison of pollinators and natural enemies: a meta-analysis of landscape and local effects on abundance and richness in crops. *Biological Reviews*, **88(4)**, 1002-1021

Shepherd M.A. (1999) The effectiveness of cover crops during eight years of a UK. sandland rotation. *Soil Use and Management*, **15(1)**, 41-48

Shore, M., Jordan, P., Mellander, P.-E., Kelly-Quinn, M. and Melland, A.R. (2015) An agricultural drainage channel classification system for phosphorus management. *Agriculture, Ecosystems and Environment*, **199**, 207-215

Silgram, M. and Harrison, R. (1998) *Mineralisation of cover crop residues over the short and medium term*. Proceedings of the 3rd Workshop of EU Concerted Action 2108 Long-term reduction of nitrate leaching by cover crops, 30 September-3 October 1997, Southwell, UK. AB-DLO, Netherlands

Silgram, M. and Shepherd, M.A. (1999) The effects of cultivation on soil nitrogen mineralization. *Advances in Agronomy*, **65**, 267-311

Skidmore, E.L. (1986) *Soil erosion by wind: An overview*. In: Physics of desertification (pp. 261-273). Springer Netherlands

Smith, D.R. (2009) Assessment of in-stream phosphorus dynamics in agricultural drainage ditches. *Science of the Total Environment*, **407(12)**, 3883-3889

Smith, J., Potts, S.G., Woodcock, B.A. and Eggleton, P. (2008) Can arable field margins be managed to enhance their biodiversity, conservation and functional value for soil macrofauna? *Journal of Applied Ecology*, **45(1)**, 269-278

Smith, J.U., Bradbury, N.J. and Addiscott, T.M. (1996) SUNDIAL: A PC-based system for simulating nitrogen dynamics in arable land. *Agronomy Journal*, **88**, 38-43

Smith, M. and Watson, G. (2011) *Potential impacts of Short Rotation Forestry on Biodiversity in Britain*. In McKay, H. (ed.) (2011) Short Rotation Forestry: review of growth and environmental impacts. Forest Research Monograph, 2, Forest Research, Surrey, 212pp

Smith, V.H., Tilman, G.D. and Nekola, J.C. (1999) Eutrophication: impacts of excess nutrient inputs on freshwater, marine, and terrestrial ecosystems. *Environmental Pollution*, **100(1-3)**, 179-196

Sparks, T.H., Parish, T. and Hinsley, S.A. (1996) Breeding birds in field boundaries in an agricultural landscape. *Agriculture, Ecosystems & Environment*, **60(1)**, 1-8

Staley, J.T., Sparks, T.H., Croxton, P.J., Baldock, K.C., Heard, M.S., Hulmes, S., Hulmes, L., Peyton, J., Amy, S.R. and Pywell, R.F. (2012) Long-term effects of hedgerow management policies on resource provision for wildlife. *Biological Conservation*, **145(1)**, 24-29

Stanley, D.A. and Stout, J.C. (2013) Quantifying the impacts of bioenergy crops on pollinating insect abundance and diversity: a field-scale evaluation reveals taxon-specific responses. *Journal of Applied Ecology*, **50(2)**, 335-344

Staver, K.W. and Brinsfield, R.B. (1998) Using cereal grain winter cover crops to reduce groundwater nitrate contamination in the mid-Atlantic coastal plain. *Journal of Soil and Water Conservation*, **53**, 230-240

Stein, A., Riley, J. and Halberg, N. (2001) Issues of scale for environmental indicators. *Agriculture, Ecosystems & Environment*, **87(2)**, 215-232

Still, K. and Byfield, A. (2007) *New Priorities for Arable Plant Conservation*. Plantlife International - The Wild Plant Conservation Charity. UK

Stopes, C., Lord, E.I., Philipps, L. and Woodward, L. (2002) Nitrate leaching from organic farms and conventional farms following best practice. *Soil Use & Management*, **18(s1)**, 256-263

Stutter, M., Langan, S. and Lumsdon, D.G. (2009) Vegetated buffer strips can lead to increased release of phosphorus to waters: a biogeochemical assessment of the mechanisms. *Environ. Sci. Technol.*, **43(6)**, 1858-1863

Suárez-Seoane, S., Osborne, P. and Baudry, J. (2002) Responses of birds of different biogeographic origins and habitat requirements to agricultural land abandonment in northern Spain. *Biological Conservation*, **105(3)**, 333-344

Tate, K.W., Atwill, E.R., Bartolome, J.W. and Nader, G. (2006) Significant *Escherichia coli* attenuation by vegetative buffers on annual grasslands. *Journal of Environmental Quality*, **35(3)**, 795-805

TBP – (2002) *Hedgerows and tree lines*. Tayside Biodiversity Partnership (TBP). Available at: https://archive.angus.gov.uk/biodiversity/pdf/Section%202/Farmland/F3.pdf (Last accessed: 03/03/2015)

