

Qualitative Impact Assessment of Land Management Interventions on Ecosystem Services ('QEIA')

Report-2: Integrated Assessment



UK Centre for Ecology & Hydrology



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Qualitative impact assessment of land management interventions on Ecosystem Services

REPORT-2: Integrated Assessment

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Contents

1	SUMMARY	4
2	INTEGRATED ASSESSMENT	8
2.1	Introduction	8
3	OVERALL METHODOLOGY AND WORKPLAN	8
3.1	Creation of Management Bundles.....	9
3.2	Analysis of the Actions.....	11
3.3	Analysis of ES and ES-Indicators	12
3.4	Final ES, Indicators and Defra Priorities.....	13
3.5	Evidence Review approach.....	15
3.6	IA approach and scoring system	16
3.7	Assumptions and scaling issues	17
4	IA RESULTS	17
4.1	Method for Analysis of scores and potential biases.....	17
4.2	Number of actions scored with positive outcome of moderate to high magnitude by Theme, ES and Management bundles	19
4.3	Themes where actions are contextually dependent (T).....	28
4.4	Themes where evidence is more limited (L).....	28
4.5	Number of actions with negative outcomes or disbenefits (Red).....	29
4.6	Themes and Defra priorities	35
4.7	A comparison of key actions proposed by the environmental services teams and top scoring actions in the IA table	35
4.8	Key findings.....	40
4.8.1	<i>The ambition of the IA approach</i>	40
4.8.2	<i>Most impactful actions</i>	40
4.8.3	<i>Context dependency, limited evidence and trade-offs</i>	41
4.8.4	<i>Defra Priority Themes</i>	43
4.8.5	<i>Most impactful actions selected by the Team</i>	43
4.8.6	<i>Top scoring actions across multiple themes and ES</i>	44
4.8.7	<i>Conclusions</i>	44
5	DISCUSSION, CAUTIONARY COMMENTS AND RECOMMENDATIONS	45
6	RECOMMENDATIONS FOR FUTURE REVIEWS AND ASSESSMENTS	46
	ANNEX-A: KEY ACTIONS PROVIDED BY THE ENVIRONMENTAL REVIEW TEAMS WHICH THEY CONSIDERED FUNDAMENTAL FOR REVERSING ENVIRONMENTAL DEGRADATION (INCLUDING RESTORATION AND IMPROVEMENT)	48
	<i>Theme 1: Air Quality</i>	48
	<i>Theme 2: Mitigation of GHG emissions</i>	48
	<i>Theme 3: Soil conservation and soil health</i>	50
	<i>Theme 4: Water</i>	51
	<i>Theme 5A: Biodiversity - Cropland</i>	52
	<i>Theme 5B: Biodiversity - Grassland</i>	53
	<i>Theme 5C: Biodiversity - Semi-natural habitats</i>	54
	<i>Theme 5D: Biodiversity - Integrated System-Based Actions</i>	55
	<i>Theme 6: Carbon sequestration</i>	56

1 SUMMARY

The focus of this project was to provide an expert-led, rapid qualitative assessment of land management interventions on Ecosystem Services (ES) proposed for inclusion in Environmental Land Management (ELM) schemes. This involved a review of the current evidence base for 741 land management actions on 33 Ecosystem Services and 53 Ecosystem Service indicators by ten expert teams drawn from the independent research community in a consistent series of ten Evidence Reviews covering the broad topics of;

- Air quality
- Greenhouse gas emissions
- Soils
- Water management
- Biodiversity: croplands
- Biodiversity: improved grassland
- Biodiversity: semi-natural habitats
- Biodiversity: integrated systems-based actions
- Carbon sequestration
- Cultural services (including recreation, geodiversity and regulatory services)

These reviews were undertaken rapidly at Defra's request by ten teams involving 45 experts who together captured more than 2,400 individual sources of evidence. This was followed by the Integrated Assessment (IA) reported here to provide a more accessible summary of these evidence reviews with a focus on capturing the actions with the greatest potential magnitude of change for the intended ES, and their potential co-benefits and trade-offs for the other ES.

It should be noted that this piece of work is just one element of the wider underpinning work Defra has commissioned to support the development of the ELM schemes. The project was carried out in two phases with the environmental and provisioning services theme (hereafter called environmental services theme) started first followed by the cultural services theme (hereafter called the cultural services theme). A cost-benefit analysis was not included in the requirement from Defra as this was being covered by a different team.

