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An indicator framework to help maximise potential benefits for ecosystem services and biodiversity from ecological focus areas

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ABSTRACT

Ecological focus areas are one of three greening measures that were introduced into the European Common Agricultural Policy by the reform in 2014, with the aim of enhancing the ecological function of agricultural landscapes. However, there are concerns that they will provide little or no additional ecological benefit (enhanced biodiversity and ecosystem services) as those that are declared may already exist and/or any new areas will be implemented on the basis of farm management burdens rather than ecological criteria, such as those which are the easiest or least costly to implement. To implement ecological focus areas to achieve greater benefits requires taking account of numerous spatial and management parameters, scientific understanding of ecosystem services, and the needs and behaviour individual and communities of species. Such an approach is not readily practical or feasible for many farm and land managers. This paper describes the development of an indicator framework which aims to distil this complex scientific information to aid decision making with regard to the implementation of ecological focus areas to enhance and increase benefits for ecosystem services and biodiversity. It involved collating scientific evidence from over 350 papers, reports and guides and then structuring this evidence to form the indicator framework. 230 impacts were identified for 20 land uses and landscape features, and these are characterised using 138 parameters and attributes, containing 708 descriptive classes. The framework aims to help land managers identify the potential benefits and burdens of different options for the specific spatial and management context of their farm, and thus select those with greatest benefits and least burden for their circumstances. Ecological focus areas are part of the first evolution of greening measures, so there is scope to improve them to make their implementation more ecological and more focused. Tools, such as the indicator framework presented herein, have the potential to support this process by educating and raising awareness of potential impacts, facilitating the transfer of scientific knowledge, and resulting in a more ecological aware industry.

1. Introduction

The Common Agricultural Policy (CAP) has been one of the most longstanding and important elements of common policy in the European Union (EU). The need for it was established in the Treaty of Rome in 1957 (European Community, 1957), when it was realised that interventions in agricultural markets by national governments (to ensure food security) needed to be harmonised and transferred to the European level as they were an obstacle to the Common Market. The CAP came into force in 1962 and since then it has inevitably been subject to many reforms to meet changing demands. Food security now sits alongside other socio-economic and environmental objectives. The most recent reform of the CAP, covering the period 2014–2020, introduced new "greening measures" to enhance the environmental performance of agricultural holdings (EC, 2013a,b,c,d). These measures include rules on maintaining permanent grassland, crop diversification and Ecological Focus Areas (EFAs). The reformed CAP came into force during 2014 (the transition period) and the greening measures came into force in 2015.

EFAs are land uses and landscape features that have the potential to deliver ecological benefits (in the context of this paper, ecological benefits refer to enhanced biodiversity (in terms of diversity and populations of species) and enhanced positive ecosystem services). They are a response, alongside other policies and initiatives, to concerns such as the decline in populations of birds, mammals and

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Table 1
Ecological focus areas and their land and feature components.

Ecological Focus Areas (Article 46 of Regulation 1307/2013)	Land and feature components
Land lying fallow	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 under Good Agricultural and Environmental Condition (GAEC) or Statutory Management Requirement (SMR)	Ancient monuments
	Ancient stones
	Archaeological sites
	Garrigue
	Hedges or wooded strips
	Isolated trees
	Natural monuments
	Ponds
	Terraces
Buffer strips	Land strips (adjacent/parallel to water)
	Land strips (other)
Hectares of agroforestry	Agroforestry
Strips of eligible hectares along forest edges – no production	Land strips (other)
Strips of eligible hectares along forest edges – with production	Land strips (other)
Areas with short rotation coppice	Short rotation coppice
Afforested areas	Woodland
Areas with catch crops or green cover	Catch crops or green cover
Areas with nitrogen fixing crops	Nitrogen fixing crops

invertebrates (Chamberlain et al., 2000; Cresswell, 2010; Donald et al., 2001; Goulson et al., 2008; Newton, 2004; Temple and Terry, 2007). There are 19 available EFAs (see Table 1) from which Member States (MSs) have chosen a selection for implementation intended to meet their own requirements. Some MSs have selected as little as 2 EFAs and others up to 18, with the scope to amend this in future (Ciaian et al., 2015; EC, 2015). The rules require farms with an arable area larger than 15 ha (i.e. excluding permanent crops and permanent grassland) to declare and maintain 5% of the arable area as EFAs (which may increase to 7% in 2017). Farmers in each MS can select one or more EFAs that they intend to declare to meet the 5% target. Failure to comply with this rule, or the other greening measures, can result in an administrative penalty and in a reduction of the payments that the farm can receive.

The implementation of EFAs clearly aims to bring about ecological benefits. However, there are concerns (Pe'er et al., 2014; Siriwardena, 2014) that simply maintaining existing areas as EFA or even creating completely new EFAs will do little in terms of additional ecological benefit. There is no consideration, for example, of having the right habitat in the right place or managing them correctly to bring about desired benefits (Dicks and Benton, 2014). There are also concerns (Cimino et al., 2015; Lakner, 2015; Matthews, 2015) that farms will select EFA options that are the easiest/least costly to implement, rather than those likely to increase ecological benefits. Although these are legitimate concerns, this does not mean that EFAs cannot have a more positive benefit if due consideration is given to relevant spatial and management parameters within the realms of what is practical and feasible for farm management. Therefore any tools or information, such as indicators, that can aid the incorporation of these factors into farm management decision making processes could help EFAs achieve their desired aim.

Indicators and indicator frameworks have the potential to help distil complex scientific information to aid decision making from the strategic level of policy making down to the level of individual farms (Bockstaller et al., 1997; de Groot et al., 2010; Ran et al., 2015; Rigby et al., 2001; van Oudenhoven et al., 2012). This paper presents work undertaken to derive a prototype indicator framework and relative performance index to assess the potential impact of EFAs on ecosystem services and biodiversity. These impacts were selected as clearly a key aim of EFAs is to maintain and enhance biodiversity and positive ecosystem services. The framework has been developed in order to support and complement existing initiatives that encourage their adoption (not as a replacement for them) and thus aims to provide guidance and direction with regard to EFA selection and management. More specifically, this paper explores how the framework tackles the issue of accounting for spatial and management parameters, with respect to potential impacts, thus presenting a novel framework for distilling complex scientific information to aid decision making.

