CAP Greening Review – Part 4 – Expert Panel Review

Views of members of the expert panel on CAP Greening

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THE CAP GREENING REVIEW

This review was commissioned by the Cabinet Secretary for Rural Affairs, Food and Environment as part of the policy development process for the Common Agricultural Policy (CAP) Greening measures to be implemented from 2015. The scope of the review was agreed within government with the review managed by the Natural Heritage Management Team within the Environment and Forestry Directorate and supported by analysts from the Rural and Environment Science and Analytical Services Division. The particular focus of the review was on the use of *equivalence* measures. These are the measures designed and implemented within member states as alternatives or supplements to the standard mandatory measures prescribed in the EU Regulations. The review was conducted by staff of the James Hutton Institute between February and May 2015 with interim results used by policy makers (and stakeholders) in decisions announced by the Minister in June 2015. Given the freedom for member states to revise and update Greening equivalence measures this document is intended to provide a record of the evidence base provided by the Greening Review and to contribute to subsequent phases of policy development and implementation. It reflects the state of play in June 2015 and does not consider later revisions to Greening.

The report of the Greening Review comes in four parts.

Part 1 is an overview of the recent trends in key environmental indicators in Scotland, covering soils, biodiversity, water quality and climate change. In addition to outlining the state and trend of each component of the environment, Part 1 also identifies current and potential future pressures. Where any of these pressures are likely to stem from agricultural practices, they are specifically identified.

Part 2 is a technical report of the distribution of measures providing definitions of the standard and proposed equivalence measures as they stood when the review was commissioned. The report provides a sectoral and regional analysis of the distribution of businesses whose pattern of land use means they would need to undertake one or more of the three Greening requirements. For these businesses, the report also identifies (as far as possible) if their pattern of land use already meets the criteria contained in the Greening measures. This analysis is based on business returns made through the Single Application Form (SAF) for 2014.

Part 3 is a series of map books that are a product of the analysis contained in the distribution of measures technical report. These define the spatial distribution of the greening requirements. National maps for each of the three standard greening requirements are followed by maps for each of the 14 agricultural regions. In addition, data currently collected allows an assessment of the degree to which the crop diversification requirement is currently being met.

Part 4 (this document) is an Expert Review of the three standard Greening measures, and where relevant the (then) proposed draft equivalence measures. This draws on research in five fields of study: agro-ecology; biodiversity and landscape ecology; climate change adaptation and mitigation; soils, and waters and catchments. Questions addressed within the Expert Review include: localised and landscape effects, trade-offs, the consequences of implementation factors not specified in the regulation; context specific factors that should be included in guidance to ensure the measure is effective and opportunities for cooperation between businesses and coordinating types and locations of measures.

Part 1 thus provides the wider context, Part 2 the numbers, types and locations of businesses affected and thus the potential scope for benefits or burdens, Part 3 the spatial distribution of the measures, and Part 4 assessments of the (then) proposed equivalence measures set against the counterfactual of the standard greening measures that would otherwise have been implemented.

SUMMARY

As part of the CAP Greening Review conducted by the James Hutton Institute, a group of senior researchers with experience across a number of research domains was convened and asked to evaluate the possible effects of both the 'standard' greening measures and of the proposed 'equivalence' measures. Those domains and the researchers contributing are as shown in Table 2.

Table 1: Domains and lead experts involved in the CAP Greening Review

Domain	Lead expert(s)
Agro-ecology	Geoff Squire, Cathy Hawes
Biodiversity and landscape ecology	Robin Pakeman, Rob Brooker
Climate change adaptation and mitigation	Iain Brown
Soils	Willie Towers, Jason Owen
Catchment Water Quality	Andy Vinten, Kit MacLeod

Key Findings

Permanent Grassland

- The threshold for change that would trigger action by the Scottish Government would be 196,962 ha of permanent pasture (assuming that total agricultural area remained the same). As unimproved semi-natural areas are protected by the *Environmental Impact Assessment (Agriculture) (Scotland) Regulations 2006* then significant losses in improved grasslands could occur (c. 22 %) before the threshold was reached.
- The measure does not enhance the protection of carbon sequestered under permanent grasslands, locally significant areas of grassland in arable mosaics, or specify the management of grasslands that may be required to maintain or enhance biodiversity.
- Improvement in soil nutrient management would be highly desirable from both diffuse water pollution and greenhouse gas emissions mitigation perspectives.
- Soil testing (considered here as an equivalence option for permanent grasslands) could start a process of positive engagement with the issues. Improvements in nutrient management can potentially offset the upfront costs of testing to land managers.
- Since there are potentially substantial societal benefits from investing in a comprehensive soils monitoring programme consideration on the balance of burden sharing/funding should be undertaken with Greening measures integrated with other initiatives such as the Scottish Soils Monitoring Strategy.
- A full consideration of a soils testing regime should be conducted but was beyond the scope of the Greening Review.

Diversification

- Having a greater diversity of crops in a field or farm in a given year or over time can in principle bring some benefit to arable land.
- Diversification defined by number and proportion of crops would, however, only have the required effects if the existing system consisted of mainly one high-intensity crop. Diversification in terms of adding low intensity crops would then be beneficial.
- Any changes in cropping are more likely to be to other similar rather than functionally different crops so the potential benefits of diversification are unlikely to be realised.
- Assessing the consequences of diversification requires intensity measures that should consider fertiliser and pesticide application rates, soil condition, presence of weeds and invertebrates and carbon footprint.
- In the Scottish context, replacement of spring by winter-sown cereals would meet the requirements for diversification but would in most cases have detrimental outcomes (both environmentally and potentially in terms of business resilience if higher-risk crops were grown).

- Given the potential for negative outcomes the provision of equivalence measures is desirable and winter soil cover and catch crops would both deliver benefits (particularly avoidance of erosion and associated diffuse pollution in a climate with likely more extreme rainfall events).

Ecological Focus Areas

- All the EFA measures proposed have the potential to result in positive outcomes and these outcomes go beyond the primary biodiversity objectives (climate, soils and waters).
- The EFA requirement does not apply to areas that, while having lower intensity production, can still have environmental issues (particularly with diffuse water pollution).
- EFA measures deliver less benefit than would the equivalent spend through more specific and targeted measures (e.g. in hotspots of diffuse pollution within priority catchments).
- For all measures, maximising the benefits (or at a minimum avoiding negative side effects) means needing to support their implementation with advice on good practice in terms of measures chosen, their location on farm and their management (without necessarily increasing their cost).
- Advice on the benefits for production/financial outcomes of appropriately managed EFA measures should be provided.
- Greater flexibility in the adaptive use of weightings within EFA measures would be desirable to ensure that the measures are appropriate to Scotland's circumstances and objectives (potentially including regional/spatial targeting).
- Not all nitrogen-fixing crops have the same potential to deliver biodiversity enhancement. Flexibility in the appropriate use of weightings would be desirable to ensure that those crops that are most beneficial for biodiversity are taken up and the intended outcomes of the EFA are achieved.
- Maintaining EFAs over time in the same location is likely to enhance their benefits.
- Benefits from some EFA measures would be enhanced by coordination between land managers in terms of the types and spatial arrangements of EFA measures (e.g. corridors or mosaics).
- EFA equivalence options should be considered if the uptake of standard EFA measures does not lead to the balance of outcomes sought by Scottish Government.

1 INTRODUCTION TO THE EXPERT REVIEW

As part of the CAP Greening Review conducted by the James Hutton Institute, a group of senior researchers with experience across a number of research domains was convened and asked to evaluate the possible effects of both the 'standard' greening measures and of the proposed 'equivalence' measures. Those domains and the researchers contributing are as shown in Table 2.

Table 2: Domains and lead experts involved in the CAP Greening Review

Domain	Lead expert(s)
Agro-ecology	Geoff Squire, Cathy Hawes
Biodiversity and landscape ecology	Robin Pakeman, Rob Brooker
Climate change adaptation and mitigation	Iain Brown
Soils	Willie Towers, Jason Owen
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The guidance for the review was to consider:

1. The effect of each of the measures individually;
2. Their potential to synergise; and
3. The added value of the *equivalence options* (as then drafted).

Where appropriate, other suggested questions for consideration were as follows:

1. Are there localised (farm/field) benefits and/or wider landscape level effects?
2. Are there trade-offs, and between what – e.g. water versus air pollution?
3. Can a measure be positive, ineffective or detrimental dependent on implementation factors that are not specified in the regulation or the equivalence option?
4. Are there context specific aspects of measures that might mean the need for greater prescription in targeting and/or management of equivalence options?
5. Are there opportunities for greater benefits by coordination of types and locations of measures between businesses?

The following sections contain the responses from each of the reviewers.

2 AGRO-ECOLOGY

Geoff Squire and Cathy Hawes

2.1 Agroecology - General Comment

Following a phase of reconstruction and reorganisation, beginning in the late 1940s, in which barley and to a lesser degree wheat replaced oats as the main cereal, intensification of agriculture in Scotland accelerated from the early 1970s. A combination of fertiliser, machinery, pesticide and improved crop varieties supported a continuous rise in yield, to the extent that grain output per unit area became as high as anywhere in the UK. By the early 1990s, the rate of rise had slackened and the arable-grass system entered a phase in which finally outputs levelled due to factors not certainly identified (Economic Report on Scottish Agriculture, 2015; Scottish Government, Results of the June Agricultural Census, 2014).

Despite the levelling of yield, pesticide usage on some of the main crops continued to increase (Scottish Government Pesticide Usage). Many indicators of ecosystem health continued to decline, including arable plants and birdlife (State of Nature Report 2013; Preston *et al.* 2002). Arable-grass soils appear to be deteriorating e.g. in terms of carbon content and water holding capacity (Valentine *et al*. 2012). The supply of feed and fertiliser has come to rely on imports from overseas, and high-value and high-input crops such as winter wheat and potato showed major falls in output during years of adverse weather (Economic Report on Scottish Agriculture, 2013). Yet there are also positives. The arable-grass system has retained a degree of crop diversity from the 1980s: with commonly 15 to 20 designated types of crop and grass occuring in a region (June Census). Farming systems also continue to show their capacity to regulate inputs as evidenced by the continued decline in phosphate fertiliser application and the steep fall from the early 1990s in nitrogen, particularly applied to grass (Fertiliser Practice, 2013).

In this context, further changes to arable-grass agriculture are needed that will stabilise and enhance the production ecosystem, variously by further reducing nitrogen inputs, especially from imports, repairing and maintaining soil condition and restoring both functional biodiversity and iconic wildlife, while as far as possible maintaining or increasing output. In each of the phases – reconstruction (1940s), intensification (1970s), levelling (1990s) - an *effect* can be identified leading from technological innovations that act on life forms (crops, wild plants, soil microbes, invertebrates), which in turn mediate ecological processes that finally result in a range of major outputs or ecosystem services. For the future sustainability of agriculture, that chain needs to be planned and managed. The possible interventions within the CAP Greening measures are now assessed as to their ability to modify the chain of effect.

2.2 Crop Diversification

Having a greater diversity of crops in a field or farm in a given year or over time, in principle, can bring some benefit to arable land. However, the numbers of different crops, or their proportions, are not the most appropriate variables with which to determine whether the desired outcome will be achieved. <u>The main influence is the type of crop and its management.</u>

Diversification defined by number and proportion of crops would only have the required effects if the existing system consisted of mainly one high-intensity crop. Diversification in terms of adding low intensity crops would then be beneficial. Otherwise, harmful cropping systems might be treated the same as beneficial ones; while relatively beneficial but not particularly diverse systems would be penalised. To illustrate these points four hypothetical holdings, that each satisfy the crop diversification requirements, are characterised by a number of indicators that together suggest the likely impact of the different combinations of crops on biophysical status, including functional biodiversity (see Table 2 below). The characterisation is illustrated by using indicators for fertiliser (N and P), pesticide, soil condition, weeds, invertebrate trophic groups and calculated carbon footprint, each classified into semi-quantitative categories, as derived below.

Fertiliser applied to arable crops typically covers a wide range of rates. Winter cereals and winter oilseed rape (WOSR) are given 170 to 210 kg ha^{-1} nitrogen, potatoes 140-160 kg ha^{-1}, spring cereals about 95-110 kg ha^{-1}, grass <100 kg ha^{-1} and legumes usually none (Fertiliser Practice 2013). Phosphate fertiliser applied is broadly proportionate to nitrogen but relatively higher in potato. Categories for nitrogen fertiliser per year averaged over the crops are defined as high >150 kg ha^{-1} N, medium 150-100; low 100-60 and <60 very low.

Pesticide can be quantified in several ways, for example by area treated, and by the number and mass of active ingredients. The pesticide area index (PAI) is estimated per crop from pesticide use surveys (Scottish Government Pesticide Usage) as total area treated with all types of pesticide divided by total area of crop type. Typical PAI values are: potato, 15-25; winter wheat 9-11, winter barley and winter oat 7-9, winter oilseed rape 5-9; spring barley 5-6; legume 4-6; short term grass <2. Categories in the table are high PAI>10; medium 10-5, low 5-2; very low <2.