Before the evidence reviews and IA could begin all actions were grouped into management bundles by the team to help navigate both the evidence reviews and IA table. A top Tier-1 level of 17 bundles were identified with a Tier-2 level of 46 sub-management bundles also created due to the breadth of actions captured by the Tier-1 bundles.

After the initial drafting of the ten evidence reviews, the ten teams came together to agree a systematic and consistent scoring system for the IA which could capture the wealth of information captured in the individual evidence reviews in a more accessible format. This was carried out during a 2-day workshop for the environmental services involving over 40 of the environmental services experts, and a 1-day workshop for 8 experts from the cultural services team.

The IA captures the evidence available, not just for an individual service but also how this may be expressed differently across a suite of proposed indicators for each individual service. Defra provided many of these proposed indicators but in some cases, where these were absent or were not considered practical, the expert teams provided possible indicators.

In total, 10 evidence reviews of 29 ES outcomes were created with an additional 4 'Other' ES included only in the IA (i.e. 33 ES total in the IA) for consideration by the expert teams at the request of Defra.

These 4 'Other' ES were requested after the initial 10 main evidence reviews had been commissioned and could therefore could not be included in the main reviews:

- i. Biorisks
- ii. Chemical pollutants
- iii. Energy Use / Renewable energy
- iv. Food and Fibre Production

The outcome of this initial preparation work was to create a final IA table (provided as an Annex to this report) covering 741 actions, 8 Themes, 33 ES and 53 ES-indicators. A total possible matrix of 39,273 scores.

During the IA workshops, a handful of individual actions were selected to capture the wide range of action types, and these were scored collectively in open forum, working across each indicator for each ES assigning a colour, number and letter. Significant debate for the first few actions enabled some high-level rules to be created which enabled more rapid and consistent scoring of remaining actions. All teams then took these rules back to inform their individual team meetings to complete scoring for their specialist ES.

The scoring system agreed included the use of combined colour, number and letter codes for each action for each indicator as follows:

- The potential impact on the service using a RAG system (negative (red); variable / uncertain (amber); or positive (green))
- magnitude of outcome (indicated by 1* (low) to 3* (high));
- contextual dependencies (indicated by a 'T'. This could include outcomes dependent on spatial location and/or actions' need to be carried out on contiguous land parcels to be effective);
- if the evidence basis follows a well understood logic chain but current evidence has significant limitations (indicated by a 'L');
- variability in outcome within a single ecosystem service or outcome which includes a dis-benefit (indicated by a 'D' e.g. some taxa will benefit but some will be disadvantaged by a specific action).

Quality assurance of the final IA was provided challenges among the teams as they undertook scoring for their specialist ES; by the project management leadership team who checked for consistency. This was followed by release of the evidence reviews and IA for external review by invited reviewers from the wider community. Most external reviewers were unable to review the IA itself due to its complexity but provided feedback on the underpinning ten evidence reviews. The expert teams then revised their evidence reviews and revisited their scores for the IA table. Finally, Defra provided a further quality assurance check which resulted in final adjustment of some scores.

This report is accompanied by, and should be read in conjunction with the:

- ten evidence reviews
- database of more than 2,400 references which underpin all of the reviews and IA scores to be exploited and added to in future years.
- IA table (an Annex to this report)
- IA pivot database for any future exploratory excel pivot analyses
- IA table in a CSV database format

The overall timeline was as follows: Most actions, ES and ES indicators were received and iterated with Defra in the summer of 2021 (with additional actions received in October 2021). The bulk of the environmental services evidence reviews were completed and drafts submitted to Defra in early March 2022 together with the linked IA scores. External review was conducted in the autumn of 2022. The Cultural Services report was commissioned in March 2022 with a draft made available to Defra in November 2022. The combined IA table

of scored actions including both environmental and cultural services was provided to Defra in March 2023. Final editing and checking was carried out during the summer of 2023. All of this work, including any external review, was conducted under a non-disclosure agreement which was lifted on public publication of these reports in late 2023.