2. Input data and methods

2.1. Overview of the challenge and the approach

The core challenge was the level of complexity that needed to be tackled due to the combination of different land uses and landscape features, impacts and contexts. Nineteen EFAs needed to be assessed, including the features that make up those EFAs (see Table 1); a taxonomy and hierarchy of impact categories were necessary to cover the broad range of ecosystem service and biodiversity impacts; and multiple spatial, ecological and management contexts were needed to cover the 28 EU Member States, and thus a range of parameters were needed to characterise these contexts. For example, woodland has potential to impact upon a broad range of ecosystem services and wildlife species and the impacts will vary considerably with spatial and management parameters such as: climate, soil, ecological zone, tree species, vegetative structure, surrounding habitats, topography, shape, etc. Thus the challenge is to capture the breadth and depth for scientific validity whilst maintaining simplicity and practicality to aid decision making.

The first step collated the scientific evidence (Section 2.2) to form the foundation for the subsequent processes. The next step processed this scientific evidence into a structure to form the indicator framework (Section 2.3). The final step undertook an impact assessment for the land uses and landscape features of each EFA (Section 2.4). The delivery vehicle for the indicator framework and the outputs of the above processes was a prototype software application known as the EFA Calculator. This was used to facilitate the construction of the framework and to deliver the knowledge gathered in a form to help farms to select and manage EFAs to enhance ecological benefits. This software is not described in detail herein, but it is freely available online (AERU, 2015a; Tzilivakis et al., 2015), where it can be accessed to explore the full database of EFAs, components, parameters, classes and impact categories, which are not practical to fully list herein.

2.2. Collation of the scientific evidence

In order to collate relevant evidence an extensive review process was undertaken which included the development of a review and search protocol, similar to that used in a systematic review (e.g. EFSA, 2010). The protocol included the following:

- Boundaries: Spatially restricted to European environments. Temporally restricted to evidence published after 1980. Content focused on potential impacts on ecosystem services and biodiversity of the different land and features covered by the EFAs.
- Search terms: A number of search terms and keywords (and combinations thereof) were derived. This included terms for land and features that constitute EFAs across Europe (see Section 2.3.2) and impact categories for ecosystem services and biodiversity (see Section 2.3.3).
- Literature type: Preference was given to peer reviewed published scientific publications, but other research project reports and farm guidance materials were also included where relevant.
- Literature databases: A number of databases were used including: Web of Science; ScienceDirect; Scopus; Google Scholar and JSTOR.
- Snowballing and personal knowledge: In addition to the databases above, the citations of relevant publications were evaluated, and personal knowledge was used to identify other potential publications.

Each set of search results were screened for relevancy (using the abstract and titles) and any duplicates removed. Those that passed the screening were then analysed for their quality and content using the full manuscript and included assessing whether or not the study fell within the study boundaries; if the aims, objectives and context were suitable; if the endpoints and outcomes were appropriate, if the methodology fitted the project aims and required endpoints etc. This process resulted in over 350 papers, reports and guides being collated and reviewed and a synthesis report was drafted (AERU, 2015b).

2.3. Structuring the scientific evidence

2.3.1. The conceptual structure

Fig. 1 shows the conceptual structure of the framework where potential impacts for land or features are characterised using a range of parameters and classes. Each land/feature may have one or more impacts, which are characterised by one or more parameters, which may have two or more parameters classes.

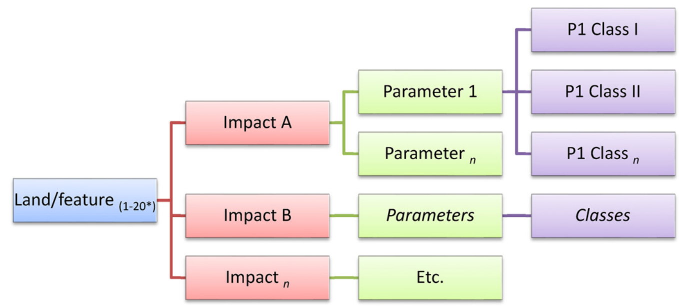

Fig. 1. The conceptual structure of the indicator framework. (*see Table 1 for 20 types of land/features).

2.3.2. Land and features

Table 1 lists the 19 EFAs as listed in Article 46 of Regulation 1307/2013 (EC, 2013c). In order to determine the impact of an EFA, the impact of its component land uses and features needs to be determined. EFAs can have multiple land and feature components, which can be single EFAs in some instances and/or can be component parts of other EFAs in other instances. For example, in Scotland, the EFA element ‘Field margins’ can be just a vegetated strip of land, but it can also include a 2 m wide ditch and a 3 m 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). Additionally, some EFAs can have the same components as other EFAs and then size and description parameters (see Section 2.3.4) differentiate them. For example, in Table 1, ‘Trees in groups and field copses’ and ‘Afforested areas’ both have ‘Woodland’ components. The size of the woodland (along with administrative rules under the rural development regulation (EC, 2013a,e)) determine whether it is ‘Trees in groups and field copses’ or ‘Afforested areas’.

To overcome this issue, and facilitate the literature review and impact assessment, a core set of land and feature components were derived (see Table 1). It is these components for which the impact assessment (see Section 2.4) is undertaken and then the impact of the EFA is determined by the features that make up that EFA. These components were derived from the description of the EFAs and from the literature. When undertaking the literature review (see Section 2.2) all the terms in Table 1 were used as search terms along with equivalent terms (e.g. for fallow land this included: bare soil, uncultivated land, set-aside, etc.).

