Offsetting land in the agricultural landscape to increase biodiversity resilience

Woolford A.R. and Jarvis P.E.

February 2017

Contents

Summary

This report looks at the concept of biodiversity off-setting when applied to building and infrastructure projects and biodiversity off-setting that can be achieved in conjunction with agricultural production. The avoidance and minimisation aspects in both landscape areas are examined. Where restoration and re-establishment of ecology is not possible, the use of biodiversity offsets to improve natural ecosystem resilience are reviewed.

The mechanisms for implementing the individual part of the hierarchies is explored; namely land sharing, land sparing, voluntary measures, regulation and wildlife friendly farming practices. Examples from the Allerton Project and Farm 4bio show how they can be practically implemented so that biodiversity decline can not only be halted, but reversed.

How much land is required to make biodiversity both sustainable and successful within agri-environment schemes is also covered. Over a 5-year crop rotation, a Centre for Hydrology study found there would be no adverse impact on overall yield in terms of monetary value or nutritional energy, when up to 8% of land was removed from cropping.

The report concludes that biodiversity off-setting has a greater chance of success if it is used in conjunction with other rural landscape management and mechanisms. These include promoting best farming practices through Integrated Farm Management (IFM), implementation of simple, but robust agri-environment legislation with the appropriate amount of land out of production rejuvenating environmental habitats.

Introduction

What is biodiversity and why is resilience important

Biodiversity definition: The amount of biological variation within and between species of living organisms and whole ecosystems in terrestrial and aquatic environments (Foresight, 2011). The Foresight Report advocates 'maintaining biodiversity', but many habitats in which our flora and fauna thrive need to be rejuvenated rather than just managed sustainability. The type of management, the amount of land and its location are key to improving biodiversity resilience.

Understanding ecosystems and the role of biodiversity

There is a wealth of services that are provided by ecological habitats that are of benefit to humans (Costanza et al., 1997). For example, these services include water regulation, supply and purification, pollination and biological control by organisms, nutrient cycling, soil erosion control, food and material production (Costanza., 1997). The preservation of functionally diverse communities is vital for a sustainable future (Garnett et al., 2013; Tilman et al., 2011), there is a need to make these services become more resilient to environmental changes and can therefore recover more quickly when compromised.

Diverse communities are a product of local and landscape complexity: complex habitats support greater biodiversity because of the more habitats they support and the greater likelihood of biodiversity exchange between habitats. However, the process of enhancing system resilience and biodiversity is determined by many complex factors, because species and the services they provide operate and are influenced by processes operating at multiple scales.

There is already evidence suggesting that agricultural productivity (Bullock et al., 2007; Naidoo & Ricketts, 2006; Shackelford et al., 2013), can be improved by the enhancement of native biodiversity, however Ratnadass et al. (2012) does suggest that diversifying farmland wildlife does not always generate improved ecosystem services on farmland. The quality of new habitats will also be important and some studies have linked the proximity of existing pristine habitats to improving agricultural yields, rather than the creation of new habitats (Ricketts et al., 2004).

There may be extraneous influences such as climate and cropping systems, as well as trade-offs between different beneficiaries and it is highly unlikely that one approach will benefit all targets (Ridder, 2008). Choices will therefore have to be made when devising any off-setting approach and acceptance that the change will not be beneficial for all species and ecosystem services.

According to The Economics of Ecosystems and Biodiversity (TEEB, 2010) ecosystem services can be categorized in four main types:

a. Provisioning services are the products obtained from ecosystems such as food, fresh water, wood, fiber, genetic resources and medicines. • Food and Fuel – it is worth remembering that this provisioning service is an ecosystem and is often overlooked when discussing more environmental issues. • Soil – with pressure to intensify production, soil resilience is critical. The use of fertilisers, plant protection products and cultivation practices are key factors in the sustainable management of soils. • Water – the impact of our soil and crop management on water quality for human health and aquatic flora and fauna is closely linked.
b. Regulating services are defined as the benefits obtained from the regulation of ecosystem processes such as climate regulation, natural hazard regulation, water purification and waste management, pollination or pest control. • Air – 8% of the greenhouse gas emissions in the UK are produced by agriculture. Nitrous oxide, methane and carbon dioxide are the main gases produced from our food production. Mineralisation of soils and fertiliser, livestock and machinery use are the primary sources of such gases. • Biodiversity – Whilst agricultural crops do host a tremendous amount of biodiversity from insects, earthworms and nesting birds. The surrounding habitats such as hedges, wetland, woodland and areas out of food production provide many opportunities to increase our native plants and animals. Landscape management is crucial to maximising such biodiversity.
c. Habitat services highlight the importance of ecosystems to provide habitat for migratory species and to maintain the viability of gene-pools.
d. Cultural services include non-material benefits that people obtain from ecosystems such as spiritual enrichment, intellectual development, recreation and aesthetic values.

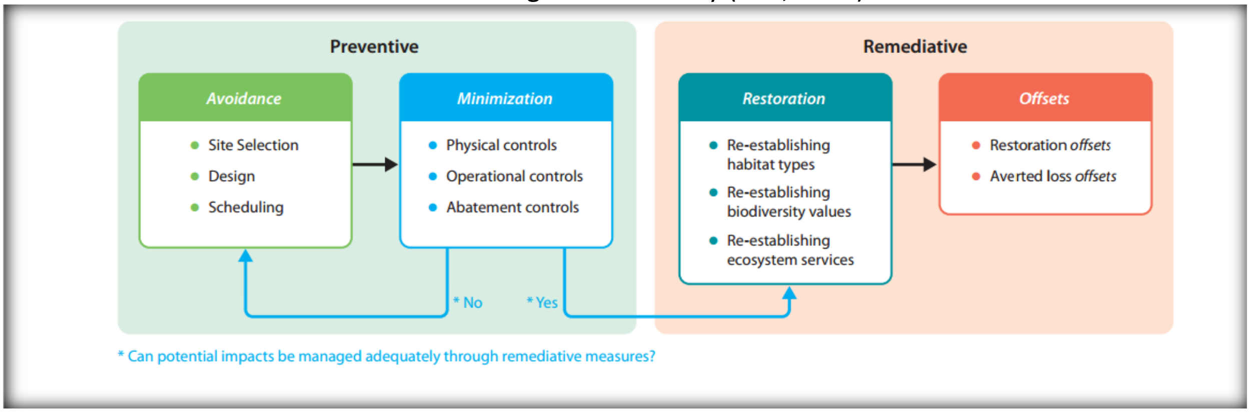
1. Biodiversity offsetting for building and infrastructure developments

"*Biodiversity offsetting is a policy approach that seeks to minimize the environmental impacts of a development project by ensuring that any damage in one place is compensated for somewhere else. In the UK, biodiversity offsets have been defined as conservation activities that are designed to give biodiversity gain to compensate for residual losses. Biodiversity offsetting is understood as a 'last resort' in a 'mitigation hierarchy', to be adopted only after all measures had been taken to avoid and minimize development impacts and to rehabilitate or restore biodiversity on-site*" (DEFRA, 2013).