Soil condition among Scottish arable-grass fields has been quantified through a wide range of indicators including bulk density, penetration resistance, carbon and nitrogen content, water holding capacity, air-filled pore space, and ex-situ seedling growth (Valentine *et al.* 2012; Squire *et al.* 2015). Relations between cropping sequence and soil characters are complex, but high input crops such as potato and winter wheat are associated with soil of poor condition, e.g. low carbon content, high bulk density, reduced water holding capacity, etc. Categories indicate the effect of the crop combination in relation to current state: negative, worsening of soil condition; even, little or slow change; positive, potential to maintain good condition or to reverse degradation.

Weeds have dual functions, limiting the crop at high density and supporting the in-field food web. In most conventional agriculture, weed control is such that weeds now rarely limit the crop. Their value to the food web is defined in terms of species and abundance, functional type, mass (usually more mass, more species), and the balance between grass and dicotyledonous (dicot) weeds, the grass being generally more inimical to yield and the dicot better for supporting the food web (Marshall *et al.* 2003; Hawes *et al.* 2005). Sequences dominated by winter cereals tend to increase grass weed proportion whereas sequences that mix season (winter and spring sowing) and dicot and grass crops tend to support more invertebrates (Hawes *et al.* 2009, 2010; Squire *et al.* 2015). Moreover, dicot weeds have a lower C:N ratio, i.e. higher %N in tissue, than grass weeds and crops. The lower C:N of dicots is closer to the C:N ratio for invertebrates and arable soil, which is possibly one reason why dicots support a greater number of invertebrates per unit mass (the invertebrates do not have to dispose of so much ingested carbon). The weed flora also contains some rare or declining species which have value as 'cultural' biodiversity. For the purpose of comparison, weed categories are defined as follows in terms of mass: negative (for food web) <20 g m^{-2} weed mass; medium, in between; positive, 40–60 g m^{-2} weed mass. The percentage dicot may introduce additional categories, e.g. >60% dicot combined with the last category would bring it to 'very positive'.

Invertebrate trophic groups are strongly influenced by season of sowing, the dicot/grass crop balance, the weed flora and pesticides (Hawes *et al.* 2009). Dicot, pollen bearing crops and their dicot weeds support the most diverse arable food web (including pollinators and biocontrol agents such as parasitic wasps) through the floral and other resources that they offer. Winter cereals offer poor quality food resources themselves and have little or no associated weed vegetation, which tends towards monocot. Spring cropping is associated with a more herbivore-based food web with a greater proportion of closely linked specialist insects. Winter cropping is usually more detritivores-based with generalist omnivores making up the largest proportion of the higher trophic levels. Given the complexity, categories are here approximated as negative, medium and positive.

In a study of fields in lowland Scotland, (Hillier *et al.* 2009) estimated annual carbon equivalents (CE) from inputs (N, P, fuel, pesticide, etc.) as on average 388 CE ha^{-1} for winter cereals, 436 for winter oilseed rape, 540 for potato, 310 for spring cereals, lower for managed grass, depending on nitrogen input, and very much lower than 300 for field beans due to the general absence of nitrogen fertiliser. Categories are high >400 CE ha^{-1}; medium 300-400; low <300.

Characterisation by the above indicators and ranking of four hypothetical farms is given in Table 3. Each example consists of three crops in combination characterised by an overall ranking for two interventions (fertiliser and pesticide) and four of the states (soil condition, etc.) that result from the interventions acting on ecological life forms and processes. The categories for each indicator were derived as stated above and the 'average' overall category was then approximated. Two high-intensity sequences, including variously winter cereals, winter oilseed rape and potato, have 'high' inputs and carbon footprint and are generally negative for functional biodiversity. The two other sequences score medium or low for inputs and positive or medium for functional biodiversity. All combinations of crops would comply with Crop Diversification measures **but have very different effects on the state of the ecosystem.**

Table 3: Examples of (hypothetical) holdings that satisfied the crop diversification requirement compared in terms of the effect on nitrogen and phosphate input, pesticide input, soil condition, beneficial weed flora, invertebrate trophic groups and carbon footprint (see text for definition of categories)

Crop type sequence (dominant first)	N and P	Pesticide units (PAI)	Soil condition	Weed flora: mass and grass/dicot balance	Invertebrate trophic groups	Carbon footprint per year
winter wheat, winter barley, winter oilseed rape	high	high-medium	negative	negative	negative	high
winter wheat, winter oilseed rape, potato	high	high	negative	negative	medium	high
spring barley, winter barley, winter oilseed rape	medium	medium	even	positive/medium	medium	medium
short term grass, spring barley, peas or beans	very low	very low	positive	positive/medium (depends on type of grass)	positive (medium if more grass)	low

Analysis of cropping sequences over about 10 years indicates farms tend to maintain a broadly consistent level of input over time, depending on location (e.g. soil), markets for their produce and farmer's preferences. High input farms, which in Scotland are a smaller proportion of the total than low input farms, are likely to maintain their activities in high input crops but may adjust the relative area of these crops. Low input farms are similarly likely to maintain their preference and again shift the relative areas. In general, therefore, the overall level of inputs and ecological risks are unlikely to change greatly as a direct result of the Crop Diversification measures.

2.3 Ecological Focus Area

Implementation of any of the measures initiates a set of interventions that act on life forms, processes and finally main outcomes as summarised in Table 4. Each of the measures results in change to several outcomes. In general, measures occupying fields or large parts of fields should have more substantive effects on indicators of soil functioning than would implementation of linear features, which have greater effects on surface movement of materials and organisms. The weightings currently allocated therefore seem to undervalue the effects on soil carbon and the nitrogen economy.

- Fallow land – the effects would depends on the type of fallow and how it is managed; allowing the natural seedbank, especially the dicot component, to emerge would be highly beneficial provided any inimical weeds were controlled. Generally very positive.
- Buffer strips – may allow plants, invertebrates, mammals and birds to exist along and in the margins of waterways, but their effectiveness also depends on their composition. Grass strips would reduce surface run-off but would be poorer for functional biodiversity than wildflower strips. Generally positive, but a botanical composition including wild legumes would probably be optimal.

- Field margins – again, the effectiveness will depend on the composition, notably high legume content, high dicot/monocot balance, and an even annual/perennial balance would favour invertebrates.
- Catch crops/green covers are potentially able to reduce losses of nitrogen and, and if ploughed-in or used as mulch could add organic carbon to the soil. Generally positive, but could be encouraged with higher weighting.

N-fixing crops are the only way in the short term to reduce nitrogen inputs, and hence imports of nitrogen fertiliser and animal protein feed; they would also strongly enhance food webs by offering high N plant material. Current estimates in Europe indicate grain or forage legumes will fix 150-200 kg ha^{-1} nitrogen in a full year and possibly 50 kg ha^{-1} nitrogen will be left in the soil through plant residues (EU Legume Futures Report, 2014). There are grounds for raising the weighting of some N-fixing crops substantially particularly those that are more effective in providing food for pollinating and other insects in line with the primary biodiversity objectives of EFAs (see Section 3.4.5). Defining the most appropriate weights is, however, complex, depending on the characteristics of the legume, the presence and composition of coexisting weed species and the landscape context. The latter defines total availability, which is potentially as important as the individual concentrations of food per unit of area as determined by legume species. The characteristics of such systems are being actively studied by the Centre for Sustainable Cropping in the James Hutton Institute.

The single weighting for all N-fixing crops is a mandatory part of the EU regulation and one which member states cannot change except though equivalence. It would be highly desirable to have a more differentiated and targeted approach to weightings that specifically encourages the most beneficial N-fixing crops (since by some metrics the best are many orders of magnitude more effective than the least). The downside of simply raising a single weighting for all N-fixing crops is the potential displacement of more beneficial EFA activities with N-fixing crops that can have more limited benefits for biodiversity. Overall, across the EFA options a degree of pragmatism on weightings and implementation rules is perhaps required, considering the measures in the agro-ecological "round" as well as from a biodiversity protection and enhancement perspective (the primary objective of EFAs). Weightings are a key tool in encouraging uptake and without uptake there can be no impact. EFA equivalence options should be reconsidered if the uptake of standard EFA measures does not lead to the balance of outcomes sought by Scottish Government.

Table 4: 'Ecological focus areas' summarised by chain of effect through main life forms, main ecological processes modified and likely consequences for overall outputs and ecosystem services.

Intervention	Life forms	Ecological processes	Main consequences
Fallow (in-field crop replacement with different vegetation depending on type of fallow, usually with reduced tillage)	Weed seedbank, sown seed, invertebrates, soil microbiome (e.g. mycorrhizae)	Growth (carbon assimilation) with low inputs; addition of organic matter to soil; soil mineralisation; soil stabilisation by microbial networks; transfer of mass and energy to invertebrate food web; potential to replenish beneficial dicot seedbank	Agrochemical input reduced; beneficial food web enhanced; soil C depletion countered (depending on type of fallow)
Buffer strips (insert linear feature in the landscape)	Wild and sown plants, invertebrates, soil microbiome - localised to linear features	Regulation of surface flow of materials; potential for localised energy/matter transfer to invertebrate food web	Surface runoff, erosion, and agrochemical impact reduced; local habitat for wildlife enhanced
Field margins (insert linear or annular feature in the landscape)	Wild and sown plants, invertebrates, soil microbiome - localised to linear features	Regulation of surface flow of materials; potential for localised energy/matter transfer to invertebrate food web	Surface runoff, erosion, and agrochemical impact reduced; local habitat for wildlife enhanced
Catch crops/covers (in-field crop replacement)	Crops, forages, invertebrates	Rapid carbon assimilation; uptake of residual mineral N and conversion to organic N; return of organic matter to soil	N loss from field reduced; soil C depletion countered.
N-fixing crops (in-field crop replacement)	Legume crops and forages; in-field soil microbiome particularly rhizobia	Stimulation of rhizobial activity, biological nitrogen fixation, growth of high N plant mass, provision of low C:N vegetation for invertebrates	Home-grown, high-nitrogen offtake increased; N fertiliser and N imports reduced; beneficial food web enhanced

2.4 Interactions, Trade-offs and Dependencies

1) Are there localised (farm/field) benefits and/or wider landscape benefits?

Most of the Crop diversification and Focus Area options could have local and wider benefits. In particular, margins and buffer strips, together with fallow, could be deployed to enhance landscape corridors within and beyond the farm. Factors of the wider landscape matrix also influence attributes of food webs (see section 2.5).

2) Are there trade-offs, and between what?

High intensity sequences based around winter wheat and potato tend to generate the highest financial returns but have the most adverse effects on biophysical attributes when compared to low intensity sequences. Some of the Ecological Focus Area measures would assist reversing general declines in soil condition, but substantive remediation might only be achieved by reducing the number of high-intensity crops or devising less intrusive soil and pest management.

3) Can a measure be positive or detrimental depending on implementation factors that are not specified in the regulation?

As indicated above, effects of some high-intensity crop-combinations are difficult to ameliorate given present typical methods of soil cultivation, traffic and harvesting.

4) Are there context specific aspects of measures that might mean the need for greater prescription in targeting and/or management of options?

In general, encouraging legume crops and forages in Crop Diversification or Focus Area measures would be beneficial. Lightening sequences of mostly winter wheat and potato could be achieved by introducing spring-sown crops, particularly a broadleaf.

5) Are there opportunities for greater benefits by coordination of types and locations of measures between businesses?

In general, measures that aim to improve local factors such as soil quality have to be tackled *in situ*. Damage done to soil or sedentary food web organisms in a field cannot be undone by growing something less damaging in another field. In other cases, there may be options for spreading harmful and beneficial practices, such as those having different carbon equivalents, across a landscape or between holdings. More generally, the only way to engineer landscape scale mosaics that are beneficial for wildlife or pest biocontrol are through coordinated efforts between groups of holdings.

Research is nearing completion into developing a comprehensive suite of indicators of biophysical status, including nitrogen fixation, soil condition, C:N ratios as generalised indicators of energy and mass transfer among organisms, and landscape scale influences on field-scale processes including crop pest biocontrol and regulation of water movement, erosion, and mineral fertiliser losses. The suite of indicators would serve as a way to assist comparative assessment of various measures in relation to needs of the system.

2.5 Landscape Effects

Recent research has shown the intensity of an arable-grass landscape affects the species of weeds and invertebrates in its component fields. A field of a given type has a significantly higher or lower population of wild plants and invertebrates depending on what types of vegetation, including cropped and semi-natural habitats, are in the landscape around it (Tscharntke *et al.* 2005; 2012).

These ‘area-wide’ effects in landscape are particularly important for mobile wildlife in general, and including invertebrate pest biocontrol organisms (Birch *et al.* 2011; Chaplin-Kramer *et al.* 2011; Rusch *et al.* 2013). While therefore in-field measures can influence a range of beneficial organisms, their impact may be limited if the surrounding landscape is managed very intensely or has little semi-natural area. Examples of landscapes in Scotland differing in these qualities are given in Figure 1 and Figure 2 while further information can be found in the link to the EU PURE project in the reference list.