2.3.3. Impact taxonomy and categories

Ecosystem services and biodiversity were selected as a means of assessing the ecological benefit of EFAs. There is an inherent and complex relationship between them (Balvanera et al., 2006; Isbell et al., 2015; Mace et al., 2012), however in the context of this study they were treated separately, in order to clearly attribute impacts to each EFA. In this study, ecosystem services are the positive tangible provisioning, regulating and cultural services that EFAs can provide to humans (Haines-Young and Potschin, 2013). Ecosystem disservices (Shackleton et al., 2016; Zhang et al., 2007), where ecosystem functions are harmful to human well-being, are not directly covered in this study, but negative impacts on positive services are covered (e.g. creation of woodland may decrease water provision downstream in a catchment). For biodiversity, this study focuses on the diversity and populations of species, with specific focus on the latter with respect to the potential impact EFAs may have on enhancing populations.

Existing impact taxonomies and classifications were utilised where possible. For ecosystem services, the Common International Classification of Ecosystem Services (CICES) system (Haines-Young and Potschin, 2013) has been used. CICES has a 4 level hierarchy of ecosystem services: Section > Division > Group > Class, with 3 Section level ecosystem services, 8 at the Division level, 20 at the Group level, and 48 Class level ecosystem services. The CICES categories (and equivalent terms) were also used to derive search terms for the extensive literature review (see Section 2.2) and a total of 19 ecosystem service impact categories were identified based on the literature collated on EFAs.

For biodiversity, no established impact classification was identified as being suitable, largely because those that have been developed were done so for a specific purpose and thus were not fit for the purpose of this study. Consequently, the European Nature Information System (EUNIS) species groups (EEA, 2015) were used as a starting point, on the basis that they would aid interpretation in the EFA Calculator software (AERU, 2015a). The EUNIS species groups were expanded, based on what was found in the scientific evidence collated, and the same 4 level hierarchy as ecosystem services was applied. This resulted in 13 Section level species groups, 26 at the Division level, and 2 Group level species groups (there were none at the Class level).

2.3.4. Parameters and classes

Each land and feature component has been described by a set of parameters and associated parameter classes. These are variable attributes or properties that are likely to affect the potential performance of the land or feature with respect to its impact. For example, 'soil texture' would be a parameter that would influence the impact of 'fallow land' on the ecosystem service of 'mass stabilisation and control of soil erosion' rates. Classes within this parameter (e.g. 'coarse', 'medium', 'medium fine', 'fine' and 'very fine') can then be used, in combination with other parameters and classes (e.g. 'ground cover' with classes of: 'none', 'natural regeneration', 'sown bird seed mix', 'sown wildflower', and 'sown grass only') to differentiate between degrees of impact. Different combinations of parameters and classes are scored in the impact assessment (see Section 2.3) to provide a means of assessing the relative impact of land and feature components, and their corresponding EFAs, for different spatial and management contexts. Some parameters can influence multiple impacts (e.g. 'ground cover' not only affects soil erosion but also influences multiple species groups), while others are more bespoke and only influence one impact (e.g. 'topography' with classes of 'banks, ridges, hollows or hummocks' and 'mostly uniform' only impacts upon reptiles). Some parameter classes are quite simple, e.g. 'are ditch sediments removed by dredging' has just 'yes' and 'no' as classes, whereas others are more detailed (e.g. 'Nitrogen fixing crop species' has 24 individual crop species as classes). Consequently there is scope to describe the spatial and management contexts of EFAs with a reasonable degree of detail, and thus differentiate the relative performance of EFAs with respect to their potential impact.

The parameters and classes were derived from the literature (see Section 2.2) using the following criteria:

- Parameters:
  - Attributes or properties that were commonly defined and cited in the literature, especially any that had been applied in the field (e.g. the Habitat Suitability Index – see Section 2.4.2).
  - Attributes or properties identified as having the most significant influence/impact on ecosystem services and biodiversity.

- Parameter classes:

Table 2
Impact matrix for fallow land.

Impacts	Ecosystem services					Biodiversity										
Parameters	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 km^2							✓								
Slope	✓			✓											
Soil texture	✓	✓		✓											
South aspect												✓			
Topography												✓			

- Classes or scales that are commonly defined and cited in the literature, especially any that had been applied in the field.
- In the absence of any specifically defined classes, the literature was examined to extract classes.
- Where a numerical scale exists, the minimum and maximum values were determined and appropriate set of value ranges were determined as classes, making note of any critical or threshold values.

This process has variable degrees of subjectivity depending on the scientific evidence available; however, in combination with expert judgement, a pragmatic set of parameters and classes was developed. It is not practical to list all the parameters and classes herein, but they can be viewed in the EFA calculator software (AERU, 2015a; Tzilivakis et al., 2015). Additional examples can also be viewed in Section 2.4.

2.4. Impact assessment

2.4.1. Impact matrices

The first step involved creating an impact matrix whereby parameters are correlated with impact categories for each land and feature component. Table 2 shows an example matrix for the impact of fallow land.

2.4.2. Impact scores

The next step involved deriving relative impact scores for each feature-impact combination. Each feature-impact was scored on a scale of −100 to +100, for negative and positive impacts respectively. Two techniques were developed to score impact

- A semi-quantitative approach, which utilises quantified data and calculations (similar to meta-modelling). A score is awarded for each possible combination of parameters, based on the quantified data.
- A qualitative approach, where scores are awarded for each class, then the scores for the classes selected are summed and weighted for each parameter

The semi-quantitative approach has the advantage that all impacts are comparable across features and tends to be less subjective than the qualitative approach. The disadvantage is there are limited number of robust models or methods available to derive quantitative data, therefore this approach can only be applied to a few impacts. The following substances were quantified:

- Water based on data from Farley et al. (2005), Sahin and Hall (1996) – impacts on provision of water as a material and for nutrition and flood protection.
- Carbon sequestered using the IPCC (2006) methodology – impacts on global climate regulation by reduction of greenhouse gas concentrations.
- Nitrate leaching and phosphate run-off calculated using the methods and data in Briggs et al. (2015); Defra (2010); Panagos et al. (2012, 2015); van der Knijff et al. (2000) – impacts on chemical condition of waters.
- Soil erosion calculated using the methods and data in Defra (2010); Panagos et al. (2012, 2015); van der Knijff et al. (2000) – impacts on mass stabilisation and control of soil erosion.