They are different from other types of ecological compensation as they need to show measurable outcomes that are sustained over time (DEFRA, 2013).

When governments look at true biodiversity **off-setting** the aim is to improve habitats in a different location from where human activity has been a detrimental influence. These are often associated with infrastructure projects such as houses, roads, railways and industrial developments. Such off-setting is often placed in an agricultural landscape and this offset is the final part of the mitigation hierarchy.

The mitigation hierarchy (TBC, 2015)



The 'Infrastructure mitigation hierarchy' is a policy for ensuring activities do not have unnecessary impacts on the environment;

- In the first instance harm, should be **avoided**, for instance by locating development at a different site.
- Where this is not possible the impacts should be **mitigated**, for instance through the detailed design of the development.
- Any residual impacts should be **compensated** for, for instance by restoring or recreating habitat elsewhere.
- **Off set** with improvements at another location.

The mitigation hierarchy is embedded in many areas of environmental legislation and regulation. For example; under the National Planning Policy framework "*if significant harm resulting from a development cannot be avoided (through locating on an alternative site with less harmful impacts), adequately mitigated, or, as a last resort, compensated for, then planning permission should be refused*."

Why does biodiversity off-setting play a role in Government policy?

The Government is determined to succeed in the global race by creating growth and delivering lasting prosperity. At the same time the Government wants this generation to be the first which leaves the natural environment of England in a better state than it inherited (DEFRA, 2013).

The current Government (2017) wants to use offsetting to help deliver the recommendations set out in Sir John Lawton's report '*Making Space for Nature'* which said areas for nature needed to be bigger, higher in quality and number, and better connected (Lawton 2010).

With a growing economy and a need to improve the natural environment some new thinking was required to resolve how the planning system deals with biodiversity. Such a system needs to incur less expense and inefficiencies that block infrastructure development, but it shouldn't encourage the wrong sort of development which eats away at nature. Such a concept should make the planning system better for developers and better for the environment.

A national or local strategy has been suggested or a hybrid of the two, but ultimately the strategy should be sustainable into the future with the possibility that offset areas may become enlarged and joined up.

Licensing

Natural England will be expected to ensure that licensing decisions are properly supported by survey information, taking into account industry standards and guidelines. It may, however, accept a lower than standard survey effort where;

- The costs or delays associated with carrying out standard survey requirements would be disproportionate to the additional certainty that it would bring.
- The ecological impacts of development can be predicted with sufficient certainty.
- Mitigation or compensation will ensure that the licensed activity does not detrimentally affect the conservation status of the local population of any European Protected Species (Natural England 2016).

How is bio-diversity off-setting progressing into policy?

a. Six pilot projects were commissioned by DEFRA in 2012 and concluded after two years; *"The level of biodiversity offsetting activity within the pilots was lower than expected, so some aspects of biodiversity offsetting remain untested and considerable evidence gaps remain, particularly for long term impacts"* (DEFRA, 2014).
b. Consultation Green paper launched in September 2013 with a November deadline (DEFRA, 2013)
c. Summary of responses on biodiversity offsetting in England published in February 2016. Quoted the next steps as follows; *"Defra recognises that respondents to this consultation have provided a significant amount of useful information and advice and will continue to work with Natural England and interested parties to further our shared understanding of how best to compensate for biodiversity loss when it cannot first be avoided or mitigated, as required by the National Planning Policy Framework."* (DEFRA, 2016).

The great crested newt – a species that that should benefit from biodiversity offsetting.

Great created newts are a widespread but still considered a rare species occurring across much of England and which are protected under European law. They are often subject to the mitigation hierarchy such as the following;

1. Can the building or project avoid damage to the great crested newt habitat.
2. Can loss or damage to the breeding and over wintering habit be minimised.
3. Can habitat be re-stablished or restored at existing location that allows breeding success and enough habitat to continue sustainability of the colony.
4. Has the proposed new 'off-set location' enough suitable or potential habitat and a management plan to enhance the existing great crested newt population.

Over the years, the population has declined as its natural habitat on agricultural land has been lost and fragmented. This has driven the species into areas of greater development pressure such as urban peripheries and brownfield sites.

The species presents difficulty for developers as there is poor data on where it is likely to be found so its presence can often be a surprise. In addition, it hibernates between October and March. This means it can only be surveyed for between April and June and can only be captured for relocation between April and September. If developers miss these windows this can have a large impact on project deadlines.

If the development plan follows the mitigation hierarchy shown earlier the last option is improvement of another habitat at a different location. This would include creating ponds, habitat and route ways that greatly enhance the new location (Woking 2015).

One note of caution is that several organisations and some of the pilot area hosts, described above, felt that there is a need to guard against 'jumping to the compensate' stage of the mitigation hierarchy without properly addressing mitigation.

2. Biodiversity offsetting in an agricultural landscape

This report also looks at the use of the mitigation hierarchy as a set of principles to help biodiversity within the agricultural landscape. The journey to offsetting allows other beneficial actions which can assist biodiversity resilience and are more familiar to farmers and rural stakeholders. **Avoiding** habitat loss is obviously the most successful way to continue biodiversity resilience. This is often unavoidable as the many of the current methods of food production impact on our rural ecosystems. **Minimising** the impact of such practices can help the future sustainability of both food production systems and our ecological biome.

Restoration of habitats and ecosystems allows biodiversity to increase. Various environmental schemes are supported by a financial payment to achieve these objectives. Land sparing and sharing, can be employed within the agricultural landscape to increase system resilience and biological diversity.