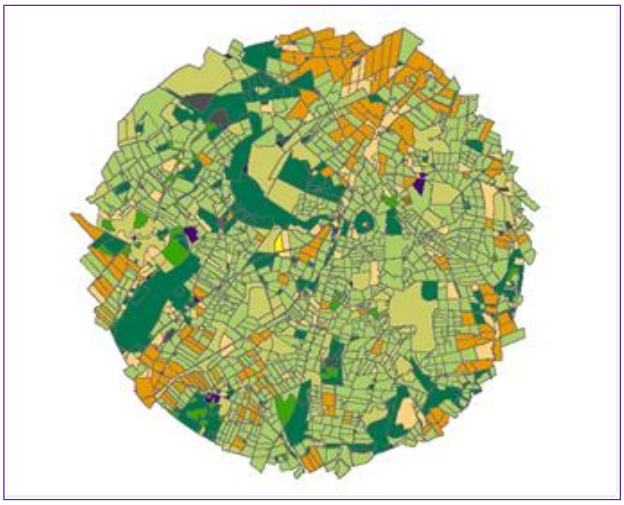

Figure 1

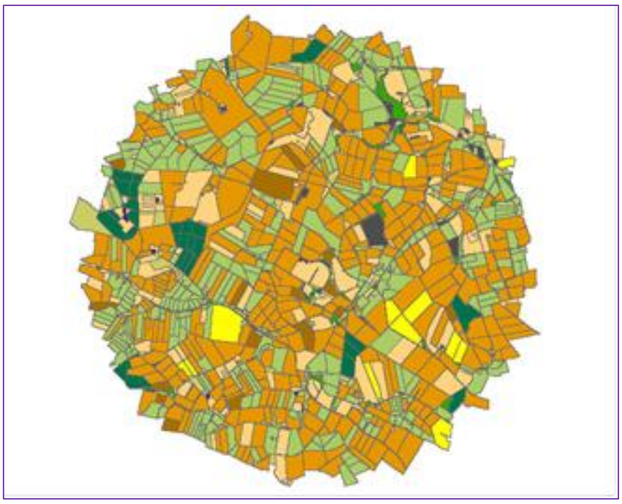

Figure 2

Figure 1 and Figure 2 above[1] show two landscapes – cereals are shown in orange and short-term and older grass in light green. Figure 2 is a more intensely managed landscape.

The characteristics that are likely to be important are field size, connectivity, diversity of crop types and their management and proportion of semi-natural vegetation. Therefore Crop Diversification is in general positive, providing that the most intensely managed crops, potato and winter wheat, do not dominate. Intensive landscapes may be de-intensified by increasing the range of crops and the proportion of spring-sown oilseed rape and legumes, for example. Among the Ecological Focus Area measures, linear or annular features should be implemented with a view to contributing to corridors and mosaics over a range of at least 5 to 10 km.

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[1] Images in Figure 1 and Figure 2 courtesy of Nora Quesada Pizarro and Graham Begg, The James Hutton Institute

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3 BIODIVERSITY AND LANDSCAPE ECOLOGY

Robin Pakeman and Rob Brooker

3.1 Background

Many components of biodiversity have suffered substantial negative impacts from increased intensification of agricultural practice since the Second World War, particularly in countries such as those of Western Europe (Robinson and Sutherland 2002, Mackey *et al.* 1998). Impacts have occurred throughout those components of biodiversity associated with farmland. For example, widespread declines of both rare and common arable weed species (Fried *et al.* 2009) have resulted from the switch from spring- to autumn-germinating cereals, and arable weeds overall have suffered from increased use of inorganic fertiliser and pesticides, the development of more competitive and resource-demanding crop cultivars, sowing at higher densities, changes in crop rotation practice, and improved efficiency of seed cleaning (Robinson and Sutherland 2002; Critchley *et al.* 2004, 2006; Fried *et al.* 2009). The decline in one species group can have implications for other components of farmland biodiversity. Weeds play an important role in supporting wider biological diversity (Marshall *et al.* 2003), and their decline has negative impacts on species further up the food chain, for example on invertebrate and bird species (Wilson *et al.* 1999; Hawes *et al.* 2010; Karley *et al.* 2011). Declines in prey abundance are just one of the drivers involved in recent declines in farmland birds. Although targeted management schemes have been beneficial in conserving farmland birds such as corncrake, other species groups such as waders continue to decline (Foster *et al.* 2013). Some of these declines may also be due to factors operating out-with farmed land (e.g. in other parts of a species' annual range). The impacts of farmland management can be central to the conservation of biodiversity at a landscape as well as a field level; local level management can be critical for those organisms that are relatively sedentary, whereas for mobile organisms the diversity and connectedness of the landscape overall can be central to maintaining a healthy population (Gonthier *et al.* 2014).

In addition to losses resulting from changing management, changes in farmland biodiversity will have resulted from habitat loss and habitat fragmentation. Habitat loss will have direct impacts on species associated with that habitat. Habitat fragmentation reduces connectivity between populations. This results in a breakdown of dispersal between habitat patches which would otherwise prevent inbreeding and the rescue of failing populations. As fragmentation increases, species associated with that habitat drop out from the assemblage as their requirements from connectivity between populations fail. For instance nuthatches occur only in landscapes with a high degree of connectivity (Bellamy *et al.* 1998) and plant species richness is lower in isolated grasslands compared to those with a high degree of connectivity (Eriksson *et al.* 2002) and is also lower in isolated woodland fragments (Honnay *et al.* 2002).

Finally, biodiversity loss is also driven by climate change, atmospheric deposition and invasive non-native species (RSPB *et al.* 2013). These cannot be addressed specifically through changing agricultural management. Arguably to mitigate the impacts of these drivers, more effort than would otherwise be expected has to be made to conserve biodiversity through improved land management.

3.2 Permanent Grassland

Definition: "*Permanent grassland is land used to grow grasses or other herbaceous forage (such as clover), either naturally (self-seeded including 'rough grazings') or through cultivation (sown), which has* ***not*** *been included in the crop rotation for five years or longer.*" The standard greening measure is aimed at preventing the overall loss of grassland. Computed at the national scale, the ratio of permanent grassland to total agricultural area must not decrease by more than 5 %. If the change is larger than this, Scottish Government would be required to take action to increase the area of permanent grassland. The intended outcome of the measure is primarily to protect the carbon sequestered under permanent grassland.

This land cover type can include habitats of high conservation importance. This includes the machair of the Western Isles and Argyll Islands, as well as large areas of peatlands with their high biodiversity and significant carbon stocks. In the uplands it includes large areas of heathland and acid grasslands as the main constituent habitats of rough grazing. In the lowlands most of the grassland is made up of improved permanent pasture, with concentrations in Ayrshire and Dumfries and Galloway (see pages 9 and 11 in Part 3 of the Greening Review).

The 2014 Agricultural Census[2] gives the total agricultural area as 5,595,968 ha, the area of grass (5th year and over) as 882,387 ha and the area of rough grazing as 3,056,855 ha. The ratio of permanent pasture to total agricultural area is thus 0.703. The threshold for change that would trigger action by the Scottish Government would be a reduction to 0.669 (0.95 x 0.703), and this represents a drop of 196,962 ha of permanent pasture (assuming that total agricultural area remained the same). As unimproved semi-natural areas are protected by the *Environmental Impact Assessment (Agriculture) (Scotland) Regulations 2006* then significant losses in improved grasslands could occur (c. 22 %) before the threshold was reached. The Agricultural Census covers a larger population than those in receipt of Pillar 1 subsidy. A similar analysis in Part 2 of the Greening Review (section 3.2.6) conducted for those businesses which submitted a SAF in 2014 indicates that improved grasslands using the PGRS crop code could see a 29% reduction in area before triggering an intervention. The inclusion of rough grazings within the standard permanent grassland measure means that it is likely to be ineffective in protecting carbon stocks in improved grasslands.

3.2.1 Suggestions for guidance

In the lowlands, the permanent grassland areas are separated by significant areas of other habitats, especially in areas where arable is the main focus of production such as the lowlands of NE Scotland. This represents considerable habitat fragmentation, and as noted in the previous paragraph, locally significant amounts of improved permanent grassland could be lost without getting close to the 5 % national threshold. These fragments might be important for a range of groups of organisms, including pollinators, and might also be important for declining bird species such as lapwing. Consequently, guidance ought to recognise that increased fragmentation and habitat loss in the lowlands could be problematic for a range of species and that advice should reflect this.

This greening measure concerns the area of permanent grassland; it does not address the quality of the permanent grassland. For instance, removal of grazing would be deleterious for ground feeding birds and low-growing plant species. Guidance should cover, where relevant, the benefits of maintaining appropriate levels of grazing to maximise biodiversity or to benefit specific plants or animals. In effect, guidelines should aim to prevent grasslands from being either overgrazed or undergrazed.

3.3 Crop Diversification

Definition: *“Crop diversification is the growing of a number of different crops that enhances biodiversity.”*

The crop diversification measure applies only to larger holdings with a concentration on arable farming; there is the reasonable assumption that smaller holdings will be bringing heterogeneity in management as a function of their different ownership. Small arable farmers have to follow a two crop rule, larger ones have to follow the three crop rule.

Mapping of the areas where the crop diversification measure applies shows that it is largely targeted to the lowlands of the east coast, where arable is the predominant land use (see Section 3.3 in Part 2 of the Greening Review). However, maps showing where businesses would need to change current cropping regimes suggest the greatest shifts in management would be required in NE Scotland in terms of total land area (see Section 3.4 in Part 2 of the Greening Review. Proportionally it would be significant in Orkney and North East Scotland where 44% of the

[2] http://www.gov.scot/Publications/2014/10/6277/6

businesses to which the 3 crop rule applies fail the requirement. However, even in areas where cropping patterns would not meet the rules, the area of new crops could be relatively small – minimum 5 % for the third crop and 20 % for the second. So for the areas marked in dark green in the corresponding maps in Part 3 of the Greening Review, a maximum one quarter of that area would see a shift in crop type.

The potential of positive impacts on biodiversity from crop diversification depend upon the choice of crops made in response to the 2 or 3 crop rules. For example, switching some winter wheat to spring wheat will have little impact on the associated biodiversity at either the field scale or the landscape scale, though it may have other environmental benefits. In contrast, switching from a cereal crop to a legume crop would benefit pollinators. It should be stressed that the biodiversity benefits of many of the crops listed in Annex D of *Basic Payments Scheme Greening* booklet[3] are unknown. It could be argued that increasing the functional diversity of the crops grown is key to seeing benefits (Benton *et al.* 2003). However, as transaction costs of switching production to completely different crops will be high, then significant shifts in cropping patterns will be unlikely as farmers will shift to crops requiring similar machinery etc.

Within the list of arable crops in Annex D of the *Basic Payments Scheme Greening* booklet there are a number that have direct benefit for biodiversity, notably "Wild bird seed" and "Wild flower/bird mix". Encouragement should be given to farmers to choose, at least for the third crop, crops that directly benefit biodiversity. The third crop has a minimum 5 %.

The biodiversity benefits of many crops are unknown, so the benefits must be taken on the basis that increased heterogeneity is a good thing (Benton *et al.* 2003). Landscape-scale effects could be beneficial, depending upon the choice of the crops grown. For instance, if more legumes were grown, then it may reduce the fragmentation of existing pollinator populations and hence buffer these populations from other environmental variation.

Guidance could encourage a shift in crop type to one with different structure, timing of harvest and potential to support pollinators or other wildlife. Guidance could also cover the management of the new crops for enhanced biodiversity benefit.

3.4 Ecological Focus Areas

Definition: *"An Ecological Focus Area is an area of land upon which you carry out agricultural practices that are beneficial for the climate and the environment. The main aim of EFAs is to improve biodiversity."*

This has a similar geographic and business focus as the crop diversification measure: it is aimed at businesses predominantly focussed on arable. EFA has five options, evaluated in the subsections that follow.

3.4.1 Fallow

Within this option, increased flowering and seed production from the weeds that germinate after the previous crop is harvested could benefit pollinators and seed-eating birds and small mammals, respectively. The option could introduce genuine habitat diversity, specifically areas of reduced management intensity. The degree of benefit realised will depend on the management of the fallow.

It should be stressed that the wild flower and wild bird seed options are specifically designed to enhance biodiversity. Allowing land to go fallow without this seed input would be less likely to have the same benefits, so the guidance should stress the benefits of using these seed mixtures.

If the fallow option is maintained for more than one year it repeats past setaside options. The overall effects of setaside on biodiversity are generally positive (summarised in Dicks *et al.* 2013), and include increased densities of

[3] http://www.gov.scot/Topics/farmingrural/Agriculture/CAP/CAP2015/Greening/GreeningBooklet

farmland birds (Roberts and Pullin 2007). The guidance should suggest that fallow areas are maintained for a number of years to achieve these benefits.