Calculations were derived for all the possible combinations of relevant parameters, then converted onto the scale of −100 to +100 using a calibration table. For example, Table 3 shows the calibration data for mass stabilisation and control of soil erosion and Table 4 shows some example scores for fallow land. The calibration data used to convert the quantitative data are consistent for all features

Table 3
Calibration data for mass stabilisation and control of soil erosion.

Score	$t\,ha^{-1}\,yr^{-1}$
−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

with these impacts (note: in this example all the data are negative as it is a case minimising a negative impact). The feature with the greatest impact defines the calibration range, and thus the impact of each feature is directly comparable.

The qualitative approach has been used for a greater number of feature-impacts. There are two variations:

- Automated: scores are awarded for each parameter class, each parameter is given a weight to account for its relative significance, and thus an overall score for any particular combination of parameter classes can be automatically calculated.
- Manual: all possible combinations of parameter classes are generated, then each combination awarded a score. Used when a parameter or parameter class changes the impact score in way which cannot be accounted for using Equation (1) (e.g. the impact switches from positive to negative or is limited by a parameter class).

The automated approach uses Equation (1) to determine the overall impact score. Each parameter is given a weight 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. Table 5 shows an example of the parameter weights and class scores that have been assigned for the impact of fallow land on reptiles.

$$Impact\ Score = \sum \left(class\ score_n \times \left(\frac{Parameter\ weight_n}{\sum (Parameter\ weights)} \right) \right) \quad (1)$$

The qualitative approach can be more subjective (compared to the quantitative approach) with increased reliance on expert judgement. The protocol below was used to systematically derive the scores and weights:

1. Identification of any existing scoring techniques, indicators or indices in the literature, especially those with documented practical field based application, and adaptation of these to the scoring system outlined above.
2. Identification of any established relationship (e.g. linear or sigmoidal) in the literature for the specified parameters, classes and impacts, and allocation of scores accordingly.
3. Identification of any critical parameters or thresholds and allocation of scores accordingly.
4. In the absence of any of the above, equal distribution of scores across the parameters and classes.

The first option, and/or a combination of options 1–3, is the most ideal as it aims to incorporate the most established and robust evidence into the indicator framework. For example, many of the

Table 4
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

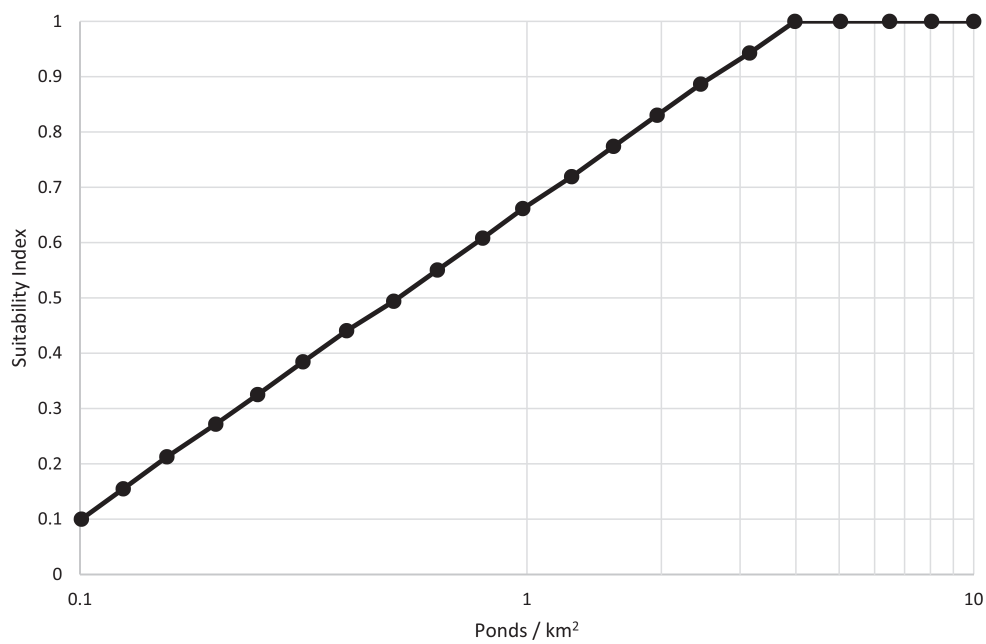

Fig. 2. Habitat suitability index for density of adjacent water bodies for *Triturus crestatus*. (Reproduced from ARG, 2010).

biodiversity impact scores are largely based on the Habitat Suitability Index (HSI) method (Oldham et al., 2000; ARG, 2010), to rapidly assess the suitability of environmental conditions for the great crested newt (*Triturus crestatus*). The index, based on empirical evidence, uses 10 habitat feature specific variables indicative of quality for *T. crestatus* populations, then combined and averaged

Table 5
Parameter weights and class scores for the impact of fallow land on reptiles.

Parameter	Weight	Class	Score
Adjacent vegetation structure	100	Large area (>1 ha) of rough grassland, scrub, hedges or woodland	100
		Small area (<1 ha) 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

Table 6
Impact scores for density of adjacent water bodies.

Density of adjacent water bodies (ponds/km^2)	Score
>1.3	100
1	67
0.5	50
0.1	10
0	0

to provide an overall score of suitability. The scoring system was then expanded further to incorporate criteria and features applicable to other biodiversity groups, based on indicators of habitat quality derived from the published literature. Oldham et al. (2000), ARG (2010) assign each habitat feature an index of between 0 and 1, with a score closer to one corresponding to a feature with greater habitat suitability (Fig. 2). Adaptation of these scores for use in the indicator framework is shown in Table 6 for the parameter 'density of adjacent water bodies'.