Targeted offsetting are projects outside conventional Greening, Cross Compliance and Agri-environment schemes.

a. Avoidance

There is an inevitable consequence of food production and infrastructure development. Parts of our ecosystem that are associated with natural capital, will be altered, compromised, reduced in area and often destroyed.

With current population growth and the associated issues surrounding evolving societies and their social and industrial policies, it is extremely unlikely that avoiding changes to our ecosystems and the biodiversity within them is likely to be achievable. There may be choices between two sites but ultimately biodiversity and ecosystem change will follow. This is the premise on which this report proceeds.

b. Minimisation mechanisms

The Foresight Report (2011) aimed to explore the pressures on the global food system between now and 2050. It aims to identify the decisions that policy makers need to take today, and in the years ahead, to ensure that a global population rising to nine billion or more can be fed sustainably and equitably.

The term ‘sustainable intensification’ became more widespread after this report and looked at increasing food **production** whilst protecting and enhancing the planets natural ecosystems. A range of minimisation mechanisms are listed below and should, if managed correctly, build a foundation for biodiversity resilience.

Good farming practice – protecting and enhancing the rural landscape starts with responsible use of fertilisers, plant protection products and soil management. This not only leads to efficient food production but reduced environmental impact and could be a land sharing contribution.

Wildlife Friendly Farming is used to incorporate a wide range of farming approaches that are designed to benefit wildlife and in some cases biodiversity per se and the environment. A wide range of other terms are also often used to describe less intensive farming approaches that may also benefit wildlife. These approaches include organic farming which excludes the use of artificial agrochemicals to other systems that use reduced inputs such as biodynamic, organic-biological, diversified and integrated farming. Generally, these systems use the management of species and habitat biodiversity to benefit agricultural production and enhance ecosystem services (Benayas and Bullock, 2012).

Integrated Farming which is the term used here to encompass these principles was defined by El Titi et al., (1993) as "a holistic pattern of land use, which integrates natural regulation processes into farming activities to achieve a maximum replacement of off-farm inputs and to sustain farm income". Integrated farming therefore incorporates the principles of Integrated Crop Management (ICM) and Integrated Pest Management (IPM) but takes a long-term, whole farm approach which considers all aspects of crop production and land management. The emphasis is on preserving farm profitability by optimising inputs, although there may consequently be ecological benefits and overall greater sustainability. In the western Europe during the 1990s many different studies investigated the potential of integrated farming to benefit biodiversity, ecosystem services, agricultural production and profitability (Holland et al., 1994). Overall integrated farming proved equally profitable (Holland et al., 1994; Jordan et al., 1997). Lower yields could be expected, but this loss was compensated for by using lower inputs of agrochemicals and energy.

Voluntary measures – In the UK several voluntary campaigns and plans exist which are complimentary to both food production and environmental enhancement. **The Greenhouse Gas Action Plan** is an industry led initiative aiming to reduce harmful gases from agricultural production. **The Campaign for the Farmed Environment** focuses on voluntary habitat options, with grower guidance delivered via fact sheets and farmer meetings. In the absence of any agri-environment measures, this campaign is a useful starting point for farm environmental management. The **Voluntary Initiative** promotes the responsible use of pesticides to protect water and the wider environment. It also ensures the availability of professional pesticides in agriculture and horticulture while avoiding unnecessary regulation on the sector. Voluntary measures fall into both land sharing and land sparing concepts.

Regulation – Current Cross Compliance and Greening rules in the UK, have a number of Good Agricultural and Environmental Conditions and Statutory Management Requirements which help protect water courses, hedgerows, woodlands, soils and wildlife. Currently 'financial farm support systems' are based upon adhering to these regulations. Regulation would fall into land sharing (better management of soil and nitrate vulnerable zones) and one could argue that land sparing habitats such as buffer and fallow land lie within 'Greening' ecological focus areas (EFA). However, the transient nature of agricultural policy makes such habitats rather temporary.

c. Restoration mechanisms

Restoring habitats is the next tranche within the mitigation hierarchy and has been behind the rationale of agri-environment schemes and targeted measures in the United Kingdom.

Such landscape management can assist biodiversity resilience, but requires careful implementation for successful results. Land sparing separates farmed land and conservation areas, without necessarily effecting agricultural production (Green et al., 2005; Benayas and Bullock, 2012). A similar approach can be used in infrastructure development where green spaces and wild life refuges are built into planning consents. Unless these have 'biodiversity' corridors to wider populations, success is likely to be limited. This approach can be combined with land sharing to enhance biodiversity and ecosystem services (Benayas and Bullock, 2012).

Global and European environmental habitats – Across Europe, agri-environment schemes are being implemented and funded through the Common Agricultural Policy. The schemes vary between each member state and even within countries or regions. In the UK, there are separate schemes for England, Wales, Scotland and Northern Ireland, which are tailored to the different farming systems that are predominant in each country. In these schemes, there are elements of land sharing and land sparing, alongside support for some more traditional farming practices. The English scheme also has different options for organic farming.

In addition, some options in agri-environment schemes are effectively land sparing, where land is taken out of production and used to create wildlife habitats. Two dividing approaches to land-sparing have thus become apparent;

(a) passive restoration of abandoned land via secondary succession.

(b) targeting specific biodiversity targets, ecosystem services or communities through active restoration (Rey Benayas and Bullock, 2012).

Land sparing can be useful, particularly in areas where agricultural productivity and profitability is lower. In this way, unproductive land can be changed to semi-natural habitats to try and alleviate the pressure on UK wildlife. Sparkes et al. (1998) found that in cereals, headlands yielded a mean loss of 7% compared to 26% in sugar beet headlands. The presence of trees along the boundary had the most pivotal influence on the yield because the area shaded by trees in the outer 9 m of the field produced 4.4 t/ha, compared to unshaded crop areas which yielded 8.1 t/ha. The turning of machinery also had a significant effect on the yield reduction, albeit to a lesser extent. Sparkes et al. (1998) conclude by suggesting that these unproductive margins, particularly when trees or hedges are present, could be managed as headland set-aside to effectively remove the poorly yielding margin. Nowadays yield mapping can help identify unprofitable areas and these can be put into AES habitats that are not only more profitable but can benefit wildlife and ecosystem services. Higher yield losses were found on an arable farm in Leicestershire; winter wheat yielded 19% lower on headlands than infield yields (Jarvis, 2011).