3.4.2 Buffer Strips

There is strong evidence that buffer strips, as compared to land without buffer strips, generally increase arthropod abundance, species richness and diversity, including bumblebees (summarised in Dicks *et al.* 2013). Buffer strips also generally benefit birds (increased numbers, densities, species richness and foraging time), plants (increased species richness) and small mammals (increased densities and activity) (summarised in Dicks *et al.* 2013). Buffer strips will increase landscape connectivity between uncultivated areas (summarised in Dicks *et al.* 2013). Some of these impacts will be more affected by the quality of the buffer strip than others. For instance buffer strips as areas of uncultivated land may provide nest sites for bumblebees (Osborne *et al.* 2008), but foraging resources for them would be enhanced by higher proportions of suitable nectar and pollen producing plants, especially legumes (Knight *et al.* 2009).

As with Fallow, the guidance should stress that the results from sowing wild flower and wild bird seed options would be likely to be better for biodiversity than the vegetation that develops spontaneously. However, seed mixtures should be tailored for situations where the strip is mown or not. Guidance should suggest that buffer strips could be used to link up other areas of uncultivated habitats in order to improve connectivity. Wider buffer strips are more likely to act as effective corridors for wildlife (Lambeck 1997). Guidance should suggest that wider buffer strips should be used where possible.

3.4.3 Field margins

The same comments and suggestions for guidance apply as for Buffer Strips.

3.4.4 Catch crops/green cover

These crops are planted to maintain a cover over the winter and prevent that land from being used for growing a winter crop for harvest the following year. Of the crop types available under this option, three could benefit pollinators if allowed to flower: Vetch, Alfalfa and *Phacelia*. These crop types should be highlighted as benefiting this group of organisms. If left ungrazed, then planted cereals and mustard could benefit seed-eating birds and mammals, as could the other crops (legumes and *Phacelia*) in a limited way. Guidance could suggest that grazing be managed to benefit these wildlife groups.

Maintaining the catch/cover crops into the spring would bring benefits if they affected wildlife in the same way as overwinter stubbles (summarised Dicks *et al.* 2013). Leaving overwinter stubbles provides some benefits to plants, insects, spiders, mammals and farmland birds, including higher densities of farmland birds in winter and increased grey partridge productivity. Guidance should indicate that leaving these crops until February or March would bring the greatest benefits for biodiversity.

3.4.5 Nitrogen fixing crops

Legumes can be of significant benefit to bees when they provide both nectar and protein-rich pollen from the flowers, but in this regard not all legumes have equal value. In particular peas (as self-pollinators, Michalski and Durka, 2009) have very limited nectar production (0.96 kg/ha) compared with cultivated beans (52 kg/ha), birdsfoot trefoil (50 kg/ha) and lucerne (126 kg/ha), with all comparing poorly with red clover at 894 kg/ha (Baude et al., 2016).

3.4.6 Suggestions for guidance

From 2016, two nitrogen fixing crops will need to be grown on the EFA. This has the aim of increasing the overall flowering period for pollinators. The guidance should indicate which nitrogen fixing crops are early- and which late-flowerers.

3.5 Equivalence Measures

3.5.1 Crop Diversification

It has been recognised that the requirements to diversify cropping may result in some switching from spring to winter barley, with potential adverse impacts for wildlife and soils. To counteract this, two alternative practices are suggested as equivalence measures: winter soil cover and catch crops.

Winter Soil Cover

As identified above, leaving winter stubbles has proven benefits for a range of wildlife, including farmland birds (summarised in Dicks *et al.* 2013). The benefits of undersowing with clover are less clear, though in some circumstances it benefited some birds, plants, insects, spiders and earthworms. Bird species benefitting included barnacle goose, skylark and nesting dunnock (summarised in Dicks *et al.* 2013). The benefits of other options have been less studied. Setting the earliest harvest date at 14 February will allow for the benefits to be felt over much of the winter period.

Catch Crops

These are brassicas left unharvested until at least 14 February. The benefits of leaving these crops plus associated weeds to go to seed in providing food for seed-eating birds are well recorded (e.g. Hancock and Wilson 2003). However, guidance should make it clear whether these crops are allowed to be grazed or not. The benefits for seed-eating birds will be reduced if these crops are grazed.

3.5.2 Permanent Grassland

The additional requirement for soil pH testing will be unlikely to have significant terrestrial biodiversity impacts. However, it may play a role in improving aquatic biodiversity.

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4 CLIMATE CHANGE ADAPTATION AND MITIGATION

Iain Brown

4.1 Overview

This review considers the implications of CAP Greening measures with regard to the two main types of climate change response: -

(i) Adaptation objectives to manage the impacts of climate change that is occurring now or is expected to occur in the future because of the continued increase in atmospheric greenhouse gases (GHGs);

(ii) Mitigation objectives that aim to reduce GHG emissions and therefore stabilise atmospheric GHG concentrations at a level that avoids 'dangerous' climate change.

The Climate Change Act commits Scotland to a 42% reduction in GHG emissions by 2020 and an 80% reduction by 2050 (compared to 1990 levels). Agriculture is a major emitter of GHG gases and therefore has an important role in meeting these targets: the delivery plan for the rural land use sector specifies a 21% reduction in emissions (compared to 1990, or 10% compared to 2006 levels). Emissions from agricultural and related land use sector were 10.1 MtCO_2 equivalent in 2011 (20% of Scotland's total). These are largely non-CO_2 gases: in 2011 4.2 MtCO_2 equivalent were due to nitrous oxide (mainly from fertiliser applications to soil), 3.0 MtCO_2 equivalent due to methane (primarily from livestock), 2.2 MtCO_2 equivalent from land use (all GHGs), and 0.7 MtCO_2 equivalent from on-farm combustion (from buildings and machinery)

The Climate Change Act also provides a statutory requirement to report on actions that manage and adapt to the risks from current and expected climate change (as defined by the UK Climate Change Risk Assessment) through the Scottish Adaptation Programme. In this context, 'risks' can also include taking advantage of the beneficial opportunities provided by climate change for agriculture. Risks can be spatially variable depending on the local context (e.g. soils or farming system) and may be manifest over different time periods.

It follows from the above that the criteria for evaluating measures in terms of climate change mitigation are rather more straightforward (i.e. reduction of GHG emissions) than for climate change adaptation which can involve a diverse range of criteria. These relating to societal issues such as food production and security, water quality, flood alleviation, conservation of biodiversity, soil quality, and landscape amenity (etc.). Because of these multiple criteria, it is possible that some measures produce trade-offs that benefit one criterion but not others, particularly over different scales. There is also potential for interventions to generate adverse secondary effects ('externalities') beyond the farm-level or synergies at higher-levels with co-ordinated approaches. This is further complicated because the inherent variability of Scotland's climate from year to year means that measures for some criteria could actually be more beneficial in some years rather than others, or there is a time lag before they have a discernible effect requiring that they are continued over several years.

The implications for each standard or equivalence measure are in this instance considered against a counterfactual position of a continuation of the status quo with no new measures.

4.2 Permanent Grassland

In terms of GHGs, the conversion of grassland into arable cropland can result in significant emissions due to loss of organic matter, as reflected in standard national/international land use conversion rates for GHG accounting. Analysis of land use change patterns shows that it is much more likely that conversion of grassland into arable occurs on better quality land (e.g. Land Capability for Agriculture class 3 or higher) that has previously been used as improved permanent grassland than for lower quality land that is currently in rough grazing. As proposed, the standard greening measure would not prevent potentially substantial conversion of such grasslands with substantial resulting GHG losses. National GHG Inventory data, however, indicates that emissions from agriculture-related land use changes have substantially decreased in recent decades (ca. -50% from 4.4 $MtCO_2$ equivalent in 1990 to 2.2 $MtCO_2$ equivalent in 2011) mainly because less land has been converted to cropland. Therefore unless other drivers generating pressure to increase the extent of arable land become much more pronounced (e.g. food security; crop prices) it seems unlikely that there will be large-scale shifts in land use from grassland to arable.

Land management may be as significant as land cover in determining GHG emissions outcomes and this is not addressed by the standard greening measure. For example land that has had some improvement in the past could be still subject to further improvement (e.g. lime application) which would also potentially result in GHG emissions from CO_2 release, dependent on the soil type, rate of application, rate of lime dissolution. The standard greening measure will not therefore actively contribute to the reduction in GHG emissions required to meet statutory targets but will at least have a limited role in averting loss of carbon from soils under permanent grassland which could result in increased emissions. Mapping of the areas that are protected by this measure (see Part 3 of the Greening Review) confirms that these are mainly upland areas. Where these are rough grazings these are least likely to be subject to agricultural improvement (on economic grounds) but could be improved for other land uses that may not be associated with agriculture (e.g. drainage schemes on grouse moors).

For climate change adaptation, the importance of local context is crucial. Local areas of permanent grassland can have an important role in climate resilience depending on their specific use and interactions with other land uses in the wider landscape. Very general measures such as that proposed for CAP Greening are by themselves unable to account for this local specificity and therefore unlikely to have a significantly positive effect in isolation, requiring integration with other measures.

4.3 Crop Diversification

This measure aims to ensure that a range of crops are grown on the arable land of each agricultural business in order to avoid single-crop monocultures. Depending on the holding area of the business, the requirements are either for a minimum of two crops (between 10-30ha) or three crops (>30ha); in both cases the main crop can only occupy a maximum of 75% arable area (and two main crops a maximum of 95%).

For climate change mitigation, the differences in GHG emissions that occur between individual crops are generally assumed to be very small compared to other land use factors and therefore not included in accounting and reporting through GHG inventories. Therefore, the direct benefits of this measure for climate change mitigation are considered to be rather limited. Indirect benefits may occur if the alternative second or third crop involved a different management system (e.g. no till) that enhanced soil organic carbon or involved reduced fertiliser application, but similarly the reverse situation could occur.

Diversification is generally considered to provide a robust strategy to manage risk and uncertainty when compared with an optimisation strategy. Farmers have long known this and because of the variability and unpredictability of the Scottish climate have usually opted for a range of crops (or a mix of land uses) as a hedging strategy to spread the risk. Recent work investigating changes in the Land Capability for Agriculture (LCA) classification system has suggested that in some parts of Scotland this year-to-year variability has increased (Brown and Castellazzi, 2015). Therefore, for climate change adaptation which involves managing long-term trends in addition to the inherent variability of the climate, diversification is a sensible approach to risk management. Diversification can also reduce the risk of pests and diseases causing large-scale damage, which are potentially increased due to climate change (e.g. due to milder winters), because pests and diseases are often crop-specific and other crops may reduce their rate of dispersion. However, other drivers act against diversification, particularly economic factors such as a favourable market or guaranteed buyer for one particular crop.

Mapping of the areas that would be most affected by this measure (in Part 3 of the Greening Review) shows that although small-scale changes may be expected across most arable areas, and hence mostly in eastern Scotland, there is a larger regional clustering in NE Scotland (Aberdeenshire and Moray) where greater change may be required[4]. These are areas where spring barley is the dominant crop linked to the association with the malting and whisky industry. Spring barley is a reasonably resilient crop for the variable Scottish climate and therefore, for those businesses not currently meeting the requirements, replacing some of it with another crop as required to meet the rules may not necessarily result in growing a crop which is as climate-resilient (e.g. winter wheat).

The design of the measures through the 3-crop or 2-crop rule although stipulating some diversification, does not necessarily mean that the additional crops will be a positive change. A potential outcome is that the second or third crop is actually a less robust choice in terms of climate adaptation compared to the primary crop. This may occur if the secondary crop was a choice such as maize (Palmer and Smith, 2013)[5] which can cause soil degradation and impacts on water quality. It may also occur if the secondary crop was chosen to be winter wheat or barley which tend to increase the risk of soil erosion by being sown during autumn when rainfall rates are generally heavier and the erosion risk higher than in spring. This emphasises the benefit of good practice guidance on implementation of the measure and the need for monitoring on the actual changes that have taken place to comply with the measure.

The key issue for climate resilience is therefore crop management: maize or winter cereals or other intensive crops such as potatoes can all be cultivated without adverse effects with good management that adjusts to the prevailing weather conditions of that year. This is not covered by the measure which is based only upon distinctions in land use. Unfortunately, it is much more difficult to audit land management rather than land use. The former is covered through the regulatory framework for water and soil quality, and through GAEC cross-compliance, sometimes with limited effectiveness due to continued problems existing with diffuse pollution and soil compaction in specific areas.

A further issue is that the measure does not prevent the growing of the same crop in a field for several years that can cause problems with soil quality and that become exacerbated during extreme events (e.g. heavy rainfall or drought) due to the reduced buffering effect of the soil. In some cases, this may cause greater problems over several years than the dominance of one crop in a particular year but at least is part of a multi-year rotation system.