Factors, such as the density of adjacent water bodies, are relatively fixed, that is, the presence of roads and pond density cannot be influenced by the presence and type of EFA land and features. They do however influence to what extent the selection of appropriate EFA features will impact on biodiversity overall. Where baseline biodiversity is low, the selection of less optimal EFA land and features is unlikely to have a significant impact. In contrast, where biodiversity is potentially high, the area will be far more sensitive to the EFA element selected. At the smaller spatial scale, within the boundary of the pond itself, ARG (2010), Oldham et al. (2000) utilise a number of indicators of pond quality including water quality, coverage of aquatic vegetation, percent shading by trees, and the frequency of drying out. These factors indicate the likelihood and extent of *T. crestatus* populations being present, and modify the potential impact of particular EFA land and features if implemented within adjacent areas. Reptiles in contrast do not benefit from increased pond density or water quality, but instead from the presence of small patches of bare ground, diverse topography and south facing aspects (Table 5), in addition to structurally diverse vegetation (Brady and Phillips, 2012; Edgar et al., 2010; HCT, 2007; Wright and Baker, 2011). As such, the presence of the reptile specific variables will enhance the habitat suitability score for reptiles, but not amphibians. The management of the cropped area itself, and how individual EFA elements influence this, also requires consideration, and it is this combined influence that the EFA Framework aims to capture.

Agroforestry and N fixing crops, for example, have two contrasting elements in terms of management, ecosystem services, and biodiversity. Agroforestry reduces tillage frequency, providing suitable habitat for reptiles during the initial phases of establishment when it is comparable to scrub vegetation (Brady and Phillips, 2012). Nitrogen fixing crops, depending on the species selected, also offer potential to reduce tillage frequency and improve habitat suitability. The shading that results from agroforestry at maturity, from conifer species in particular, is however less suitable for reptiles. As such the score is lower for reptiles compared to those N fixing crop species where re-establishment may be in excess of three years. However, agroforestry does receive a higher score for amphibians that prefer moist shaded conditions during the terrestrial phase of their lifecycle (Oldham et al., 2000).

The examples above all use Equation (1) to calculate the impact scores, but instances exist where Equation (1) is not appropriate (i.e. where summing the class scores and applying the parameter weights does not account for significant exceptions with respect to potential impacts such as particularly critical or sensitive parameter classes). In these instances a more manual technique has been taken, similar to the quantitative approach, in that all possible combinations of parameter classes need to be assigned a score. 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: selection of 'yes' gives a positive impact for mass stabilisation and control of soil erosion; selection of 'no' inverses and the score to a negative impact, i.e. terraces not maintained can potentially increase soil erosion (Arnáez et al., 2015).

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 relevant 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. By default the CFC is set to 1, and can then be adjusted for each feature-impact based on the evidence available on the relative importance of one feature compared to another.

2.4.3. Aggregation of impact scores

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 be of importance with respect to the decisions being taken. The EFA Calculator software is not immune to this problem. Given the range of potential impacts on ecosystem services and biodiversity and the number of raw (non-aggregated) impact indices and data, 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 in relation ecosystem services and biodiversity). The aggregation hierarchy used here does not necessarily hide detail or reduce transparency, it simply provides a means by which to manage the level of detail, for example by providing users with the facility to choose the level of detail that is conducive to their requirements.

With respect to the aggregation methodology, the hierarchy of the impact taxonomy (see Section 2.3.3) was used to provide the aggregation framework, i.e. aggregating from Classes up to Sections. Positive and negative impact scores are averaged and aggregated separately. This is to avoid potential negative impacts becoming hidden by being 'cancelled out' by positive scores (and vice versa). 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 (class level) 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 (accounting for the impact category and sub-categories). The aggregation process potentially results in 4 values, i.e. positive and negative values for ecosystem services and biodiversity.

3. Results

3.1. The indicator framework

The indicator framework described above provides a means to characterise the potential impact of 20 different types of land

Table 7
Overview of feature-impacts.

Land/feature Impact category	Agroforestry	Ancient monuments	Ancient stones	Archaeo-logical sites	Catch crops or green cover	Ditches	Fallow land	Garrigue	Hedges or wooded strips	Isolated trees	Land strips (adja-cent/parallel to water)	Land strips (other)	Natural monuments	Nitrogen fixing crops	Ponds	Short rotation coppice	Terraces	Traditional stone walls	Trees in line	Woodland
Ecosystem services																				
Provisioning:																				
Provision of water as a material																	√			√
Provision of water for nutrition																				√
Regulation & maintenance:																				
Global climate regulation																				√
Pollination & seed dispersal	√					√	√	√	√		√	√		√	√	√				√
Pest control	√				√		√		√					√		√			√	
Chemical condition of freshwaters	√				√	√	√		√		√			√	√	√			√	√
Flood protection						√														√
Mass stabilisation & control of soil erosion	√				√		√				√			√		√	√			√
Filtration/sequestration by flora and fauna									√		√								√	
Mediation of smell/noise/visual impacts									√										√	
Cultural:																				
Aesthetic services		√	√	√		√			√	√			√		√		√	√		√
Heritage & cultural services		√	√	√						√										
Biodiversity																				
Amphibians	√				√	√	√			√	√	√		√	√	√				
Aquatic plants						√									√					
Biodiversity (general)						√									√					√
Birds	√				√	√	√		√	√	√	√		√	√	√		√	√	√
Fish						√									√					
Fungi			√															√		√
Invertebrates	√		√		√	√	√	√	√	√	√	√		√	√	√		√		√
Lichens																		√		√
Mammals	√				√	√	√	√	√	√	√	√		√	√	√		√		√
Reptiles	√		√		√		√	√		√	√	√		√		√	√	√		
Terrestrial plants	√		√		√	√	√	√	√	√	√	√		√		√		√		√

management and landscape features which can constitute EFAs. The impact assessment process has resulted in 230 feature-impact combinations, characterised using 138 different parameters containing 708 parameter classes. Table 7 shows a summary of the feature-impacts. There are 58 impact categories in the raw data, therefore to aid communication herein ecosystem impacts are presented aggregated to the Class level and biodiversity impacts have been aggregated to the Section level.

It should be noted that the feature-impacts listed in Table 7 are based on the scientific evidence that was collated. Other potential impacts may be associated with the EFA land management and landscape features, but a lack of evidence and/or a lack of scientific consensus in the evidence collated meant they were not included. However, there is scope for the framework to be expanded and evolve in the future as scientific knowledge and understanding grows (see Section 5).