These schemes build on protection and enhancement and help rejuvenate neglected or historical habitats. This will involve numerous schemes that provide an opportunity to take land out of food production and implement management practices that are beneficial to soil, water, air and wildlife (Natural England, 2017). Separate schemes exist within the countries of the UK, with the current English Scheme (Countryside Stewardship) being the most complex.

A UK study by Pywell et al. (2012) quantified the effectiveness of land-sharing options, within the widely adopted English agri-environment scheme (AES), known as the 'Entry Level Stewardship Scheme' (ELS). The scheme at one point covered over 60% of available farmland, was simple to implement and popular with farmers. However, most options within ELS did not target specific conservation aims, while there are only a few evidence-based options that do target specific taxa. These options have been unsuccessful in their conservation aims (Kleijn et al., 2011), particularly for rarer species (Kleijn et al., 2006). However, the more recent Countryside Stewardship Scheme includes packages of options aimed at particular groups, such as farmland birds and pollinators.

Pywell et al. (2012) found that evidence-based options yielded a greater species richness in both common and rare plants, bees and birds, often to a 10-fold or 100-fold extent per sampling unit. By contrast, the general options were only able to increase the diversity of common plants and bees to a minimal extent, having absolutely no effect on birds or rare taxa. Depending on the mobility of the taxonomic group, spatial targeting appeared highly important for plants (Pywell et al., 2012), as rare arable plant dispersal is limited even between adjacent fields (Bischoff, 2005). Due to greater mobility, bumblebees were less influenced by spatial targeting (Pywell et al., 2012; Holland et al., 2015). Bumblebees were one of the few groups to improve their breeding populations in response to the provision of appropriate foraging resources and (flower-rich) habitats with more nests on Higher Level Schemes compared to ELS schemes (Wood et al., 2015). However, HLS did not increase the diversity of wild bees (bumblebees and solitary bees) because most HLS flower-rich habitats only provided more of the common plant species that already existed on ELS farms (Wood et al., 2016). To improve bee diversity a greater plant diversity is needed.

Lastly, birds were not influenced by spatial targeting (Pywell et al., 2012), as they will forage over several kilometres during winter when resources are scarce (Siriwardena et al., 2007). Whittingham (2006) highlighted that spatial targeting may still be vital during the breeding season, however, when they effectively become a located around a central place and foraging is limited to restricted areas. The English AES was evaluated more intensively for its effects on birds through a survey of 2000 1 km squares (Davey et al., 2010). This revealed only very limited evidence of the scheme on birds, with only two species showing a landscape-specific positive response to the area under ELS management. Further investigation of the data did reveal regional differences in the bird's response to different AES options (Davey et al., 2010). Thus, AES options should be targeted to the region to replace missing resources and to target particular species.

These studies underline the importance of applying evidence-based conservation efforts for increasing populations of rare species and biodiversity in general. A lasting comment by Pywell et al. (2012) describes the bottom-up effects that evidence-based options can have on a range of taxa. An uncropped, annually cultivated field margin can provide rare arable plants with herbicide-free and uncompetitive conditions for growth. These plants can provide valuable pollen and nectar to bumblebees and other pollinators that are stressed from declining food resources. The plants once pollinated, will provide high energy winter feed for farmland birds, in the form of high yielding and oil rich small seeds.

Agri-environment schemes at the Allerton Project, United Kingdom

The use of land sharing and sparing options within agri-environment schemes at the Allerton Project in Leicestershire has shown how declining biodiversity has been halted, rejuvenated and now flourishes (Stoate & Leake, 2002; Stoate et, al. 2013).

Land sharing

Currently in the UK there are a number options within agri-environment schemes which work on the principles of land sharing, they are usually a compromise between conservation benefits and food production output. Some examples from the Allerton Project are shown below

- Conservation headlands (see picture below), where annual broad leaved flowers/weeds are allowed to grow in outside 6metres of cereal field.

- Low input grassland – benefits to sward diversity and nutrients status.

- Species rich grassland management, grazing and cutting regime allow less competitive plus annual grasses and flowers to seed and flourish.

- Sky lark plots, allows bare ground to encourage nesting and landing site.

- Agro-forestry project – more diverse habitat supporting more insects and woodland birds whilst still allowing some agricultural production.

Land sparing in agri-environment

Commercial agriculture operations are run adjacent to areas taken out of production, with the specific aim of enhancing and rejuvenating environmental habitats for flora and fauna. Some examples from the Allerton project are shown below;

- Pollen and nectar field margins to encourage pollinators and insects.

- Wild flower margins.

- Wild flower meadows.

- Wild bird seed mixtures – encouraging farmland bird.

- Beetle banks provide an insect rich habitat.

d. Targeted measures

Enhanced management in our Sites of Special Scientific Interest (SSSI) is an aim of Natural England. These sites are some of the most biological diverse in the country and can provide a rich source of flora and fauna which can spread to the wider landscape. The evolving Cluster Farmer and facilitation grants also has some wider landscape enhancement opportunities. This landscape approach looks at joining up wildlife corridors and habitat areas and therefore is land sparing.

Landscape changes via land-sparing and targeted measures can improve biodiversity in some cases, but in others, can be detrimental to specialist and rare species. In southern Europe, although active restoration of cropland to predominantly pine (Pinus spp.) plantations can be beneficial for the likes of carbon sequestration (Benayas et al., 2010), this afforestation can cause serious damage to open-habitat species. High quality habitat replacement with forested stands combined with increased predation risk (Reino et al., 2010) led to specialist forest bird reductions, replaced by generalist species. Shrub land undergoing secondary succession favours woodland bird species of conservation concern in Europe (Benayas et al., 2010) and therefore should be encouraged in suitable areas. Similar declines in rarer bumblebee populations compared to more generalist species can also be caused by poorly targeted habitat management.