4.4 Ecological Focus Areas (EFAs)

This measure places a requirement for businesses with arable areas over 30ha to have 5% of their land within a recognised EFA option (fallow, buffer strips, field margins, catch crop/green cover, N-fixing crops). The presumption for EFAs is that they will be particularly useful in enhancing biodiversity. Some of these EFA options may be harder to monitor than others (e.g. field margins, catch crops) because of their small extent or association with other land uses. In farming terms, the uptake of the fallow option may be considered more likely because to farmers it seems the least complicated to implement.

Mitigation

Each of the options has potential benefits for climate change mitigation either by taking land out of crop production (and therefore reducing loss of soil carbon during cultivation and reduced application of fertiliser) or by introducing a cropping regime that reduces the risk of soil carbon loss (catch crop/green cover, N-fixing crops). An important issue, however, will be how this is incorporated into standardised emissions inventories. The area of land is relatively small because of the 5% threshold. Assuming with full implementation that this 5% of the eligible arable land in Scotland (ca. 750,000ha is eligible) is put into fallow as the most likely option to be taken up by farmers, and assuming a maximum technical GHG potential for fallow of 1.46tCo2/ha/yr (Feliciano *et al.*, 2013) then a sequestration potential of ca. 54.75ktCo2/yr may be provided. This could contribute ca. 2% to a reduction in GHGs from land use change.

[4] Although more of these seem to involve businesses that have a third crop area that is too small therefore these need only involve a change on 5% or less of their land.
[5] Palmer and Smith (2013) in an extensive field study of 3,243 sites in SW England found that 75% of land under maize showed serious structural degradation and was producing enhanced surface runoff.

Buffer strips and field margins would be likely to provide a similar GHG sequestration potential whilst N-fixing crops (e.g. clover) have a comparable maximum technical potential of ca. 0.98t/Co2/ha/yr (Feliciano *et al.*, 2013). Similar benefits may be gained from catch cops/green crops assuming a min-till management system. Additional GHG benefits for these options would occur through removal of fertiliser application[6], but would be not likely to apply to catch crops/green cover. These preliminary estimates assume that the same area of land remains out of production each year to comply with the measure but if the EFA requirement was rotated to different areas of the holding each year then a more complex pattern of emissions and sequestration would result with less likelihood of a net sequestration benefit.

Adaptation

In terms of the climate-change adaptation benefits, EFAs could play a role in enabling farmland biodiversity to adapt to change. An important factor in this will be the contiguity and connectivity of the EFA converted land. In general, larger areas of EFA land are more likely to provide better in situ adaptation to change because they allow the possibility of a more diverse and resilient ecosystem, which enhances the range of ecosystem services provided. Connectivity between EFAs would facilitate species dispersal as an adaptation response to find a more suitable climate (or microclimate). Conversely, small isolated fragments of EFA scattered across farm businesses are likely to be least beneficial. It would be desirable to reward co-operation between farmers to encourage the creation of larger FEA areas. In addition, initiatives to encourage the maintenance of existing EFAs into following years would also be advantageous to allow benefits to accrue across multiple years.

Although the benefits from the different EFA options will vary considerably dependent on location, the general weighting scheme provides a broad indication of the anticipated overall benefits. Field margins can be particularly beneficial for farmland biodiversity and buffer strips for enhancing water quality, as well as providing other ecosystem services, therefore justify an extra weighting. In a climate change context, with an increased risk of heavy intense rainfall events both can be useful in slowing runoff and both reducing flood peaks and retaining water quality, although the presence of surface and subsurface field drainage schemes may reduce their potential benefits. Field margins are likely to be beneficial for pollinators and for species that can counteract pests and diseases, which have both been identified as important in implementing field-scale adaptation for agriculture and biodiversity.

For climate change responses, it is possible that the most useful aspect of the EFA measure is the notion of weighting. This allows the encouragement of particular land uses that are more beneficial for multiple benefits based upon scientific evidence but also allows the possibility to subsequently modify weightings as more evidence becomes available on the changing environment following the principles of adaptive management. Therefore EFA-related weighting schemes could be developed further to encourage proactive adaptation measures that aim to address climate change issues before they become a problem by contrast to the reactive measures typically adopted for agriculture. To fully realise this as a policy lever, weightings would be best implemented through spatial targeting linked to local/regional priorities.

4.5 Synergies between measures

As the permanent grassland measure is effectively a neutral measure, the most likely combination of measures as active interventions is the integration of EFAs with crop diversification on arable land. In this case the adjacency of particular crop / EFA option combinations would seem particularly important, and this may be determined by design on grounds of economics or pragmatic convenience. This may be further complicated by year-to-year changes in which the benefits of the EFA units may be lost if they change location (this may be considered unlikely if the same land use patterns occur as with CAP Set-aside land). At present it is not possible to envisage synergies between the

[6] Basal fertilisers are allowed to encourage a ground cover, wild flowers or wild bird seed mixtures.

measures as they are designed in terms of climate change objectives and it is considered that the dominant factors will be convenience and reduction of potential economic losses.

4.6 Equivalence measures

4.6.1 Permanent Grassland

The proposed equivalence practice for this measure is to additionally require soil testing on all permanent grassland on which fertiliser is required (so excluding rough grazing as fertiliser is associated with improved grassland).

Implementation of this option would affect a large area of improved grassland particularly in SW Scotland where it is the dominant land use. Diffuse pollution from agriculture is identified as a problem in several catchments that have large proportions of improved grassland and acts against meeting the criteria for achieving a good status for water bodies in the Water Framework Directive. Regular monitoring of soils if this led to changes in management (such as liming to manage pH values) could be therefore have benefits for soil quality and environmental protection. With a projected increase in both winter rainfall and heavy rainfall events, this would provide a prudent strategy to manage risks to soil and water quality in a changing climate, although the logistics and costs for soil monitoring would have to be incorporated.

If soil testing and associated advice provision led to more efficient nutrient management and reduced fertiliser application then this would also be beneficial for climate change mitigation measures as loss of N as N_2O provides the single largest contribution of GHGs to the national inventory. Efficient fertiliser application at levels beneficial for grass uptake/growth with a minimum loss to water and atmosphere would also actually have benefits for farmers in terms of reduced expenditure. Similarly, reduction of lime application to optimal levels consistent with soil pH and associated fertiliser application could have benefits both for GHG (CO_2) emissions and reduced farm expenditure. It may be possible to further emphasise the benefits of good nutrient management by linking testing with advice and with incentives for the uptake of precision farming. The key challenge is in making the link between testing and active management change.

4.6.2 Crop Diversification

Equivalence for this measure is provided through either providing a winter soil cover requirement or a catch crops requirement instead of the standard two-crop or three-crop rule.

Winter soil cover may be provided by green sown covers such as undersown grass leys, rye or clover (etc.) that are not harvested before 14th February or possibly winter stubble (subject to EC agreement). This practice would allow businesses with large areas of spring crops (particularly spring barley) to continue to maintain this extent beyond the 75% single crop limit of the standard measure in return for providing a temporary winter cover rather than bare ground. By comparison with conversion of the land to autumn-sown crops this has the benefit of avoiding the increased risk of soil erosion and associated reductions in water quality. These can accompany autumn sowing due to the prevalence of heavy rainfall events which are likely to increase due to climate change (projections for increased winter rainfall have medium confidence but for autumn only low confidence). The presence of crop covers during winter can also provide additional food and shelter for wildlife compared to bare fields, notably for farmland birds and for migratory birds that temporarily use arable land (migration patterns are changing as the climate shifts).

Catch crops are defined to include those crops such as turnips, swedes and fodder crops (etc.) that can provide a winter cover and are not harvested before 14th February. These may be considered to be equivalent in their benefits for soil quality, water quality and biodiversity as with cover crops, although this will be influenced by the specific cultivation system.

In terms of benefits for climate change mitigation objectives these are likely to be limited, although the reduction of risks from soil erosion may help to maintain soil organic carbon. Potential soil carbon sequestration benefits from maintaining a vegetative cover have been identified with technical potential as high as 0.98tCo2/ha/yr (Feliciano *et al.* 2013) but these assume an all-year cover and this would be at least partially lost by spring cultivation. In terms of national targets, these changes in land management would not presently be included anyway because they are not currently recorded through the national inventory system.

4.6.3 Ecological Focus Areas

No additional equivalence measures are currently suggested by the Scottish Government. It is also indicated that regional/collective implementation of the EFA requirement will not be permitted. However the benefits of coordinated use of EFA requirements as mentioned above (section 4.4 Ecological Focus Areas (EFAs)) and the use of weightings through spatial targeting have previously been noted as worthy of further consideration in scheme design.

4.7 References

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5 SOILS

Willie Towers and Jason Owen

5.1 Permanent Grassland Measure

Much of Scotland falls into the Unimproved Permanent Grassland outside Natura category and as such an EIA is required in order for that land to be converted to an improved grassland or arable system. Much of this ground is assessed as Land Capability for Agriculture (LCA) Class 6, suited for rough grazing only, and as such there is little prospect of conversion even if there was a desire from landowners to do so. Much of the remainder will fall into LCA Class 5. Although this land has the potential to be converted to improved grassland, at present and for the foreseeable future, the economic and environmental considerations indicate that change is very unlikely to occur. There will be very little or no impact on soils in this area by this measure.

Improvement on the Unimproved Permanent Grassland within Natura category is prevented under the measure. Irrespective of this, over much of this land, any agricultural improvement would be ill advised at any rate given the severe biophysical limitations (climate, slope, wetness, rockiness) over much of this land.

Improved grassland covers much of the remainder of the area affected by this measure and is particularly common in Ayrshire, Dumfries and Galloway, the Clyde Valley, Caithness and Orkney and scattered throughout North East Scotland, in essence the main dairy and beef producing areas. Both options of ploughing the land either to sow new grass or a one-off crop of say barley, are allowed under the regulations and both are well established sustainable management options in this sector of Scottish agriculture. These requirements are unlikely to have any major impact on soils as they replicate current practice and on a field by field basis, some will fall out of the 'permanent' category and into 'arable' on a temporary basis whereas others will fall back into the permanent category five years after the last use for cropping.

5.2 Permanent Grassland Equivalence Measure

A grassland soil-testing regime has been proposed as an *addition* to the standard measure, the objective being to encourage and inform an improved fertiliser management regime that will help to reduce greenhouse gas (GHGs) emissions from agriculture. It only applies to improved permanent grassland where fertiliser application is standard practice in contrast to unimproved grassland that is not fertilised. Arable land that is also heavily fertilised, and much of which is subject to NVZ regulations, is also excluded.

Intuitively, the development of a basic soil and nutrient management plan should be an inherent part of overall farm management and there are good financial as well as environmental arguments for it. It formed part of the Farm Soils Plan published by the then Scottish Executive in 2005. Many farmers are likely to be adhering to sound nutrient management principles in any case, but the inclusion of it as an equivalence measure would make it a requirement for farmers to receive their full Greening payment and from 2017 this could also result in administrative penalties being applied to their Basic Payment.

The guidance on soil analysis lacks some detail at the moment, notably over what area does a single sample characterise? This is an important consideration with regard to the costs of this proposed measure. The details of the sampling methodology have still to be worked out but it is proposed that all fields under improved permanent grassland would be tested for soil pH – fertiliser efficiency is dependent on soil pH. Sampling frequency would be once every 5-6 years on a rolling programme. The analysis in section 3.2.4 of Part 2 of the Review indicates that the number of fields containing improved permanent grassland which would be included in this measure is over 202,000 fields covering more than 800,000 Hectares. This would mean that 35,000-40,000 fields would be sampled each year. Estimates for the cost of this depend on the sampling strategy which determines the number of samples that would need to be analysed. As an example, based on operating a W sampling scheme every 4 hectares, this may generate a total of 200,000 soil samples. At an indicative cost of £10[7] per sample, the cost of analysing the improved permanent grassland in Scotland for soil pH would be in the order of £2million for the 5-6 year period. This would equate to an annual cost of around £333,000-£400,000 per annum.

Were the requirement to conduct soil testing for pH to become compulsory under permanent grassland equivalence, this would represent a tremendous opportunity for the Scottish science community to significantly augment the soil collection currently held in the National Soils Archive. This resource facilitates long term monitoring experiments on the state of Scottish soil. Were there to be a requirement that soil analysis laboratories should forward a portion of each sample for archiving, this could be stored in a new dedicated soil archive facility. Indicative costings for the establishment of such a facility have been made and are estimated to be in the region of £400,000. In addition, handling and storage of these samples would require a staff complement of approximately 2 full time staff members plus appropriate management (0.5 FTE). Supplementary analysis would require appropriate staffing and equipment dependent on analysis undertaken.

5.3 Crop Diversification Measure

As stated in the Scottish Government Greening guidance booklet,

'Crop diversification has benefits for soil organic matter by:

- Reducing the bad effects of climate change
- Reducing soil erosion, pest and weed control
- Improving water quality.'