3.2. Application of the indicator framework

3.2.1. The EFA calculator software

The potential impact of any specific EFA is not determined until the framework is applied (i.e. an EFA is described and quantified in the context of a farm where it is located). A software application, the EFA Calculator (AERU, 2015a), has been developed to serve as the delivery vehicle for the indicator framework on farms. This section provides an example of how the indicator framework is used within the EFA Calculator to help guide farms towards improving the ecological benefits of new and existing land and features on the farm. The indicator framework (and associated scientific evidence underpinning it) is used in a number of different ways to provide feedback on the potential impact of new and existing land and features on the farm including evaluation of existing land and features and guiding the creation of new land and features.

3.2.2. Evaluation of existing land and features

The EFA Calculator provides tools to describe the land and features that exist on a farm. Each feature can be described in terms of its dimensions (e.g. area, length, width, height, etc.) and parameters describing spatial and management factors (e.g. soil texture, climate, ecological zone, adjacent vegetation structure, etc.). The parameters are used as 'look up' variables to retrieve the potential impact on ecosystem services and biodiversity (as were determined in the impact assessment). These impact values are then multiplied by the area of the land/feature. Feedback on the relative impact or ecological performance of the feature can then be provided for an individual, group or all features on the farm. Impact scores are expressed as a proportion of maximum obtainable multiplied by the area of the feature (or total area of the group of feature). These performance scores are used in a number of ways to communicate potential impacts.

Firstly, a graphi graphical icon system is used to display potential impacts in a number of ways including a tabular, flat or hierarchical view. Fig. 3a shows an example (for a block of woodland on a farm) of the hierarchical view where the impact icons are displayed using the CICES hierarchy and Fig. 3b shows a similar approach for biodiversity.

The red and green bars to the right of the icons in Fig. 3a and b express potential negative and positive impacts respectively. This visual expression of potential impacts is accompanied by a text description. The performance scores are classified into very low (0–20), low (21–40), moderate (41–60), high (61–80), and very high (81–100). These are then used to provide a summary report. For example, for Fig. 3a the report highlights that the positive impacts on ecosystem services are relatively moderate, with the main ones being: atmospheric composition and climate regulation; intellectual and representative interactions; and liquid flows, and there are also some moderate negative impacts including mass flows and provision of water. Similarly, for Fig. 3b the report highlights the positive impacts on biodiversity are relatively high especially for fungi, mammals, terrestrial plants and birds.

The parameters and classes selected to describe the land/feature are also examined, and a report generated to highlight where potential improvements could be made with respect to different impacts. For example, the woodland in this example was described as 'moderate' for the parameter 'presence of open spaces', consequently it has been identified as an area that could be improved (i.e. to 'high presence of open spaces'), which would then be beneficial to terrestrial plants and invertebrates, as the presence of open spaces aids in maintaining a proportion of early-successional habitat as well as a greater diversity of habitats.

3.2.3. Guiding the creation of new land and features

The scores, icons and text guidance above can be used in the alternative context of creating new EFA land and features on a farm. Firstly, the potential impact scores in the indicator framework can be used as a means to prioritise features that could be implemented on the farm. This is done by selecting impact categories as ranking criteria. For example, this could be the top level categories of ecosystem services and biodiversity, or it may be sub-categories (e.g. provision of water or birds). The database, that underpins the EFA calculator, can be interrogated using the selected criteria to determine those features that have the greatest potential positive impacts for the impact categories. The ranking can be done using best, worst or average case data (in the absence of descriptive parameters) and/or the scores can be refined using parameters that may apply to the whole farm, e.g. rainfall or ecological zone. In so doing this guides farms towards creating features that may have the greatest ecological benefits for their given location.

Secondly, when a new feature is created in the EFA Calculator, feedback is provided on the potential impact of that feature. This feedback uses the icons shown in Fig. 3a and b and/or the associated guidance text. As parameter classes are selected, potential increases or decreases in impact are highlighted. When the icons are viewed, the red/green bars will go up or down based on what is selected, thus providing immediate feedback steering selection towards that will potentially increase ecological benefits. Similarly, when text guidance is viewed, information on the potential impact of different options (classes) for different parameters are displayed, thus again steering selections towards increasing ecological benefits.

4. Discussion

The ecological and environmental impacts of agriculture in Europe have been the topic of much debate over recent decades. This has included multiple concerns including nitrates and pesticides in water; loss of habitats and declines in populations of birds and honeybees; emission of greenhouse gases; soil erosion; water use; and many more (Chamberlain et al., 2000; Cooper et al., 2009; Cresswell, 2010; Donald et al., 2001; Goulson et al., 2008; Hart et al., 2013; Henry et al., 2012; Louwagie et al., 2009; Newton, 2004; O'Mara, 2011; Pimentel and Kounang, 1998; Rey Benayas and Bullock, 2012; Skinner et al., 1997; Warren et al., 2003; Woods et al., 2010). The emergence of the ecosystem services concept in recent years encompasses all of these issues; presents them alongside the provisioning services of food, fibre, energy and water; and recognises that a holistic and integrated approach is necessary to achieve all the outcomes society desires. Therefore the introduction of EFAs as part of Pillar I of the CAP has been welcomed as a potentially useful contribution towards delivering ecological benefits (Allen et al., 2012; Birrer, 2014; KLU, 2014). However, there are