In terms of real-world application, Benayas et al. (2008) suggested a new concept for designing woodland ecosystems across agricultural landscapes, by utilizing small-scale active restoration as a driver for passive restoration over much larger areas. The establishment of 'woodland islets' is an approach to woodland restoration within extensive agricultural landscapes devoid of native natural vegetation. Over a tiny fraction of the agricultural area (<1%), although small was densely planted and sparse blocks of native trees and shrubs will form a more extensive network over a large area, while using only a fraction of the resources for large-scale reforestation (Corbin and Holl, 2012). Any surrounding and abandoned land can then be colonized, to further accelerate succession at a grander scale (Cole et al., 2010), particularly when facilitated by animal-mediated dispersal, which are shown to reduce the chances of forest community collapses (Montoya et al., 2008). The 'colonization deficit' of plant species (and thus plant diversity) is due equally to degraded dispersal infrastructure and degraded habitat quality (Ozinga et al, 2009). The woodland islets approach allows for flexibility of land use – vital for an industry subjected to such a high degree of fluctuating policy and economic drivers (Benayas and Bullock, 2012).

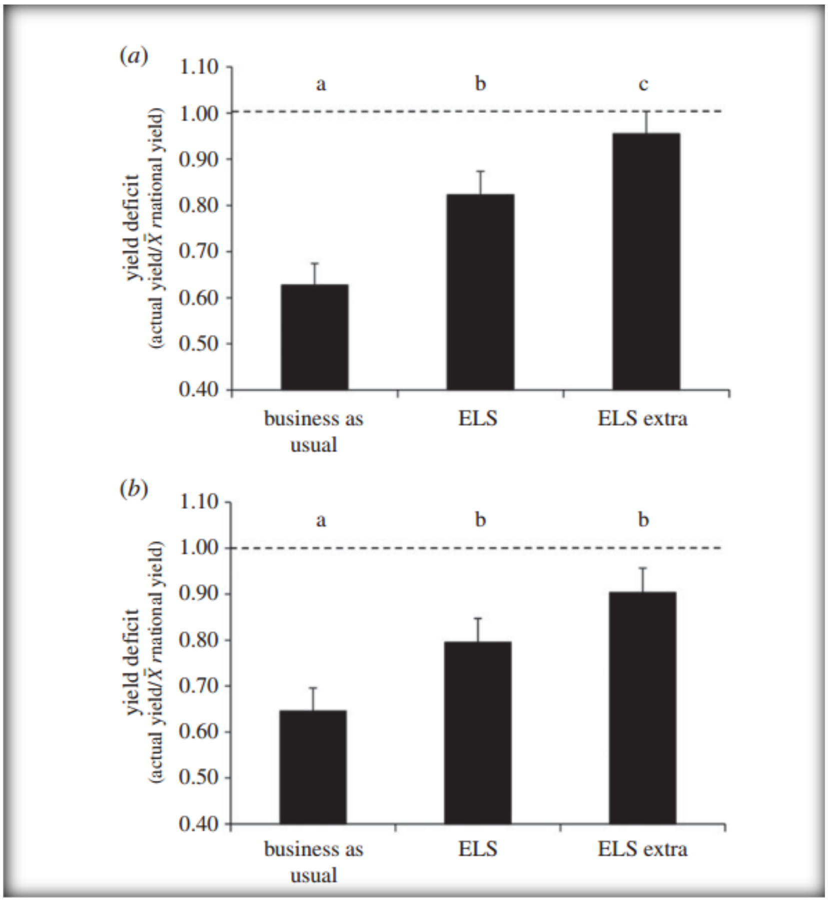
There may be other reasons to make land sparing worthwhile which help re-establish ecosystem services. If soils become degraded or develop high populations of herbicide resistant weeds as well as changes in crop values, can make land unprofitable. Switching to alternative cropping such as grassland or placing into AES habitats may be more profitable in the long-term. The type of cover, if chosen appropriately, can be used to create additional environmental and agronomic benefits. As weather patterns change we may see more UK domestic agricultural policy use land sparing to alleviate flooding and soil erosion problems.

e. Land required for land sharing

A recent study by **The Centre for Ecology and Hydrology** (CEH) (Pywell et al, 2015) replicated two treatments removing 3% (Entry Level Stewardship) or 8% (ELS Xtra) of land at the field edge from production to create wildlife habitat in 50–60 ha patches over a 900 ha commercial arable farm in central England, and compared these to a 'business as usual' control (no land removed).

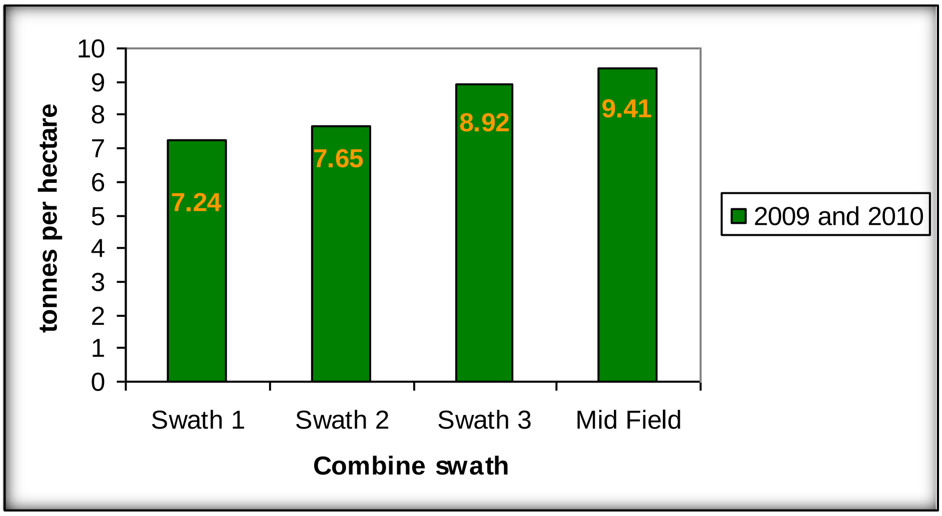
The results suggested that over a 5-year crop rotation, there would be no adverse impact on overall yield in terms of monetary value or nutritional energy. The basis for such a result was the poor relative performance of field margins which when removed from production improved economic performance per hectare. Some yield reduction of wheat at the field edge was up to 10% (Pywell et al, 2015).

Benefits were seen to crops which relied on pollinators where habitats surrounding fields were placed in appropriate environmental habitats. Such habitats also help with providing more ground roving beetles which can reduce pea and been weevil populations by 30%, yield improvements were most noticeable in winter bean crop.