Key findings of the IA include:

- The final IA table (as an Annex provided as separate file) includes 741 actions, 8 Themes, 33 ES and 53 ES-indicators. A total possible matrix of 39,273 scores. This was a massive undertaking to face the project team and is a more ambitious integrated assessment of agri-environment actions than any previously carried out for the UK to our knowledge. The benefit is the rich information captured which recognises that many actions may have consequences beyond their primary targeted outcome. These may be of an equal or more positive magnitude (i.e. a co-benefit) or result in a negative outcome (i.e. a trade-off).
- The team have followed best practice when providing policy advice and have made clear uncertainties, assumptions, limitations of the approach and potential biases in the final analysis of scores.
- Of the 39,273 possible scores, the team provided 6,480 colour coded scores (16% of the total possible scores). The remaining scores are where actions were not considered relevant to a specific ES indicator or were merged or split with another action. In a few cases actions were already covered by regulation so were not considered further. Of the 741 actions, a total of 10 actions were not considered relevant or of sufficient potential impact to be assessed by any team for any ES indicator.
- In response to a request by Defra to identify the most impactful actions and management bundles, it was agreed impactful scores would be defined as amber or green scores with a rating of 2* or 3*. When the number of these impactful scores were expressed as a percentage of the total of scores made by the teams the following findings were identified:
 - The cultural services theme (which includes both cultural and regulatory services) was generally scored as more impactful (20-65% of all scores were impactful) relative to the environmental services theme (20-40%). Across all themes, the proportion of the more potentially impactful scores were highest for the Cultural, Biodiversity and Soil themes (all > 50%). This reflects the high priority given to many ES by Defra within these themes with the exception of the cultural services theme which was not in general prioritised highly by Defra.
 - For Management Bundles Tier-1, actions to 'Maintain and restore cultural heritage sites' and 'Natural regeneration' actions had the most impactful scores (> 60%) when the environmental and cultural services these were combined. It is interesting to note the potential value for both environmental and cultural services themes of 'Natural regeneration' which may not be a well-recognised phenomenon and deserves further exploration.
 - When the environmental and cultural services themes were reviewed together for the Management Bundles Tier-2 level, sub-management bundles within the 'Habitat creation' bundles represented 6 of the top 10 bundles with the highest proportion of most impactful scores (between 60-80% of all scores). This is perhaps not surprising as habitat creation is one of the most fundamental changes which can be made in the landscape.
 - 'Habitat creation' was also found to be the Management Bundle Tier-1 with the most consistent potentially impactful scores across multiple ES themes (i.e. an impactful score was only counted

once for each ES theme), particularly when these bundles included planting of woody species or creation of freshwater bodies. The top scoring actions with the highest potential impact across 5, or all of the 6, environmental services themes are listed below together with the number of potential dis-benefits in parentheses (i.e. the number of red colour codings). Note the high number of potential dis-benefits for 'Climate measures'.

Action code	Management Bundle Tier 1 / Tier 2
ECPW-291C	Habitat creation / water bodies and buffer zone (2 reds)
ECAR-032	Habitat creation / agroforestry (1 red)
ECCM-024C	Habitat creation / woody features (3 reds)
ECCM-048	Habitat creation / woodland (2 reds)
ECCM-074C	Climate measures / climate change and adaptation (<i>Plant</i> bioenergy crops) (4 reds)
ECCM-074EM	Climate measures / climate change and adaptation (<i>Enhance or manage</i> bioenergy crops) (4 reds)
ETPW-092	Soil management and protection / tillage (no reds)

- Trade-offs or disbenefits were scored highest for management bundles relating to 'Food and fibre production', 'Livestock management' and 'Climate measures'. These trade-offs were most frequently noted for ES 'Biodiversity', Global, regional and local climate regulation', 'Biorisks' and 'Resilience to drought'. This suggests important potential trade-offs for other environmental outcomes when climate or agricultural efficiency is being targeted.
- When the level of evidence was considered for the scores provided for each ES, outcomes for 'Soil' and 'Regulatory' ES were the most certain (<5% of impactful scores identified as being based on limited evidence) whilst those for 'Air quality', 'Biodiversity' and 'Carbon and greenhouse gas emissions (GHG)' were the least certain (>30% of impactful scores identified as being based on limited evidence).
- The importance of the context in which an action is made was considered of least importance for 'Soil' and 'Regulatory' ES (< 15% of impactful scores identified as contextually dependent). This is likely to indicate that actions will directly link to outcomes for the soil in that location). For all other ES a high level of context dependency was identified for all scores (> 30% of impactful scores were identified as contextually dependent). This indicates careful targeting is required for many desired outcomes to be realised.
- Overall, this analysis represents only an initial probe into the richness of the evidence captured by the teams and further analysis is likely to reveal further insights to inform selection of actions for the ELM schemes in future iterations.