Tengberg, A. Fredholm, S., Eliasson, I., Knez, I., Saltzman, K. and Wetterberg, O. (2012) Cultural ecosystem services provided by landscapes: Assessment of heritage values and identity. *Ecosystem Services*, **2**, 14-26

Tews, J., Brose, U., Grimm, V., Tielbörger, K., Wichmann, M.C., Schwager, M. and Jeltsch, F. (2004) Animal species diversity driven by habitat heterogeneity/diversity: the importance of keystone structures. *Journal of Biogeography*, **31(1)**, 79-92

Thiere, G., Stadmark, J. and Weisner, S.E.B. (2011) Nitrogen retention versus methane emission: Environmental benefits and risks of large-scale wetland creation. *Ecological Engineering*, **37(1)**, 6-15

Thomas, C.F.G. Marshall, E.J.P. (1999) Arthropod abundance and diversity in differently vegetated margins of arable fields. *Agriculture, Ecosystems & Environment*, **72**, 131-144

Thomson, P. (2014) *Top Crops – guide to cover crops for biodiversity*. Game Conservancy Trust, UK

Toth, J.D. and Fox, R.H. (1998) Nitrate Losses from a Corn-Alfalfa Rotation: Lysimeter Measurement of Nitrate Leaching. *Journal of Environmental Quality*, **27**, 1027-1033

Trabucco, A., Zomer, R.J., Bossio, D.A., van Straaten, O. and Verchot, L.V. (2008) Climate change mitigation through afforestation/reforestation: A global analysis of hydrologic impacts with four case studies. *Agriculture, Ecosystems and Environment*, **126(1-2)**, 81-97

Tsonkova, P., Böhm, C., Quinkenstein, A. and Freese, D. (2012) Ecological benefits provided by alley cropping systems for production of woody biomass in the temperate region: a review. *Agroforestry systems*, **85(1)**, 133-152

Twisk, W., Noordervliet, M.A.W. and ter Keurs, W.J. (2003) The nature value of the ditch vegetation in peat areas in relation to farm management. *Aquatic Ecology*, **37(2)**, 191-209

Tzilivakis, J., Lewis, K.A., Green, A. and Warner, D.J. (2010) *The Climate Change Mitigation Potential of an* EU Farm: Towards a Farm-Based Integrated Assessment: Final Report for EC Project ENV.B.1/ETU/2009/0052. European Commission, Brussels

Tzilivakis, J., Lewis, K., Green, A., Warner, D., Fialkiewicz, W., Olearczyk, D., Bordet, C. and Langevin, B. (2013) *Optimal design of climate change policies through the EU's rural development policy*. Final Report for project 071201/2011/609681/SER/CLIMA.A.2. European Commission

Ucar, T. and Hall, F.R. (2001) Windbreaks as a pesticide drift mitigation strategy: a review. *Pest Management Science*, **57(8)**, 663-675

Uetz, G.W., Van Der Laan, K.L., Summers, G.F., Gibson, P.A. and Getz, L.L. (1979) The effects of flooding on floodplain arthropod distribution, abundance and community structure. *American Midland Naturalist*, **101(2)**, 286-299

USDA – United States Department of Agriculture (2012) What is alley cropping? Available at: http://nac.unl.edu/documents/workingtrees/infosheets/WT_Info_alley_cropping.pdf (Last accessed: 03/03/2015)

Usher, M.B., Field, J.P. and Bedford, S.E. (1993) Biogeography and diversity of ground-dwelling arthropods in farm woodlands. *Biodiversity Letters*, **1(2)**, 54-62

Uusi-Kämppä, J. and Jauhiainen, L. (2010) Long-term monitoring of buffer zone efficiency under different cultivation techniques in boreal conditions. *Agriculture, Ecosystems and Environment*, **137(1-2)**, 75-85

Valcárcel, M., Taboada, M.T., Paz, A. and Dafonte, J. (2003) Ephemeral gully erosion in northwestern Spain. *Catena*, **50**, 199-216

van der Knijff, J.M., Jones, R.J.A and Montanarella, L. (2000) *Soil erosion risk assessment in Europe*. European Soil Bureau. European Commission

van Dijk, A.I.J.M. and Keenan, R.J. (2007) Planted forests and water in perspective. *Forest Ecology and Management*, **251(1-2)**, 1-9 van Dijk, W.F.A., van Ruijven, J., Berendse, F and de Snoo, G.R. (2014) The effectiveness of ditch banks as dispersal corridor for plants in agricultural landscapes depends on species' dispersal traits. *Biological Conservation*, **171**, 91-98

Vanhinsbergh, D., Gough, S., Fuller, R. J. and Brierley, E.D. (2002) Summer and winter bird communities in recently established farm woodlands in lowland England. *Agriculture, Ecosystems & Environment*, **92(2)**, 123-136

Vetaas, O.R. (1992) Micro-site effects of trees and shrubs in dry savannas. *Journal of Vegetation Science*, **3(3)**, 337-344