The guidance suggests that soil organic matter benefits as a result of crop diversification improving water quality. It seems more plausible that water quality is improved as a result of crop diversification having a beneficial effect on soil organic matter. Similarly the statement suggests that soil organic matter is improved as a result of crop diversification reducing soil erosion. Again, it seems more plausible that that soil erosion is reduced as a result of crop diversification having a beneficial effect on soil organic matter.

Notwithstanding the way the text is worded, there is a lack of hard evidence that crop diversification will have the stated desired effect. There are a number of considerations here. Firstly, farms that do not grow the required number of crops may be doing so because the climate and soil conditions restrict the range of crops that can be grown, in essence livestock farms with limited scope for arable cropping. In addition, increasing the range of crops might not necessarily fit into the farming system and put strain on farm finances due to increased capital expenditure.

Secondly, even where growing conditions are suited to increasing the range of crops, this may not necessarily produce the benefits sought by this measure. Crops differ in terms of the length of time in the ground, their nutrient requirements, the management interventions required to maximise yield and the number of vehicle passes needed to implement these interventions. In some circumstances, farmers may be compelled to move from relatively benign spring-sown crops such as spring barley to others such as potatoes, winter cereals or maize which have higher nutrient demands, involve more vehicle passes and in the case of potatoes quite intrusive cultivation techniques. These can all contribute to greater risks of soil erosion and compaction as well as increased costs. Different tillage options e.g. no or minimum till, will have beneficial effects with respect to reducing soil erosion risk and potential CO_2 loss but all improved agricultural soils do require ploughing at some time.

[7] Note that estimates for the cost of soil pH are currently being sourced from commercial companies.

A diversification based change that would see increased soil organic matter content and better structural stability, is to increase the amount of temporary grass in the rotation. It is an eligible crop but it does not feature heavily in the analysis of current cropping practice. It is most common, not surprisingly, in the more livestock orientated parts of Scotland – Ayrshire, Dumfries and Galloway, Caithness, Orkney and the higher parts of Aberdeenshire and the Borders. Even here, it is the main crop (>75%) in a relatively small number of areas and businesses. The temporary grassland area could be increased through substitution with another eligible crop. However, the grass needs to find a use or market and given the disinvestment in fencing in recent years, it would most likely be as silage for use elsewhere. Other eligible crops in general provide higher profits.

Analysis of current cropping practice indicates that the majority of Scottish farmers are already complying with the two and three crop rules suggesting that this Greening measure will have little impact on soils across the wider Scottish landscape. In tandem with this, the majority of the arable area therefore also complies although it is notable that a disproportionate number of small farm businesses are in this category. The main area of 'non-compliance' is in NE Scotland, likely to be due to the effect of the predominant malting market and the lack of alternative cropping opportunities on the higher ground. Spring barley is a short-term spring sown crop and if these businesses were compelled to move to alternative more demanding crops, there may be negative consequences for soil quality. Ironically, it is those parts of Scotland that are normally viewed as the most intensive and where water quality, in general, is poorest due in part to soil and nutrient management, that current practice is compliant with the Measure. This could be viewed as an adverse unintended consequence of the measure in that it does not impact where it is intended.

5.4 Crop Diversification Equivalence

The proposed measures are to ensure that at least 25% of the eligible arable area on each farm either has winter soil cover, a catch crop or a combination of these over the autumn and much of the winter months. It is proposed that these are used as an alternative way for farmers to comply *instead* of the standard measure, not an addition to it.

The absence of a vegetation cover on soil coupled with a rainfall event on sloping ground is the trigger for an erosion event. We have no control over the last two (although contour ploughing would help) but vegetation cover is something that can be managed. This measure would reduce soil erosion risk over that proportion of the ground and it would be particularly effective if it was adopted on parts of farms where the risk is greatest e.g. steeper slopes and/or near water courses.

The most practicable solution is to retain winter stubbles from the previous crop but the Scottish Government are seeking clarification whether this option is permitted under the equivalence rules. This and a number of the suggested catch crops are standard practices across much of Scottish agriculture.

The equivalence measure will help those areas that are not currently compliant with the standard measure where spring cropping is predominant and retention of stubbles/undersowing of grass are more common practices. Those areas where autumn sowing is more common and where the equivalence measure is less achievable will still meet the standard crop diversification requirements.

5.5 Ecological Focus Area (EFA) Measure

As stated in the Scottish Government's guidance booklet '…the main aim of EFAs is to improve biodiversity'. As such, this measure will have little impact on soil but what little it has will be largely positive in that the soil is vegetated and therefore much less at risk from erosion and with opportunities for the soil carbon stock to re-establish. Buffer strips may accumulate high concentrations of nutrients given that their main objective is to minimise the transport of nutrients to water bodies.

From a soil perspective and possibly a management perspective, leaving the ground fallow is probably the best of the five options offered although 'fallow' in the context of the EFA guidance does require some intervention in terms of weed control. Temporary grass, in essence part of the arable rotation, is also an eligible cover to qualify as fallow. Some guidance is required on the management of this option.

6 CATCHMENT WATER QUALITY

Andy Vinten and Kit McLeod

6.1 Introduction

This brief review considers the impact of the greening measures on water quality, specifically ***Maintenance of Permanent Grassland, Crop Diversification*** and ***Ecological Focus Areas***. It draws on two CREW reports produced for the Scottish Government one advising on the Scotland Rural Development programme 2014-20 for targeting support to deliver maximum benefit for the water environment (Akoumianaki *et al.,* 2014; Macleod *et al.,* 2013) and the second a report on SRDP impacts prepared for the SG Rural Statistics Unit (Vinten *et al.,* 2015). The review also draws on the current and previous RESAS strategic research programme and other literature.

The way land is managed affects the quality of Scotland's water environment. SEPA estimated that in 2015 rural diffuse pollution will contribute to adverse effects on water quality in about 400 water bodies across Scotland: these are mainly rivers with 40 groundwater bodies and 35 lochs (SEPA, 2014). In this review, we address both impacts on water quality environment and water quantity environment. To assess the effect of a measure on water quality at the landscape scale involves looking at a range of water quality problems e.g. phosphorus, nitrates and pesticides and the vulnerability of sensitive water bodies to those problems. The unit of assessment could be for example be a Water Framework Directive (WFD) waterbody with plant communities at less than good status, a WFD protected area for drinking water or a WFD Natura 2000 site (Akoumianaki *et al.,* 2014). For water quantity the focus is on potential for natural flood management (Akoumianaki *et al.,* 2014) and also low flows, which can lead to vulnerability to downgrading of ecological status under WFD (Vinten *et al.,* 2015).

Land managers need to comply with 'good agricultural environmental condition' (GAEC) separately to Greening to meet Basic Payment Scheme requirements. In addition, land managers are required to comply with general binding rules for diffuse pollution mitigation[8] and also have opportunity to undertake funded measures under the SRDP rural priorities scheme. This diversity of instruments relating to water quality makes it difficult to separate out causality for changes in water quality. A key conclusion of the Agri-environment-climate Working Group (Scottish Government, 2014) was that though most options were basically "sound" a "lack of meaningful data on the location, extent and impact of agri-environment options seriously hampered the ability of the group to assess the effectiveness of the current SRDP." Given the similarity of the Greening measures to some within the SRDP it would perhaps be worth considering: regional priorities, local targeting and preparing for the eventual evaluation of the greening measures (i.e. collection of baselines and/or counterfactual cases)

While greening measures generally have a positive impact on water quality, as discussed below, since they are not targeted at specific hotspots of pollution their impact will be substantially lower than for a similar spend using more targeted measures. This means less progress on improving the ecological classification of Scotland's waters under the WFD and on drinking water supplies under, for example, the Nitrates Directive. For this reason, SEPA, under the guidance of the diffuse pollution management advisory group (DPMAG) prioritise their diffuse pollution mitigation efforts to focus on 'priority catchments'. During the first cycle of the WFD River Basin Management Plans there were 14 priority catchments. In the second cycle to achieve objectives for the water environment then a further 43 priority catchments are likely to be added to reduce diffuse source pollution. SEPA have identified a further 60 'diffuse pollution focus areas' with lower intensity hill farming and sheep grazing where different solutions will be needed compared to the priority catchment approach.

[8] http://www.farmingandwaterscotland.org/ farmingwaterscot/info/2/know_the_rules

6.2 Permanent Grassland

6.2.1 Localised effects (farm/field)

The main effect of this measure in terms of water quality will be on the avoidance of nitrate leaching associated with ploughing out of improved permanent grassland (PGRS). The measure could also encourage some conversion of arable land to low input grassland, with beneficial effects on sediment, agro-chemical and nutrient losses to water (Macleod *et al.,* 2013). There may also be potential effects on water quantity through retention of more water in the landscape or return to the atmosphere as evapotranspiration.

The impact of ploughing out of improved grassland, if the following crop is well managed and allowance is made for the additional N release, should be no more than 40-50 kg N/ha, with most of the impact occurring over the year following ploughing out. However it may be significantly higher where (a) little allowance is made for the N release by reducing N fertiliser and manure applications (b) land is left fallow over winter (c) a following arable crop in autumn is poorly established (d) grazing occurs during the season immediately prior to ploughing out. On heavier soils, these figures may be reduced by 50% or more (Smith *et al*., 1984; Vinten *et al*., 1990), because of loss of N to the atmosphere as N_2 and N_2O and slower mineralisation. Some N_2O lost in drains will also outgas to the atmosphere (Reay *et al.*, 2003). The impact of retaining the area of improved permanent grassland will therefore be to reduce the frequency of ploughing out, giving potential benefits of reduced nitrate leaching to ground and surface waters.

6.2.2 Wider landscape level effects of the measure

Pre-implementation estimation of impact of the Greening measure for permanent grassland is only possible over regional or national scale as there are no specific requirements at farm or catchment level. The national scale estimate of difference between N inputs to agriculture and outputs from agriculture for Scotland is around 150 ktonnes/year (Fernall, 2010). This Gross Nutrient Balance (GNB) approach does not attempt to estimate the relative importance of the main loss mechanisms of leaching, denitrification, nitrous oxide emission during nitrification, ammonia volatilisation etc., or the change in soil storage. To set the national greening requirement in the context of the GNB, consider the extreme case of a 1 year decrease in PGRS due to additional ploughing out equivalent to 5% of the total agricultural area (239,808 ha or 29% of the PGRS area) assuming no semi-natural pastures are converted). If we further assume an impact on nitrate leaching of 40 kg N/ha, this would mean the release an additional 9.5 ktonnes of N , increasing by 6% the GNB-estimated difference between inputs and outputs of Nitrogen. Specific levels of loss would depend on preceding and subsequent management regimen (see section 6.2.3, particularly the last paragraph for discussion of possible rates of loss).

If such a decrease in area occurred uniformly across the PGRS in Scotland, only around 9% would impact on Nitrate Vulnerable Zones (see Figure 3 which compares the distribution of PGRS with the NVZ boundaries[1]). Using a national water balance model, it is estimated that the impact of loss of grassland on nitrate-N concentrations draining to groundwater in the NVZs would be around 0.6 mg N/L, if all the impact occurred in the year following ploughing out, compared to a drinking water standard of 11.4 mg N/L. This means at aquifer scale, impacts are also likely to be quite small; however individual, shallow private water supplies in phreatic aquifers could be positively affected if located in fields which prior to this measure, were at risk of conversion from permanent grassland to arable.

This assessment assumes good management of livestock grazing prior to ploughing out. In section 6.2.3 the impact of timing of removal of livestock prior to ploughing out is discussed. If this took place immediately prior to ploughing (a worst case), as opposed to one year previously (a best case and as recommended in section 6.2.3), the losses incurred could be over 3 times as much. Extensive, one off ploughing out across large areas, such as the post war

[1] For further analysis on PGRS and NVZs please see section 3.6.9 in Part 2 of the report

ploughing out of large swathes of permanent grassland in southern England, can cause a much larger impact, especially when located over important drinking water aquifers such as the chalk in Southern England (Foster and Crease, 1974) or the Devonian Sandstones in Fife (Trabada and Vinten, 1998). It is possible the Permanent Grassland measure may make such impacts less likely.