Future recommendations include:

- Long term commitment beyond the usual scope of many land management payment agreements may be needed therefore to realise many outcomes. Indeed, many actions (and their intended outcomes) are reversible: permanence and longevity cannot be assumed without ongoing management and support which the team recommend.
- The lack of uniformity of ongoing, independent monitoring data recording these metrics means that evaluation of the impact of management interventions in practice, in real schemes and at both field and landscape scale, is not universally available. Evidence is often limited to small-scale and short term (i.e. < 4 years) trials and experiments under controlled conditions which limits the assessment of broader landscape outcomes, their variability between years and issues of displacement. Greater effort to create an improved evidence base is urgently needed which is

consistently and routinely updated and synthesised using approaches as described here capturing co-benefits and trade-offs across multiple ES.

- We recommend the commissioning of regular updates of these evidence reviews and IA to ensure an adaptive and agile approach can be taken going forward. This should include:
 - updates and improvements to the evidence base and the IA. Ideally this should follow a systematic approach rather than rapid expert approach adopted here (due to time constraints). This ongoing review process will increase confidence and ensure payments and other incentives are well supported by the whole community;
 - review of new actions as new innovative management practices become available;
 - additional commissioning of research to fill evidence gaps identified here.

2 INTEGRATED ASSESSMENT

2.1 INTRODUCTION

The Integrated Assessment (IA) provides an easily accessible, visualisation and analytical tool to review the likely impact of the more than 700 actions proposed by Defra for inclusion in the Environmental Land Management (ELM) schemes on Ecosystem Services (ES). The IA summarises the findings from a series of ten Evidence Reviews completed by expert teams which collated over 2000 individual sources of evidence from the scientific literature. These Evidence Reviews are intended to be read in conjunction with the IA table and report as they provide the supporting evidence base to the scores compiled in the IA.

Due to the urgency of the need for these evidence reviews, there was insufficient time for systematic reviews and therefore the reviews relied on the knowledge of the team of the peer reviewed and grey literature, with some rapid additional checking of recent reports and papers. This limitation of the review process was clearly explained to and understood by Defra.

The outcomes provided by Defra include a range of environmental and cultural services, drivers and other benefits. For simplicity this range of outcomes are called Ecosystem Services (ES) for the remainder of this report.

The approach builds on that carried out for Welsh Government in 2019 by the ERAMMP team (Environment and Rural Affairs Monitoring & Modelling Programme) for an Evidence Pack and Integrated Assessment for the Welsh Government Sustainable Farm Scheme¹.

3 OVERALL METHODOLOGY AND WORKPLAN

A series of steps were followed to deliver the IA. These were:

- I. Grouping of land management actions into a set of management bundles (called Tier-1) within which sub-bundles were identified (called Tier-2);
- II. A review of actions and indicators provided by Defra and removal of duplicates and/or split or merged actions (where actions were in reality sub-actions of other actions);
- III. Assessment of ES and outcome indicators with suggestions for improvements from the team

¹ <https://erammp.wales/en/r-sfs-evidence-pack>

- IV. Addition of actions considered of priority by the team but missing in the original list provided by Defra;
- V. Drafting of 10 rapid evidence reviews following an agreed standardised template. Actions reviewed by each team were prioritised to those where there was known impact, either positive or negative. Where the impact was considered minor, a complete review was not required but a co-benefit and trade-off section could be provided to support a review by another team. Where no impact was likely from a particular action, teams did not review that action;
- VI. Team workshop to agree a standardised scoring approach for the IA;
- VII. Completion of the IA by all teams based on the content of the evidence reviews and agreed rule-base from the team workshops;
- VIII. External review of the evidence reviews;
- IX. Response by expert teams to external review comments and revision of IA scores;
- X. Collation of reference database used in the 10 expert reviews;
- XI. Identification of key environmental actions considered critical by the individual expert teams and comparison with scores from IA table (see Section 4.7);
- XII. Request to review 50 additional actions in IA from Defra;
- XIII. Final quality assurance of IA table;
- XIV. Analysis of IA table;
- XV. Drafting of IA report and Executive Summary;
- XVI. Submission of:
 - a. Ten evidence reviews;
 - b. Evidence review reference database;
 - c. IA report, Table and Database;
 - d. Executive Summary.