Yield of field beans (2006-2011) on three separate farming systems on CEH (Pywell et al, 2015).

At the **Allerton Project** margin effects showed a 19% reduction in wheat yield from the outside 7 metres to 14-21 metres yield. Each combine swath was 7 metres with swath 1 being the perimeter swath.



Combine yield from wheat fields at the Allerton Project showing increase in yield from the field edge (Jarvis, 2011).

Having established the lower yielding potential of the outside areas of the field, the impact of 'sparing' this land for environmental habitats is not as financially detrimental as taking out the 'mid-field 'higher yielding land.

For effective ecological intensification, ecological management plans must be harmonious with agricultural output increases and crucially, ecological management must not constrain crop management nor other ecological services (Pywell et al., 2015). To encourage widespread farmer and grower uptake, it is also important that the benefits are highlighted, along with management advice (de Snoo et al., 2013). Perhaps most importantly, the yield benefits of ecological intensification management need to be taken into consideration against any potential cost to the farm. For example, the amount of land taken out of production to provision of healthy habitats, needs to give growers some fixed cost savings (Pywell et al., 2015).

f. Evaluating success of land sharing and sparing

I. Farm4Bio - Managing uncropped land to enhance biodiversity

The Farm4Bio project was designed to answer questions on several key factors that affect the successful application of popular agri-environment schemes (Holland et al, 2013).

Notably, it set out to determine whether active management (as in HLS) leads to higher levels of biodiversity than ELS farm management. In testing this, it would also attempt to document the relationship between proportions of uncropped land, biodiversity and to answer the question of how best to arrange this land.

Seven approaches – four actively managed, two farm managed, and one organic – were tested on four farms across southern England and East Anglia. All plots were monitored for abundance and diversity of plants, insects and birds.

The data showed that actively managing habitats encouraged beetles and linnets, with an increase in birds on the farmland bird index and Biodiversity Action Plan species compared to the national trend. Farmer-managed farms with more grass margins, on the other hand, saw an increase in the population of spiders but a decline in birds.

Increasing the amount of uncropped land had a positive effect on both butterfly and bee diversity and abundance, as well as little effect on 16 farmland bird species and a significant effect for three declining species.

The actively managed habitats supported more and bigger chick-food insects, with populations three times larger and the weight of insects twice as high. The chick-food index only exceeded the level required to maintain a grey partridge population in the wild bird seed mixture. However, this habitat is only suitable if the vegetation at ground level is sufficiently open for foraging chicks. The high weed levels within this habitat were supporting the insects rather than the sown plants.

The recommendation was that the current levels of uncropped land could support significantly more biodiversity if it were more positively managed. Every farm should aim to provide flowers in summer and seeds in winter and the more the better.

II. Quantification of ecological services for sustainable agriculture (QuESSA)

In QuESSA, the following ecosystem service provision in relation to semi-natural habitats were assessed: natural predation of pest, pollination, landscape aesthetic, soil fertility and organic matter, erosion, and disservices. Assessments were performed following a standardized design in each case study consisting of 18 focal crop fields bordered by semi-natural habitats (SNH) divided equally into three categories (six fields of each): woody SNH, herbaceous SNH or another crop field as control (Jeanneret et al, 2013).

Fields were selected along a gradient of SNH proportion measured in a landscape sector of 1km radius around each field. Vegetation traits were recorded in the adjacent SNH to the crop field as well as the main management practices applied in the field by interviewing the farmer. Habitats and fields in the landscape sector around the focal field were recorded by ground mapping. Generic and simple methods were developed and tested among case studies regardless of the farming systems and the crop under investigation in order to generate general information.

For the **predation of pests**, sentinel-preys were exposed in fields (standard fishing baits – *Calliphora* larvae, *Ephestia* moth eggs, Aphids, plasticine preys, weed seeds, etc.). Initial testing was conducted to determine the most efficient sentinel-prey techniques that showed sufficient variation in response as well as the most practical for further assessments. Sentinel-preys kept for assessment of general predation overall were the *Calliphora* larvae exposed on the ground, *Ephestia* eggs exposed on the ground and on the plants, *Chenopodium album* and *Poa trivialis* seeds exposed on the ground. In each case study, the predation rate of crop specific pests was estimated by using either sentinels of the particular pest or by measuring predation directly with predator exclusion methods. Natural enemies were recorded by using pitfalls for ground dwelling predators, and with pan and sticky traps for flying ones. Camera recording was used to identify predators acting on sentinel-preys.

Pollination delivery was assessed by a) comparing bagged and hand pollinated plants with an open pollination treatment to determine the level of insect pollination; b) assessing the potential for yield gain under optimal pollination (supplementing the pollen deposition on stigmas by hand) compared to the actual level of pollination, and analysing the potential pollination deficiency on yield; c) identifying the flower visitors and measuring the rate of visits; d) recording the pollen deposition on flowers by single pollinators using several techniques, eg. by providing non pollinated flowers ("mobile bouquet") to 3 pollinators in the field. The insect pollination efficiency on yield was estimated by measuring the fruit and the seed set as well as seed weight and oil content (oilseed rape).

Other ecosystem services in QuESSA included landscape aesthetic (8 case studies), soil erosion (1 case study), soil fertility (4 case studies), organic matter storage (2 case studies), and biodiversity conservation. In addition, the impact of semi-natural habitats on so-called disservices was recorded, namely weed invasion (3 case studies) and bird damage (1 case study).

Regarding the **landscape aesthetic**, photographs were taken of element combinations of woody SNH or grassy SNH, or another crop field as control as for pollination and predation assessment. Pictures were taken at three or four different vegetation stages during the season.

Soil erosion by water was quantified by using astroturf mats having grass-like features installed on upslope and downslope sides of elements of the four SNH classes, and inside the crop fields with and without green manure crop.