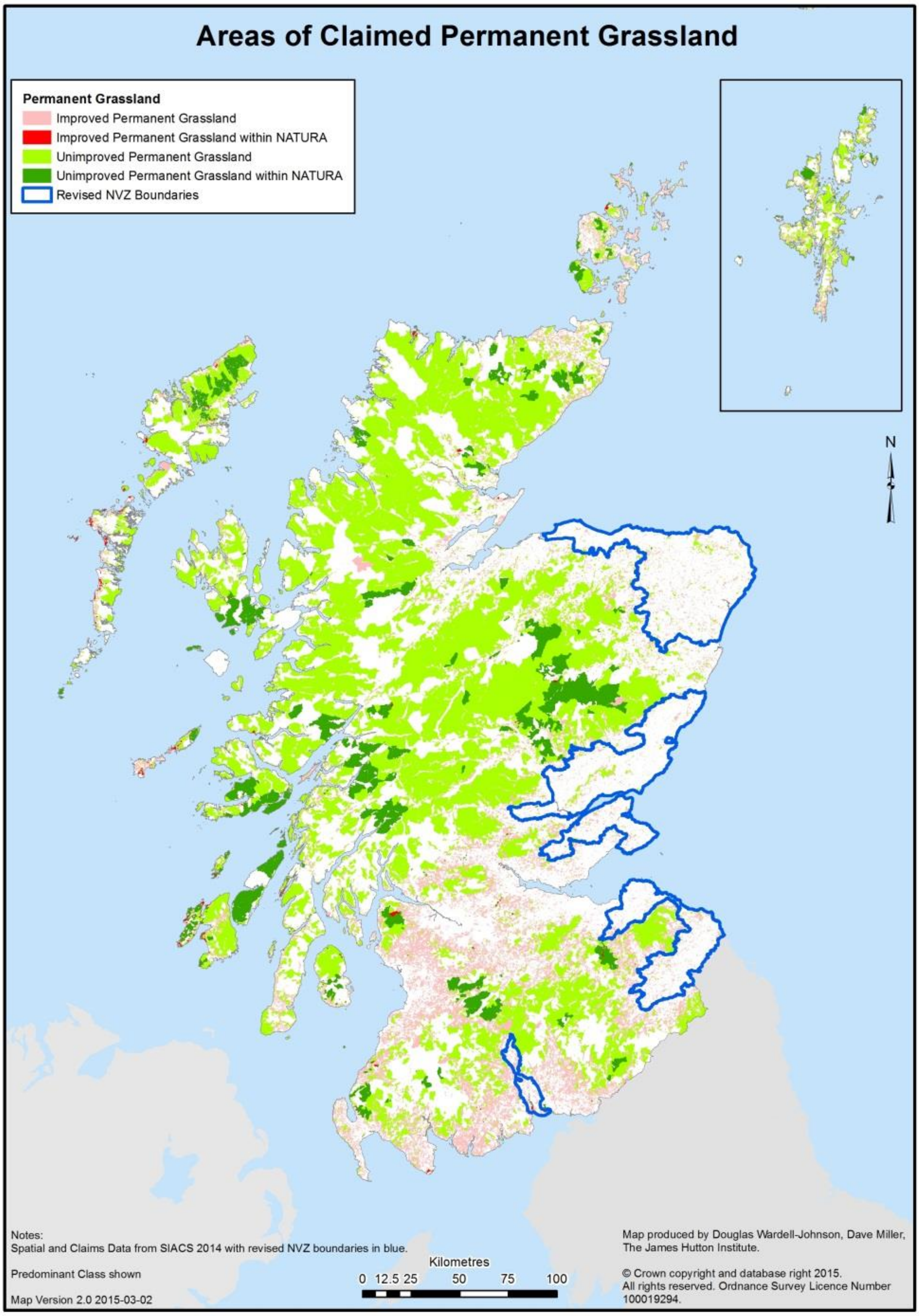

Figure 3: Areas of Permanent Grassland with revised Nitrate Vulnerable Zone (NVZ) boundaries

6.2.3 Implementation factors

The level and timing of mineral and organic nutrient application and stocking density of livestock on grasslands are the two main factors influencing their potential to cause impacts on the water environment (Bilotta *et al.*, 2007). The baseline level of leaching of nitrogen as nitrate from the original permanent grassland to water depends very strongly on the fertilisation and grazing management regime of the grassland (e.g. Whitehead *et al.,* 1990 showed a range from 40-360 kg N/ha; see also Hawkins *et al.,* 1996; Haygarth and Jarvis, 1996; Scholefield and Stone, 1995). Ploughing out such permanent grassland for reseeding or conversion to arable use will lead to temporarily enhanced mineralisation of soil organic nitrogen sources (which are normally protected from leaching), into mineral forms (ammonium and nitrogen). The fate of this additional N mineralisation depends on a number of factors, including:

1. The following crop. A quickly established grass reseed will provide a sink for N released into the mineral N pool in the soil, and so reduce the likelihood of losses. If the following crop is arable, then release from warm soils in autumn following ploughing out may not coincide well with demand for N from the cereal crop.

2. N fertiliser application adjusted to allow for this additional release. If there are judicious adjustments made to the N application rates, losses can be mitigated. However, because timing of release of nitrate from soil organic N sources may not fit well with N uptake requirements, especially of arable crops, there is likely to still be an impact on water (Vinten *et al.,* 1991).

3. The composition of the previous sward. Swards which have relied on N fixing clover to supply the grass with nitrogen, and used lower inputs of mineral fertiliser as a result, are likely to be less prone to nitrate leaching when ploughed out (Davies, 1996; Davies *et al.,* 2001).

4. How the grass has been managed prior to ploughing out. Where a grass crop has been the subject of intensive grazing immediately prior to ploughing out, especially if the ploughing out occurs in autumn, it is likely there will be much more labile organic matter and urine N inputs. These are highly concentrated and spatially heterogeneous, prone to rapid mineralisation and nitrification and thus have potential for large losses to water (e.g. Eriksen, 2000; Adams and Jan, 1999).

5. Soil factors. On soil with heavier textures, such as clay loam, sandy clay loam and silty clay loam, the rate of mineralisation of the soil organic matter will be much slower, due to poor soil aeration (Vinten *et al.,* 1992). There is a greater likelihood that the nitrate released will be lost to the atmosphere as harmless nitrogen gas (N_2) or the greenhouse gas, nitrous oxide (N_2O). If the soils are artificially drained, or naturally imperfectly or poorly drained, much of the nitrate leached will be lost to surface water systems, posing little threat to groundwater, whereas if the soils are light textured and well drained, the risk of loss to phreatic aquifers is much greater.

Ammonium is unlikely to be lost to water in significant quantities, but in well-limed grasslands, ammonium will be rapidly nitrified to nitrate, which is readily lost by leaching to water. However, if soil pH is maintained at a lower than optimal level, this may help to reduce the risk to water quality associated with ploughing out.

6. Climatic factors. Higher rainfall will increase risk of nitrate formed within the soil being leached, rather than being taken up by growing crops, but will also dilute the nitrate concentration, decreasing the risk of concentrations that are considered harmful to ecosystems or drinking water.

7. Timing of ploughing out. Where grass swards are ploughed out in autumn, when the soil is still warm, there is an enhanced risk of nitrate being lost to water before a subsequent crop establishes itself (e.g. Djuurhuus and Olsen, 1997).

Many of these factors were studied in a major study at the Bush Estate, Penicuik, Midlothian on the mineralisation and fate of N following ploughing out of long term grass and grass-clover swards (Davies *et al.,* 2001; Vinten *et al.,* 2002). The net effect of ploughing on N release from grassland soils (140 kg/ha) was higher than from ploughing out grass-clover (85 kg N/ha) (Davies *et al.,* 2001) over 18 months. Where swards had not been grazed for a year prior to ploughing out, the net release was much smaller (40 kg N/ha). Estimated first year leaching losses from ploughed out grass clover swards were 45 kg N/ha where the sward was re-sown compared to 103 kg N per ha where the soil was left fallow. On grass plots, estimated leaching losses from ploughing were 43 kg N/ha where the sward was re-sown compared to 204 kg N per ha where the soil was left fallow. This gives an indication of the adjustment to fertiliser N recommendations required to allow for ploughing out of grassland. Soil testing for N, however, is not recommended as the release from organic sources is gradual and spatially and temporally highly variable. The permanent grassland equivalence option will reduced the risk of poor management of fertilisation and manuring after ploughing out.

6.2.4 Context specific aspects

It is possible that occasionally the measure might encourage some conversion from low input arable land to high input grassland, which might encourage an element of pollutant swapping (high sediment, P and pesticide losses swapped for higher nitrate leaching and microbial pollution). While the management factors and targeting may influence the size of impact of the measure, at catchment scale these would not make the measure detrimental or ineffective.

The ability of land managers to plough permanent grass and immediately sow a new grass ley and still retain its status as 'permanent grass' has potential to have a negative effect on the water quality environment. Erosion of soil and associated diffuse substances are more likely on bare reseeded ground compared to an established grassland sward (Butler and Haygarth, 2007). However, it is not envisaged that this practice will be strongly influenced by the adoption of the greening measures.

6.2.5 Opportunities for co-ordination and location of measures

The stronger protection of non-NATURA improved grassland areas in lowest corners of fields and riparian zones, to act as buffers for sediment and nutrient pollution, may well be warranted, especially in priority catchments. This targeted protection could be accompanied by linkages to funds for SRDP water pollution measures such as wetlands, pasture pumps, buffer strips, swales[9] etc.

We recommend that an element of any permanent grassland equivalence measure should be introduced to target the lowest area of fields, where pollution runoff has the opportunity to be filtered and/or treated, prior to discharge to water.

6.3 Crop Diversification

6.3.1 Localised (farm/field) effects

If the effect of crop diversification were to decrease the area of winter crops grown in favour of more spring crops, then this could have an impact on water quality. Winter and spring crops count as separate crops in the Greening – Basic Payments Scheme (2015) guide, so on land with a predominance of winter crops at present, it may be that greening will increase the area of spring crops grown. On the other hand it is perfectly possible to fulfil greening requirements while only growing winter crops.

Increasing the area of winter crops grown would increase the losses of sediment and phosphorus to water via soil erosion, as erosion is much more likely from ploughed and sown land, especially if the crop is poorly established, than from stubble or ploughed land.

[9] http://www.gov.scot/Topics/farmingrural/SRDP/RuralPriorities/Packages/ReducingDiffusePollution

The annual export coefficients for P used to assess the cost-effectiveness of buffer strips to mitigate P export to Rescobie Loch by Balana *et al.* (2012) (see Table 5) highlight the difference between grass and spring crops (risk class 2 or 3) and winter crops (risk class 4).

Table 5: Annual export coefficients for P from agricultural land (kg/Ha/yr)

P export per year (kg/Ha)	Crop Risk Class	Slope Category		
		Low (<4°)	Medium (4-13°)	High (>13°)
1.	Very Low (e.g. Rough Grazing (RGR))	0.01	0.02	0.03
2.	Low (e.g. Temporary Grass (TGRS))	0.06	0.1	0.14
3.	Moderate (e.g. Spring Barley (SB))	0.2	0.5	0.7
4.	High (e.g. Winter Wheat (WW))	0.7	1.1	1.5
5.	Very High (e.g. Ware Potatoes (WPOT))	1.3	2.2	3.1

The impact on nitrate leaching to water is likely to be more variable, because the lack of a growing crop acting as a sink for nitrogen over winter, is counteracted by the smaller amounts of N fertiliser used on spring crops, leaving lower residual impact on N leaching in the following autumn. If the cultivations for spring cropping are delayed until spring, leaving the land in stubble, this would also reduce the risk of nitrate leaching. Studies on drained plots on a clay loam soil at Bush estate, showed lower nitrate leaching losses from stubble fields compared with fallow land cultivated in autumn (Vinten *et al.,* 1991).

6.3.2 Wider landscape level effects of the measure

If the measure increases the extent of winter stubble retention, as opposed to presence of ploughed, sown land in autumn, this might be expected to reduce losses of sediment and associated P and pesticides to surface watercourses; however, where winter crops are well established, there will be lower loss of nitrate to water compared to leaving the land in stubble. We consider the former beneficial effect to outweigh the negative effects of less autumn cultivation, especially for surface water quality.

6.3.3 Implementation factors including targeting and management of measures

How the land is cultivated and fertilised in relation to the crop requirement is likely to be more important for potential effects on the water quality environment than if two or three different crops are grown on a particular holding. Guidance should encourage the retention of winter stubbles, or grass in positions in the landscape where storm water overland flows are concentrated as a way of mitigating of diffuse pollution.

6.4 Ecological Focus Area

6.4.1 Scope of greening measure

- There are five EFA options that land managers may use on their own or in combination to meet the EFA commitment and these have different weightings based on suggested environment benefits: fallow land (x1.0); buffer strips (x1.5); field margins (x1.5); catch crop/green cover (x0.3); and nitrogen-fixing crops (x0.7).
- Several elements of EFA are complementary to GAEC and meet the requirements of both e.g. buffer strips along water courses.
- Field margins and buffers need to be on or adjacent to arable land. Where adjacent means the area of the EFA option must be contiguous (touching) to arable land.

6.4.2 General Comments

The rules about management of EFAs are directed at protecting terrestrial biodiversity e.g. no agricultural production or fertilizer/herbicide addition to fallow areas. Options that could result in detrimental effects on quality environment of watercourses or bodies (particularly those in close proximity with a high level of hydrological connectivity) include: 1) applying basal fertilizer to aid establishment of a wildflower mixture or wild birdseed mixture; 2) changing the ground cover; and 3) temporarily storing farm yard manure for the field.