3.1 CREATION OF MANAGEMENT BUNDLES

The following Action Management Bundles were used to structure and focus presentation of the evidence reviews and IA (Table 1).

At the top level, 17 Tier-1 level bundles were identified. Many of these bundles, as they capture such a broad set of actions, were split into a further Tier-2 set of 46 management bundles (54 if Tier-1 bundles are included which were not split).

When writing their reviews, the teams have in most cases included in their structure either Tier 1 or 2 bundles as subsections to help the reader find the topic they are specifically interested in e.g. 'Habitat creation / Woodland'.

Table 1 Tier-1 and Tier-2 Management bundles into which all management actions were assigned.

Tier-1 Management bundle	Tier-2 Management bundle	Notes
Habitat level actions		
Habitat creation	Woodland	Bioenergy crops are in climate measures
	Woody features	
	Hedgerow	
	Scrub	
	Mountain, moor and heathland	Matches to NCEA asset class, Includes lowland heathland.
	Cropland	Include reversion
	Grassland	e.g. Low-input; species rich; mass flower crops etc

Tier-1 Management bundle	Tier-2 Management bundle	Notes
	Coastal	Includes sand dunes; salt marsh; shingle; cliffs
	Agroforestry	Where not captured from categories above e.g. inter-cropping
	Ponds and wetlands	For ditches – see water resource management
	Water bodies and buffer zones	
	Horticulture	
Natural regeneration	Woodland	
	Scrub	
Systems action	Mixed systems and cross-habitat actions	
	Landscape actions	
	Pests and disease management	Include Integrated Pest Management
	Predator management	
	Invasive management	
Specific wildlife targeted actions	No 2 nd level	e.g. boxes; banks, feeding areas for specific taxa
Restoration, management and enhancement	Woodland	Includes extension and connecting; burning and wildfires;
	Woody features	e.g. veteran trees
	Hedgerows	
	Scrub	Includes burning and wildfires
	Mountain, moor and heathland	Matches to NCEA asset class Includes burning and wildfires and lowland heathland.
	Cropland	Low-input cereals; rotations; crop selection and diversity; field margins; buffer strips; fallow and fodder; under and over-sowing
	Grassland	Species rich; low input; sward diversification; grazing; cutting, haylage and silage; rotations
	Coastal	Includes sand dunes; salt marsh; shingle; cliffs
	Rivers / water bodies / storage and sediment traps	
	Boundary features	
	Riparian areas	
	Horticulture	
Actions for habitats with specific hydrological characteristics	Peatlands and wetlands	Includes Paludiculture
	Floodplains	
Targeted resource and waste management		
Livestock management	Housing and handling	
	Feeding and watering strategies	
	Selection and diversification	
Drainage, irrigation and wastewater	Drainage	
	Irrigation	
	Wastewater	
Soil management and protection	Cover cropping	Includes all vegetation cover actions
	Tillage	
	Compaction management	
	Contaminants	

Tier-1 Management bundle	Tier-2 Management bundle	Notes
	Fertiliser, nutrient, manure and mulch management	
Litter and waste	No 2 nd level	Includes beach cleaning; plastics etc
Climate		
Climate measures	Climate change mitigation and adaptation	Bioenergy crops are included here
	Energy measures to protect the environment	
Planning and People		
Monitor, plans, databases, consultation and resulting action.	No 2 nd level	
Create and enhance access and PROW		
Create and enhance access and PROW	No 2 nd level	
Signposting, information, facilities and events		
Signposting, information, facilities and events	No 2 nd level	
Heritage, Parks and Gardens		
Maintenance and restoration of cultural heritage sites	No 2 nd level	
Maintenance and restoration of habitat features in parks and gardens	No 2 nd level	
Geodiversity		
Geodiversity actions	No 2 nd level	

3.2 ANALYSIS OF THE ACTIONS

A list of more than 700 actions, each with their own unique code and longer description, were provided to the team for review by Defra with respect to their impact with respect to a series of outcomes or 'Ecosystem services (ES)' (see Section 3). No change to the wording of any action was permitted by Defra to maintain traceability and policy team ownership within Defra.

The primary, secondary and tertiary intended outcome for each action was indicated by Defra with the action spreadsheet.