Vickery, J.A., Feber, R.E. and Fuller, R. J. (2009) Arable field margins managed for biodiversity conservation: a review of food resource provision for farmland birds. *Agriculture, Ecosystems & Environment*, **133(1)**, 1-13

Vidon, P.G.F. and Hill, A.R. (2004) Landscape controls on nitrate removal in stream riparian zones. *Water Resources Research*, **40(3)**

Villa, F., Bagstad, K.J., Voigt, B., Johnson, G., Portela, R., Honzak, M. and Batker, D. (2014) A methodology for adaptable and robust ecosystem services assessment. *PloS One*, **9(3)**, e91001

Walker, M.P., Dover, J.W., Hinsley, S A. and Sparks, T.H. (2005). Birds and green lanes: Breeding season bird abundance, territories and species richness. *Biological conservation*, **126(4)**, 540-547

Wallace, K.J. (2007) Classification of ecosystem services: problems and solutions. *Biological Conservation*, **139**:235-246

Warner, D.J., Davies, M., Hipps, N., Osborne, N., Tzilivakis, J. and Lewis, K.A. (2010) Greenhouse gas emissions and energy use in UK-grown short-day strawberry (Fragaria xananassa Duch) crops. *Journal of Agricultural Science*, **148**(6): 667-681

Wattenbach, M, Zebisch, M., Hattermann, F., Gottschalk, P., Goemann, H., Kreins, P., Badeck, F., Lasch, P., Suckow, F. and Wechsung, F. (2007) Hydrological impact assessment of afforestation and change in tree-species composition - A regional case study for the Federal State of Brandenburg (Germany). *Journal of Hydrology*, **346(1-2)**, 1-17

Whalen, J.K., Sampedro, L. and Wakeed, T. (2004) Quantifying surface and subsurface cast production by earthworms under controlled laboratory conditions. *Biology and Fertility of Soils*, **39(4)**, 287-291

Willi, J.C., Mountford, J.O. and Sparks, T.H. (2005) The modification of ancient woodland ground flora at arable edges. *Biodiversity and Conservation*, **14(13)**, 3215-3233

Williams, P., Biggs, J., Whitfield, M., Thorne, A. Bryant, S., Fox, G. and Nicolet, P. (1999) *The Pond Book: A Guide to the Management and Creation of Ponds.* Ponds Conservation Trust, Oxford, UK

Williams, P., Whitfield, M. and Biggs, J. (2008) How can we make new ponds biodiverse? A case study monitored over 7 years. *Hydrobiologia*, **597(1)**, 137-148

Wilson, B. (2002) Influence of scattered paddock trees on surface soil properties: a study of the Northern Tablelands of NSW. *Ecological Management and Restoration,* **3(3)**, 211-219

Wilson, W. (2012) *Cover crops: What are the benefits?* Farmers Weekly Tuesday 13 March 2012

Withers, P.J.A. and Lord, E.I. (2002) Agricultural nutrient inputs to rivers and groundwaters in the UK: policy, environmental management and research needs. *Science of the Total Environment*, **282-283**, 9-24

Wolton, R., Morris, R., Pollard, K. and Dover, J. (2013) *Understanding the combined biodiversity benefits of the component features of hedges.* Report of Defra project BD5214

Woodhouse, S.P., Good, J.E.G., Lovett, A.A., Fuller, R.J. and Dolman, P.M. (2005) Effects of land-use and agricultural management on birds of marginal farmland: a case study in the Llŷn peninsula, Wales. *Agriculture, Ecosystems & Environment*, **107(4)**, 331-340

Wratten S.D. (1998) *The role of field boundaries as reservoirs of beneficial insects*. In: Environmental Management in Agriculture: European Perspectives, Ed. J. R. Park, pp144-150. Belhaven Press, London

Wratten, S.D., Gillespie, M., Decourtye, A., Mader, E. and Desneux, N. (2012) Pollinator habitat enhancement: benefits to other ecosystem services. *Agriculture, Ecosystems & Environment*, **15**, 112-122

Wright, D. and Baker, J. (2011) *Selecting Environmental Stewardship Options to Benefit Reptiles*. Amphibian and Reptile Conservation, Bournemouth, UK

Wuellner, C.T. (1999) Nest site preference and success in a gregarious, ground-nesting bee Dieunomia triangulifera. *Ecological Entomology*, **24**, 471-479

Yahner, R.H. (1982) Microhabitat use by small mammals in farmstead shelterbelts. *Journal of Mammalogy*, **63(3)**, 440-445

Yeo, I.-Y., Lee, S., Sadeghi, A.M., Beeson, P.C., Hively, W.D., McCarty, G.W. and Lang, M.W. (2014) Assessing winter cover crop nutrient uptake efficiency using a water quality simulation model. *Hydrology and Earth System Sciences*, **18**, 5239-5253

Zanchi, G., Thiel, D., Green, T. and Lindner, M. (2007) *Afforestation in Europe: Final Version 26/01/07.* Institute for European Environmental Policy, London