6.4.3 EFA Fallow Land

Where a managed grass fallow occurs (e.g. unfertilised grass), the vegetation will act as a sink for nutrients, but may still be prone to loss of nutrients to water in the first year. Longer-term fallow options with good vegetation cover, should have a beneficial impact on water quality. Fallow land, especially if it lacks an effective sink for nutrients in the form of a crop, or root systems to bind the surface soil, will be prone to losses of nutrients, particularly where the land has previously been used intensively (e.g. Goulding (2000) cited an average of 140 kg N/ha leaching from rotational set aside land in the Nitrate Sensitive Areas scheme in England).

6.4.4 EFA Buffer strips

Riparian buffer strips between two and twenty metres in width are an option for EFA with an area weighting of 1.5. A managed, established, vegetated and unfertilised grass/woodland buffer alongside watercourses can enhance biodiversity and encourages the following of a natural course, which contributes to flood control and improves water quality. Riparian buffer strips of all widths from 2 to 20m are likely to have a significant impact on water quality through mitigation of sediment runoff, denitrification of nitrate transported from adjacent arable fields, and prevention of spray drift into watercourses (Macleod *et al*., 2013).

There is a large body of literature on the efficacy of buffer strips installed at water margins (e.g. Collins *et al*., 2009; Krongvang *et al*., 2005; Uusi-Kamppa *et al*., 2000; Hoffmann *et al*., 2009, Roberts *et al*., 2012). In Scotland, Balana *et al.* (2012) assessed the cost-effectiveness of variable width buffers on P loading from land to Rescobie Loch (in the Lunan water catchment). They used metadata sets of Collins *et al.* (2009) and Krongvang *et al.* (2005) to estimate buffer strip efficiency of P removal as a function of field slope and crop. The study showed that a combination of 2m, 6m and 20m buffer strips were able to mitigate P loads to the loch sufficiently to make the loadings low enough to restore the loch to good status, while not incurring disproportionate costs.

There is also an ongoing CREW project (2015), on the effect of buffer strips on pollutant loads to water and other benefits and impacts. Within this project, a very useful approach to assessing impact of buffer strips, as a function of width, was highlighted. In this approach, site specific erosion risks and sediment trapping are factored into width guidance by Dosskey *et al.* (2008). These authors used simulations and validations of the process-based model VFSMOD (Vegetated Filter Strip Model) to produce a graphical design aid depicting 7 relationships between trapping efficiency and width according to a range of site conditions plus a range of modifiers (termed adjustment rules) acting to select up or down the spread of curves to fine tune specific site conditions. The appropriate buffer width needed at a given site to provide the required reduction in sediment (or dissolved pollutant) needed to achieve the target water quality thresholds can then be determined. The adjustment rules are driven by four factors: slope, soil texture class, field length and soil cover management. Slope and soil texture affect trapping efficiency of the buffer and field length and management affect the runoff and sediment loads into the buffer. In summary the simulations and adjustment rules show that:

- under certain site properties a <5m buffer can have a high retention efficiency but under other conditions (e.g. greater slope) much larger buffers are required,

- trapping efficiencies are highly sensitive to all factors, particularly for buffers with narrower widths between 5-10m,
- trapping efficiencies are very low for water and dissolved pollutants (N) relative to sediment (P).

A national scale assessment of the impact of buffer strips using the approach of Balana *et al.* (2012) but with standard 8m buffer width was carried out by Vinten *et al.* (2015). These authors obtained impact indicators for SRDP measures implemented under the Scottish Rural Payments scheme (2007-2013), and Figure 4 shows the distribution of these impact indicators, using data obtained from SG-RPID, by the Scottish Government Rural Statistics Unit.

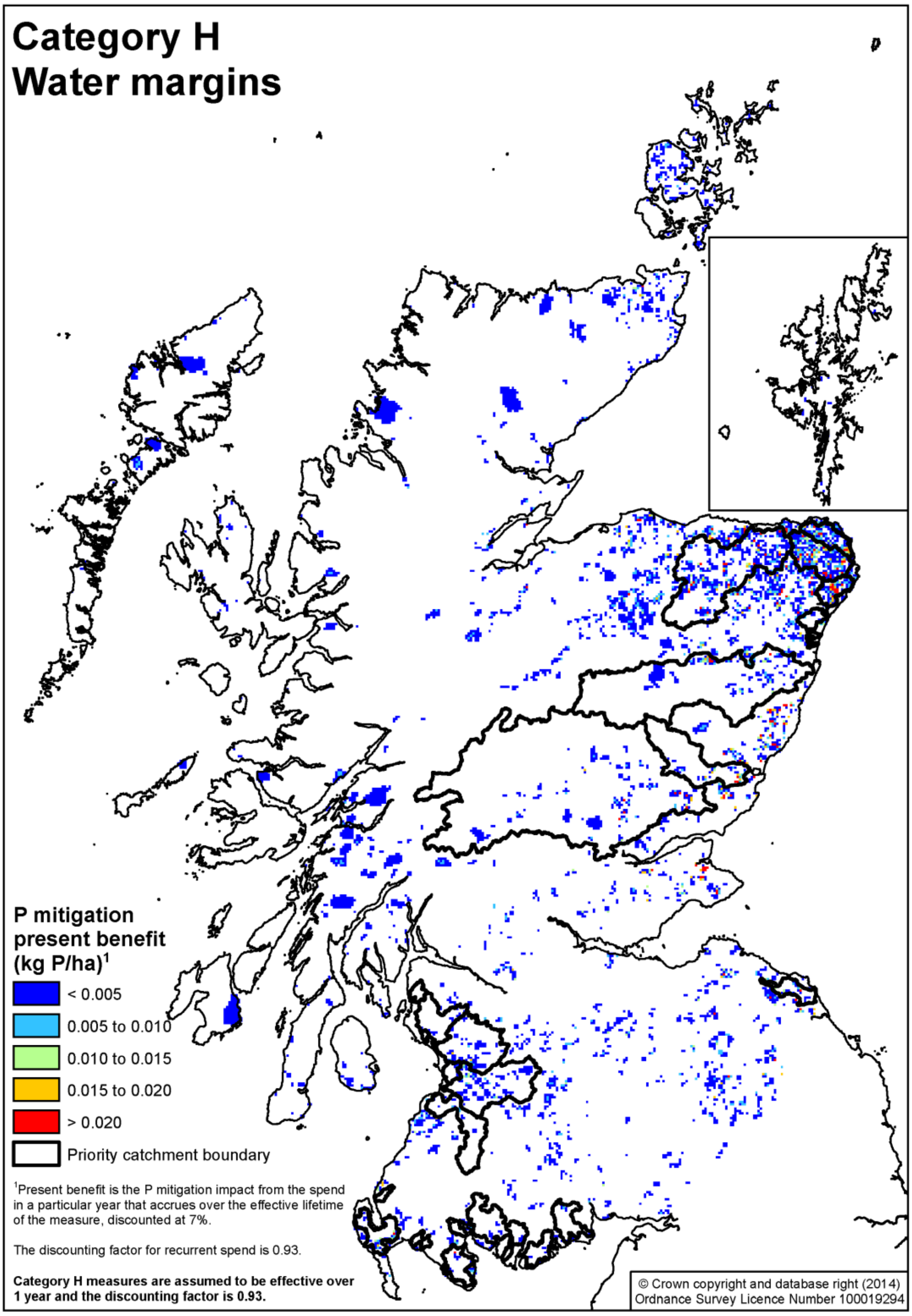

Figure 4: Map of impact spend on SRDP 2007-2013 measure for water margins on total P loads to water

Implementation factors

The Greening guidance states buffer strips need to be adjacent to a watercourse or water body. Land managers are not allowed to undertake agricultural production (apart from cut and remove silage/hay), graze or apply fertilizer or herbicide and this is likely to provide potential for positive effects to the water quality environment. The ability to change the ground cover to wild flower mixture, wild bird seed mixture or grass sward should be considered as any cultivation and fertilization of riparian areas has potential for negative effects on the water quality environment (Butler and Haygarth, 2007). The spatial targeting of this measure to at risk parts of the landscape, such as riparian corners of fields or sites where concentrated overland flow crosses the field boundary, would greatly enhance the efficacy in improving water quality.

6.4.5 EFA-Field margins

The adoption of field margins has many similar impacts to the adoption of riparian buffer strips (see above), but the impact on water quality may be significantly lower because of the lower connectivity of non-riparian fields with water (e.g. Lexartza-Artza and Wainwright, 2009). Moreover, because the downslope margins are not targeted, there may be large sections of field margins that do not receive overland flow of water, and so have much less likelihood of having an impact on water quality. Nonetheless for most fields in Scotland, during storm events, the connectivity to surface water drainage systems is quite high, so the benefits of field margins on downslope edges of arable areas of Scotland, for mitigation of sediment transport to surface water, may often be similar to those for riparian margins of the same width and layout (SNIFFER, 2006). The mitigation impact of field margins on water quality may be around 20-30% of that for riparian margins of similar dimensions, but this depends on the nature and connectivity of the landscape with water (Lane *et al.,* 2009). With respect to losses of nitrate to groundwater, on freely drained sites, the areal impact of field margins will be similar to riparian margins. However, the hydrological conditions of riparian margins, due the proximity of surface water, are often different to field margins. This means that nitrate transported laterally with water through riparian margins is more likely to be lost by denitrification than is the case with field margins. If field margins were targeted at areas of high connectivity with watercourses or water bodies, then the potential for positive effects on the water quality and quantity environment would be much greater.

6.4.6 EFA-Catch crop/green cover

The CREW Rural Development options synthesis indicated that cover crops could provide benefit to the water quality environment and no effect on the water quantity environment (Macleod *et al.*, 2013). Catch crops/Green crop cover grown over the autumn/winter have potential to remove nutrients from the soil at a time when they would otherwise be vulnerable to leaching. The roots also help bind the soil together and the cover minimises the erosive impact of rain on bare soil. If they are well established, they may provide a valuable sink for nitrogen compared with ploughed land or stubble. However, they can be sown till 1 October, and the presence of a freshly sown fine tilth in autumn, means that such crops, if late established, can be vulnerable (as are winter cereals) to loss to water erosion of sediment and associated pollutants such as P. Where such crops are ploughed in during spring, when soils are at or above field capacity, there may be problems establishing following crops due to anaerobic conditions developing in the soil, hampering root development. Macdonald *et al.* (2005) found that early sown cover crops are most likely to be effective when grown on freely drained sandy soils where the risk of nitrate leaching is greatest. They are less likely to be effective on more poorly drained, medium-heavy textured soils. In the short-term, mineralization of N derived from relatively small cover crops in cereal based cropping systems is unlikely to contribute greatly to nitrate leaching and adjustments to fertilizer N recommendations will not usually be necessary. In addition to the above point the land manager needs to consider soil testing and reductions in subsequent additions of mineral and organic fertiliser.

6.4.7 EFA-Nitrogen fixing crops

The value of nitrogen fixing crops for water quality lies in two main potential impacts:

Minimising artificial fertiliser use, especially nitrogen. This means that the risk associated with rapid leaching and runoff of newly applied bag fertiliser is much diminished. Whether the use of N fixing crops alters the longer term balance sheet for nitrogen depends on the efficiency of utilisation of the extra N likely to become available after the N rich crop residues are incorporated. The timing of release of this residual N may not coincide well with crop growth requirements. For example, if a legume crop residue, such as peas, is ploughed into warm soil in autumn, but establishment of the following cereal crop is delayed, the N mineralised from crop residues will be vulnerable to loss both by leaching of nitrate and by denitrification to nitrous oxide and nitrogen gas (Vinten *et al*., 1991; Baggs *et al*., 2000). If such incorporation occurs in spring, when soils are at or above field capacity, then similar issues of anaerobic conditions developing occurs as for catch crops/green cover.

Improving soil structure leading to better drainage characteristics. Well-drained grassland soils, particularly if they are grazed, have a much higher propensity for excess nitrate to be lost by leaching. Poorly drained soils, under most circumstances, have a lower leaching potential and N loss by denitrification is likely to be greater than by leaching (Goulding *et al*., 2008). Improvement in soil structure resulting from single year legume crops such as peas will not be as marked as for longer term clover rich leys, but the root system of the legume will penetrate deeply into the soil, and so influence subsoil structure. The provision of drainage in an inherently poorly drained soil also alters the pattern of phosphate loss (Haygarth *et al*., 1998), with lower risk of surface runoff and erosion, but higher risk of soluble and particulate P transport to artificial drainage systems.

We conclude that while N fixing crops are highly beneficial in terms of improvement of soil structure, as well as their role in providing habitat for insect pollinators, and as alternatives to reliance on artificial N fertiliser, the impacts on water quality will be mixed, with possible positive or negative impacts depending on soils, subsequent crop management etc. Landscape levels effects of nitrogen fixing crops on the water quality environment depends on the overall percentage of land draining to a water body that has reduced sources and potential to mobilise diffuse substances and reduction in connectivity with the water course or water body.

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