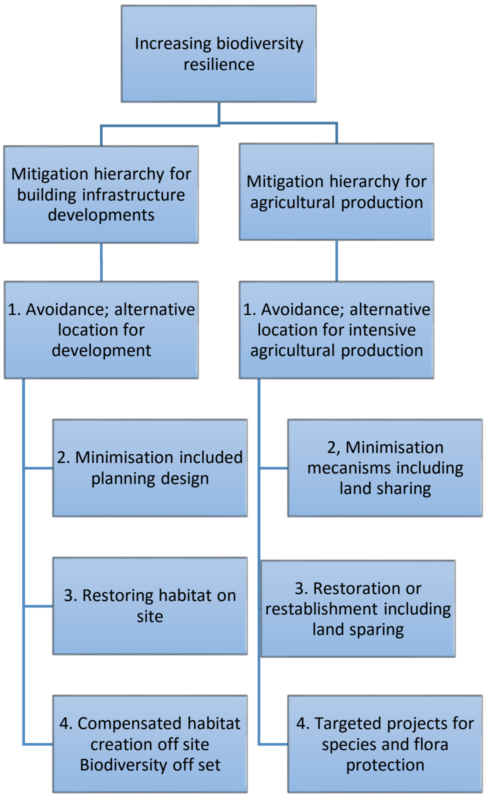
Soil fertility was assessed by taking soil samples from focal fields and from woody linear and herbaceous linear SNH. Soil organic carbon content was measured with dry combustion method with a Carbon/Nitrogen analyser.

Decomposition rate was also measured by burying tea bags. **Organic matter storage** was calculated using loss on ignition from soil samples collected in the SNH classes and crop fields. While recording the vegetation, the predators and the pollinators to characterize SNH, a large part of **biodiversity** was simultaneously assessed (vegetation, pan, sticky and pitfall traps). All collected organisms put together provide the basis for a biodiversity conservation value of the SNH.

As **disservices**, weed populations and bird damage were recorded. Weed composition was determined by scoring density and percentage cover of the species in sunflower fields in Italy and Hungary. Bird damages were estimated by quantitative observation of damages on fruits at harvest in pear orchards in the Netherlands, and by interviewing farmers.

3. Combining both hierarchies

To build long term biodiversity resilience there is a case for using a multi-faceted approach that is complimentary, rather than two systems that work in isolation. An evolving strategy that combines both hierarchies, as shown in the figure below.



Conclusions

This report shows that there are areas of similarity within the infrastructure planning process and the management of landscape for agricultural food production. Both have an impact on natural ecosystems and the biodiversity that resides within them. Understanding that prudent management within both hierarchies could prove mutually beneficial to biodiversity resilience and increase long term sustainability.

There can be conflicting areas within farm management when both food production and environmental enhancement share the same area of land and both aims are compromised. This often means the land sparing concept is often more successful in terms of clear demarcation.

There are numerous benefits to the health and sustainability of the planets resources. From practices to make soils more resilient against drought and flooding through to increasing biodiversity. Some studies have shown that economic performance is not compromised with up to 8% out of production and 'land spared'.

Improving habitat, promoting best farming practices through Integrated Farm Management, implementing simple but robust legislation with the appropriate amount of land out of production through our current agri-environment schemes could rejuvenate some of the semi-natural habitats within our agricultural landscape. Biodiversity offsetting and its targeted improvements can build on these to deliver the greatest chance of success.

References

Benayas, J.M., Bullock, J.M. & Newton, A.C. (2008) Creating woodland islets to reconcile ecological restoration, conservation, and agricultural land use. Frontiers in Ecology and the Environment 6: 329-336.

Benayas, J.M., Galván, I. & Carrascal, L.M. (2010). Differential effects of vegetation restoration in Mediterranean abandoned cropland by secondary succession and pine plantations on bird assemblages. *Forest Ecology & Management* 260: 87-95.

Benayas R & Bullock J (2012) *Restoration of biodiversity and ecosystem services on agricultural land.* Science and Business Media- Ecosystems, Vol. 15, p. 883-889.

Bullock, J.M., Pywell, R.F. & Walker, K.J. (2007) Long-term enhancement of agricultural production by restoration of biodiversity. *Journal of Applied Ecology.* Volume 44, Issue February 2007. Pages 1–5

Cole, R.J., Holl, K.D., Zahawi, R.A., (2010) Seed rain under tree islands planted to restore degraded lands in a tropical agricultural landscape. Ecological Applications 20, 1255–1269.

Corbin, J.D. & Holl, K.D. (2012) *Applied nucleation as a forest restoration strategy*. *Forest Ecology and Management*, **265**, 37–64.

Costanza, R., R. d'Arge, R. de Groot, S. Farber, M. Grasso, B. Hannon, K. Limbueg, and S. Naeem. et al. 1997. *The value of the world's ecosystem services and natural capital*. Nature 387:253–259.

Davey, C.M., Vickery, J.A., Boatman, N.D., Chamberlain, D.E. & Parry, H.E. (2010) *Assessing the impact of Entry-Level Stewardship on lowland farmland birds in England. Ibis*, **152**, 459–474.

DEFRA (2013) *Biodiversity offsetting in England, Green paper*. September 2013

DEFRA, (2014) *Evaluation of the Biodiversity Offsetting Pilot Programme Volume 2 (Annex): Pilot Reports June 2014* Defra project code: WC 1051.

DEFRA, (2016) *Consultation on biodiversity offsetting in England Summary of responses*. February 2016

de Snoo, G.R., Herzon, I., Staats, H., Burton, R.J.F., Schindler, S., van Dijk, J. (2013) *Toward effective nature conservation on farmland: making farmers matter.* Conserv. Lett.**6**, 66–72

El Titi, A., Boller E.F. & J.P. Gendrier, (1993). Integrated Production, Principles and Technical Guidelines. Publication of the Commission Integrated Production Guidelines and Endorsement. Bulletin No r6, International Organisation for Biological Control/West Palaearctic Regional Section (IOBC/WPRS), Switzerland, 96 pp. (update on www.iobc-wprs.org).

Foresight. (2011) *The Future of Food and Farming Final Project Report*. The Government Office for Science, London.

Garnett, T. *et al*. (2013) *Sustainable intensification in agriculture: Premises and policies*. Science **341**, 33–34.

Green R. E., Cornell S. J., Scharlemann J. P. W., Balmford A. (2005) *Farming and the fate of wild nature*. Science**307**, 550–555.

Kleijn D., Rundlöf M.,Scheper J., Smith H. G., Tscharntke T. (2011) *Does conservation on farmland contribute to halting the biodiversity decline?* Trends Ecol. Evol. **26**, 474–481.