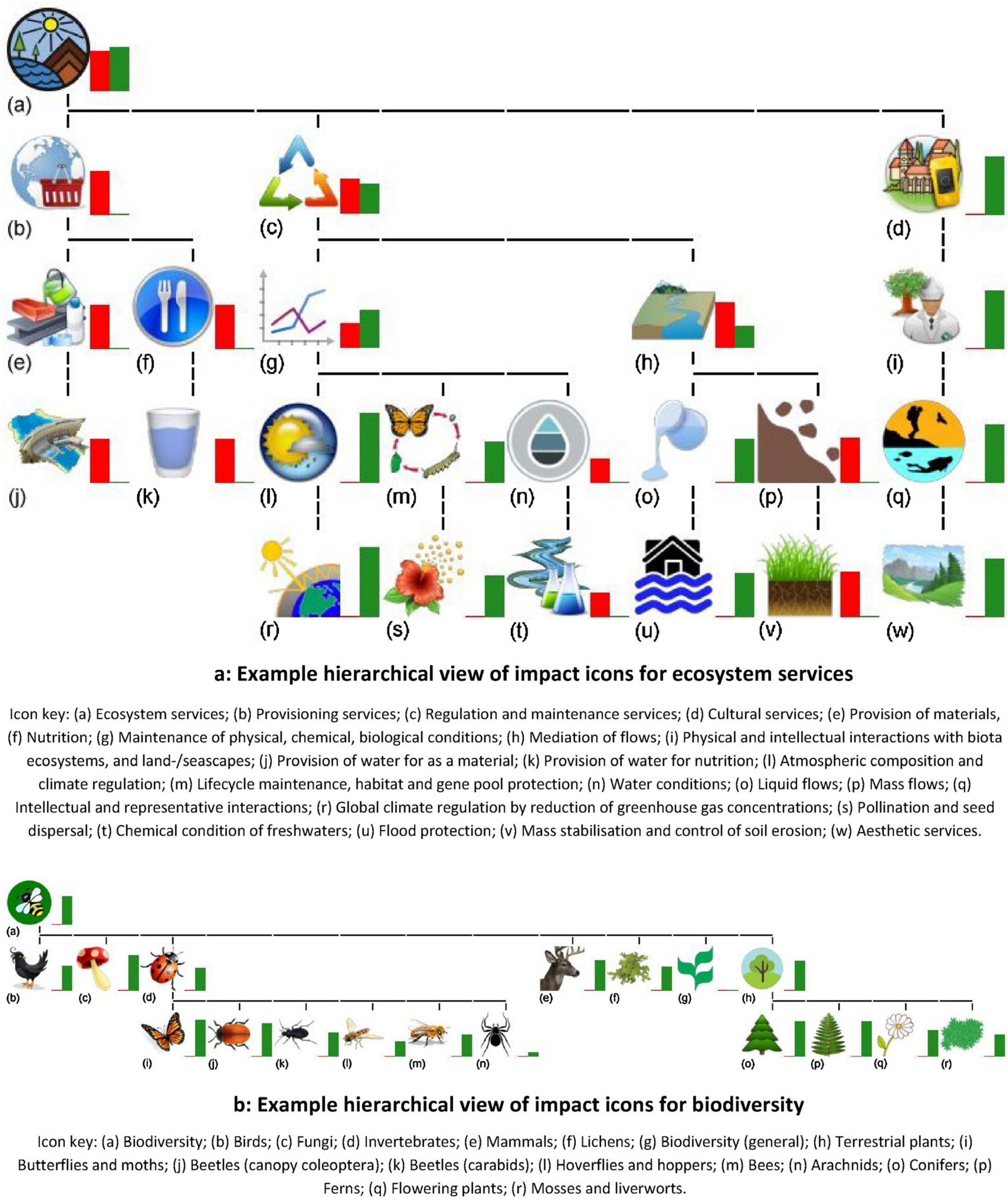

Fig. 3. Example hierarchical view of impact icons for (A) ecosystem services and (B) biodiversity.

concerns (outlined in the introduction) that EFAs may be neither ecological and/or focused.

EFAs are part of the first evolution of greening measures, so it is not unexpected that there is scope for improvement, and discussions are ongoing on this, especially in relation to simplification of the CAP (Council of the European Union, 2015). It should also be remembered that EFAs are not an isolated instrument, there are also the other greening measures; there are requirements that must be met as part of cross-compliance (EC, 2013b) and there are numerous voluntary measures in the form of agri-environment schemes provided under rural development regulation (EC, 2013a,e) (pillar II of the CAP). This highlights the fact that there can be multiple initiatives to bring about positive outcomes, and EFAs should ideally integrate and coordinate these to enhance and/or increase those outcomes. In many respects, this picture is reflected at the farm level where there may also be different actions and initiatives to address different issues, and a more integrated approach is required to ensure all initiatives are pulling in the same direction and/or maximising the chances of increasing desirable outcomes. This is part of a general conceptual shift from compliance towards performance (at both policy and farm levels), such as payments for ecosystem services (Reed et al., 2014; Smith et al., 2013), and thus there is a growing need to be able to assess, measure and monitor this.

The policies and intervention mechanisms, such as financial incentives, provide a means to encourage the adoption of desirable practices to bring about ecological benefits. The indicator framework presented herein is not an alternative mechanism to these, but can be considered a complimentary tool, in terms of provision of guidance and awareness raising, that can operate within the existing landscape of policies and interventions. It also needs to be acknowledged that demonstrable outcomes and improvements in performance, with respect to ecosystem services and biodiversity, are most likely to arise from detailed local knowledge; site surveys (including ecological surveys) to provide quantitative data; development of detailed management plans (possibly utilising the expertise of ecological consultants); and spatial mapping, e.g. using Graphical Information Systems (GIS) (Benton et al., 2003; Fahrig et al., 2011; Smeding and Joenje, 1999; Tscharntke et al., 2005; Vickery et al., 2004). The indicator framework cannot, and does not aim to, replace these activities, but it can support and compliment them.