Holland, J.M. (1994). *A MAFF LINK project - integrated farming systems.* In: Dedryver, C.A. (ed.) Interntaional Organisation for Biological and Integtrated Control/Western Palearctic Regional Section Working Group, Integrated Control in Cereals: 237-244.

Holland, J.M., Storkey, J., Lutman, P.J.W., Henderson, I.G., & Orson, J. (2013). *The Farm4Bio project: managing uncropped land for biodiversity*. Aspects of Applied Biology, 118: 89-99.

Jarvis P.E,. (2011) *Establishing the income foregone of 'in-field options', in both Entry Level Stewardship and the Campaign for the Farmed Environment; based on a study of winter wheat headland and mid-field yields.* MSc Thesis.

Jordan, V.W.L., Hutcheon J.A., Donaldson, G.V. and Farmer D.P. (1997) *'Research into and development of integrated farming systems for less-intensive arable crop production: experimental progress (1989-1994) and commercial implementation'*. In: Agriculture, Ecosystems and Environment 64, pp141- 148.

Jeanneret, P, Matthias Albrecht, Martin Entling, Brice Giffard, Bart Heijne, Herman Helsen, John Holland, Camilla Moonen, Barbara Smith, Mark Szalai, Maarten Van Helden, Eve Veromann (2013) QuESSA – WP3 *Developing methods to assess ecosystem services.*

Lawton J, (2010). *Making Space for Nature: A review of England's Wildlife Sites and Ecological Network* Chaired by Professor Sir John Lawton CBE FRS Submitted to the Secretary of State, the Department for Environment, Food and Rural Affairs on 16 September 2010

Montoya D, Zavala MA, Rodriguez MA, Purves DW. (2008) *Animal versus wind dispersal and the robustness of tree species to deforestation.* Science **320**:1502–1504.

Naidoo, R. & Ricketts, T.H. (2006). *Mapping the economic costs and benefits of conservation.* PLoS Biol., **4**, 2153–2164.

Natural England, (2016) *Proposed new policies for European Protected Species licensing. Analysis of responses to the public consultation held between 25 February and 7 April 2016*

Natural England (2017) Countryside *Stewardship: Mid Tier Manual* ISBN 978-1-78367-255-4

Ozinga WA, Römermann C, Bekker RM *et al*. (2009) *Dispersal failure contributes to plant losses in NW Europe. Ecology Letters,* ***12****, 66–74.*

Pywell R, Heard M, Bradbury R, Hinsley S, Nowakowski M, Walker K & Bullock J (2012) *Wildlife friendly farming benefits are birds, bees and plants.* Conservation Biology Leeters, Vol. 8, p. 772-775.

Pywell RF, Heard MS, Woodcock BA, Hinsley S, Ridding L, Nowakowski M, Bullock JM. (2015) *Wild life friendly farming increases crop yield: evidence for ecological intensification.* Proc. R. Soc. B 282: 20151740. http://dx.doi.org/10.1098/rspb.2015.1740

Ratnadass A, Fernandes P, Avelino J, Habib R (2011) *Plant species diversity for sustainable management of crop pests and diseases in agroecosystems: a review.* Agronomy for sustainable development.

Reino L., Porto M., Morgado R., Moreira F., Fabião A., Santana J., Delgado A., Gordinho L., Cal J., & Beja P. (2010). Effects of changed grazing regimes and habitat fragmentation on Mediterranean grassland birds. Agriculture, Ecosystems & Environment, 138, 27–34. doi:10.1016/j.agee.2010.03.01

Ricketts, T.H., Daily, G.C., Ehrlich, P.R. & Michener, C.D. (2004). Economic value of tropical forest to coffee production. *Proc. Natl Acad. Sci. U S A*, **101**, 12579–12582.

Ridder, B. (2008) *Questioning the ecosystem services argument for biodiversity conservation*. Biodivers. Conserv., **17**, 781-790.

Shackelford N, Hobbs RJ, Burgar JM, Erickson TE, Fontaine JB, Laliberté EL, Ramalho CE, Perring MP, Standish RJ. (2013) *Primed for change: developing ecological restoration for the 21st century.* Restor. Eco.l 2013, 21: 297–304.

Siriwardena, G.M., Stevens, D.K., Anderson, G.Q.A., Vickery, J.A., Calbrade, N.A. & Dodd, S. (2007) *The effect of supplementary winter seed food on breeding populations of farmland birds: evidence from two large scale experiments.* Journal of Applied Ecology, **44**, 920–932.

Sparkes D, Jaggard K, Ramsden S & Scott R (1998) *The effect of field margins on the yield of sugar beet and cereal crops.* Ann. Of Applied Biology, Vol. 132, p. 129-142.

Stoate, C. & Leake, A. (2002) *Where the Birds Sing*. The Game Conservancy Trust. ISBN 1 901369 10 2

Stoate, C, Leake, A, Jarvis, P, Szczur, J (2013) *Fields for the future; The Allerton Project - A winning blueprint for farming, wildlife and the environment.* Game and Wildlife Conservation Trust.

TBC (2015). *A cross-sector guide for implementing the Mitigation Hierarchy,* The Biodiversity Consultancy

TEEB (2010). The Economics of Ecosystems and Biodiversity: *Mainstreaming the economics of nature a synthesis of the approach, conclusions and recommendations of TEEB.* http://www.teebweb.org/wp-content/uploads/Study%20and%20Reports/Reports/Synthesis%20report/TEEB%20Synthesis%20Report%202010.pdf

Tilman, D., C. Balzer, J. Hill, and B. L. Befort, (2011). *Global food demand and the sustainable intensification of agriculture.* Proc. Natl. Acad. Sci. U.S.A., 108, 20260–20264.

Whittingham, M.J. (2007*) Will agri-environment schemes deliver substantial biodiversity gain, and if not why not?* Journal of Applied Ecology, **44**, 1–5.

Woking (2015)https://www.woking.gov.uk/news/archive?item=000055DAD6D5.C0A801BA.00001869.0016

Wood T, Holland J, Hughes W & Gouston D (2016) *Targeted agri-environment schemes significantly improve the population size of common farmland bumblebee species.* Molecular Ecology – School of life sciences, Vol. 24, p. 1668-1680.