With regard to spatial planning and mapping, the scientific evidence gathered showed that the value of habitats (in terms of maintaining or increasing populations of species) can only be maximised if there is good connectivity between habitats on the farm and if the farm level landscape structure is heterogeneous (Bailey, 2007; Benton et al., 2003; Hunter, 2002; Le Coeur et al., 2002; Fahrig et al., 2011; Menz et al., 2011; Morandin and Kremen, 2013; Shackelford et al., 2013; Wolton et al., 2013). These two issues appear to be of equal or greater importance than the value of any single habitat in isolation. The indicator framework presented herein attempts to account for some aspects related to this. For example, by accounting for the general connectivity of each feature and/or adjacent features, using the parameters that are available for describing each feature and then using these to adjust the impact scores accordingly. With regard to heterogeneity in the landscape, there is also an additional criterion for ranking new features (see Section 3.2.3), whereby a Feature Diversity Index (FDI) can be calculated using Equation (2). If the feature does not exist on the farm then it scores a maximum FDI of 1. If it already exists, the 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 ranking the feature.

$$FDI_n = 1 - \left(\frac{area\ \ of\ all\,features}{area\,of\,feature_n}\right) \quad (2)$$

However, the indicator framework cannot account for the physical location of any specific feature in the landscape in relation to other specific features. This ideally needs to be done using GIS tools and techniques. Such tools and techniques are emerging, as it is a requirement under Article 70(2) of Regulation (EU) No 1306/2013 (EC, 2013b) that the land parcel identification system (LPIS – a GIS system that is a key component of the Integrated Administration and Control System (IACS) for area based subsidies in the EU) contains a reference layer to accommodate stable EFAs by 2018. Consequently, various initiatives are underway to develop LPIS EFA layers, and there may be scope to develop environmental assessments into these. For example, Ekotoxa in the Czech Republic (Pražan and Trojáček, 2015) are developing a system (within their LPIS GIS) to assess both the potential economic and environmental impacts of implementing EFAs. The environmental assessment is basic, e.g. identifying bare fallow on sloping land as at risk of erosion, but it illustrates that there is scope for this sort of assessment. If such an approach could be enhanced by integrating the indicator framework presented herein, in whole or in part, this could potentially result in a powerful and valuable tool.

The framework has tended to focus on positive impacts associated with EFAs, especially with respect to biodiversity. It has also assessed potential negative impacts on ecosystem services, with respect to where negative effects (e.g. soil erosion) are not minimised or are increased (e.g. the implementation of fallow bare areas on land at risk of erosion); and/or where there are negative impacts upon services (e.g. the reduction in water provision from planting of woodland). However, the impact of EFAs on ecosystem disservices has not been specifically covered, especially any disservices to agriculture. For example, the impact of EFAs on pest control (i.e. increasing populations of pest predators) has been assessed, but the ecosystem disservice of EFAs on increasing pest populations (Wood et al., 2015; Zhang et al., 2007) has not been assessed. It is envisaged the pest control (service) and pest populations (disservice) would balance out (reach equilibrium), but this has not been explored in this study and thus is an area that could be improved in the future.

Finally, a concern raised in the introduction, is that in order to satisfy legal requirements the majority of farms will overlook EFAs with the greatest ecological benefits in favour of other options that have lower or no benefit because they are the easier to implement, have lower costs or a lower management burden. A basic attempt was made to account for these farm management factors in the indicator framework by including farm labour as an impact category, and consequently identifying which features impact upon this. Land taken out of production was also used as a criterion for ranking land and features when considering creating new EFAs (see Section 3.2.3). The assessment of management impacts could be much improved, but it does provide a basic mechanism to identify synergies and trade-offs between ecological and management benefits and burdens. It does not solve the problem of trade-offs between ecological and management impacts, but it does help place them in context so they can be evaluated within decision making processes.

5. Conclusions

In developing solutions to support decision making on farms, a balance needs to be struck between enough detail to provide a scientifically valid picture, whilst keeping the detail (and associated data requirements) as simple as possible in order to provide clarity for decision making and facilitate easier options assessment (Niemeijer and de Groot, 2008; van Oudenhoven et al., 2012; Villa and McLeod, 2002). It is important that the indicator framework makes the decision making process easier and it does not 'muddy the waters' and/or 'stagnate' the decision making process.

The indicator framework presented herein utilises a relatively simple scoring technique but captures a broad range of complex information. Over 350 papers, reports and guides were collated and the pertinent knowledge synthesised and distilled, resulting in 230 feature-impact combinations, characterised using 138 different parameters containing 708 parameter classes. There is undoubtedly more scientific evidence that could have been gathered and collated, and there is potential for additional feature-impacts to be added, with additional parameters and classes to characterise them.

Efforts have been made to ensure the framework, and the indicator parameters used, are based on sound scientific evidence. However, any indicator framework that employs scoring and indices, rather quantified units, can be viewed as subjective and thus there is scope for disagreement among experts and practitioners. In a few instances, such as with the semi-quantitative approach (see Section 2.3), the scores have been based on quantitative data and are thus more robust, but in the other instances the data are more qualitative thus are more subjective and consequently the scope for interpretation and disagreement increases. This is somewhat unavoidable given the breadth of impacts that needed to be covered by a common framework. However, perhaps the more important attribute of the indicator framework is that in many respects it is quite simple and also has the capacity to adapt and evolve as scientific understanding and knowledge evolves.

The framework has been developed to specifically assess EFAs, but ultimately it has been designed to assess any land management or landscape feature. As such there is scope to extend it to cover other features and/or initiatives and schemes, such as the other greening measures or those under Pillar II of the CAP. In so doing, it could extend the framework towards providing a more comprehensive system for evaluating the potential impact of land management and landscape features.

Finally, EFAs in the context of the CAP are relatively new and thus their efficacy as a means of providing ecological benefits remains to be determined. Likewise the framework presented herein is a relatively untested prototype, thus it is not possible to provide any evidence on its effectiveness. Also, it is important to acknowledge that although the framework aims to provide an assessment of the potential impact of land management and landscape features on ecosystem services and biodiversity, it does not necessary mean it will directly result in an increase the overall ecological performance of the farm. This is still down to the decisions made on the farm. However, the framework does provide a means by which to communicate potential impacts in the form of tools, such as the EFA Calculator software. There is potential for it to be used to educate and raise awareness of the potential impact of any particular land management or landscape feature. This potential could be increased if the concepts and approaches presented herein could be integrated into existing farm management tools (such as GIS applications), which could greatly increase the exposure of this knowledge and increase the scope for widespread adoption. This awareness raising and transfer of knowledge, combined with the mandatory requirement for EFAs for some farms, could result in a more ecological aware industry. It also increases the capacity of the industry to adapt and respond to issues which will be vital in the coming decades when it is faced with the multiple challenges of feeding a growing population, with more scarce resources and changes in climate, alongside the need to maintain essential ecosystem services and biodiversity.

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