All actions were assigned to the Tier-1 and Tier-2 Management Bundles. The teams then reviewed all the actions with the following outcomes:

- More than 70 actions were found to be too large for review and were split and marked as a 'S' with a link to other more detailed actions which were scored. A common change of this type was the splitting of actions which included both 'creation' and 'enhanced management' of the habitat as the team considered outcomes were significantly different in magnitude and could not be effectively scored if evaluated together. These split actions are indicated by an action code followed by '_C' or '_EM' in separate rows respectively.
- Other actions were found to be duplicates as actions had been developed within individual policy teams and it was agreed with Defra these could be deleted.
- The team also noted that a significant number of actions were only minor modifications of a similar action listed for a different priority or the evidence base would not support the level of granularity

requested. Scores were then noted as a merged 'M' with a link to the similar action where a score was provided.

- Defra also encouraged addition of actions from the team where these were considered to be an important omission. A total of 16 new actions were added and these can be identified by the name of the expert team and a number e.g. 'Grass_01'. They were:

Action code	Action description
AQ-01	Free range poultry/pigs in woodland
AQ-02	Monitor AQ and GHG footprint of agricultural buildings to actively manage emissions
AQ-03	Monitor indoor concentrations of ammonia and GHG
AQ-04	Use fertiliser with urease and nitrification inhibitors
Carbon_01	Conservation of long-established woodlands with existing high carbon stocks
Carbon_02	Longer rotations in even-aged managed stands
Carbon_03	Create and implement woodland carbon plan
Carbon_04	Enrichment of woodland growing stock
Grassland_01	Adapt mowing or first grazing dates on improved or semi-improved grassland; use mowing techniques to reduce mortality
Grassland_02	Mob grazing
Arable-01	Extended stubble - unharvested crop stubble followed by a one-year fallow
Arable-02	Unvegetated, ploughed fallow (natural regeneration) for one year
Arable-03	Annually cultivate headlands and leave unsown
GHG-01	Farm Animal Genetic Improvement
GHG-02	Improved Productivity
GHG-03	Improved Animal Health

- A few actions were found to cover areas already covered by existing regulations. These were not scored but marked as 'R'.
- 50 additional actions were provided by Defra for inclusion in the IA after the main evidence reviews were completed. These are identified in red and labelled as 'QEIA_{nn}' (where nn is a non-sequential series of numbers). Only c.20 were considered of sufficient magnitude and/or not to duplicate other actions already reviewed and were scored by the teams. These actions only appear in the IA Table.

The final IA table includes 741 actions, 8 Themes, 33 ES and 53 service indicators. A total possible matrix of 39,273 scores.

3.3 ANALYSIS OF ES AND ES-INDICATORS

The Evidence Reviews and IA are all focussed around a series of outcomes provided and defined by Defra. They are a complex mix of outcomes and are not all ecosystem services as is usually understood by the community. For simplicity however here the outcomes will be referred to as 'ES'.

The team assessed the ES indicators for those ES and the following definitions and clarifications were agreed with Defra ahead of the IA scoring:

- 'Condition of agricultural land' was changed to 'Maintain enhancing abundance and species richness of wider farmland biodiversity' following the advice from the biodiversity teams;
- 'Air pollutants removed' has been coded only with respect to active removal e.g. through canopy capture. It does not include avoided or reduced emissions;

- 'Nitrogen deposition and exceedance of critical loads' has only been assessed where targeted actions would be likely to have impact at a local scale;
- 'Recapture of carbon' is only considered with respect to non-nature solutions for capturing carbon dioxide rather than, for example, woodland creation;
- 'Water supply' is only considered with respect to the potential for less water needed by agriculture;
- 'Pests and disease' does not include animal livestock health;
- 'Reduction in greenhouse gases (agriculture)' only includes actions which improve the efficiency of agriculture per unit GHG emitted and not displacement e.g. due to habitat creation;
- 'Food and fibre production / Area under production or with intensive management outside of ELM' relates to the issue of potential displacement when land is taken out of production and may have reduced production efficiency per unit area of land. Red therefore indicates a risk of compensatory food and/or fibre production outside of the ELM scheme.

The team note that the ES outcome 'Mass stabilisation and Control of Coastal Erosion' seems to go against the need to work with natural processes and recognise coasts are dynamic. We have worked within the definition provided but recommend revisiting this topic.

The team also noted that the ES outcome of 'Flow variability' probably duplicated flood and drought extreme columns as it is hard to consider how they would not represent flow variability. The team suggest this could be reviewed or redefined in future iterations and these ES were removed.

The issue of soil moisture / drought resilience / water inundation on land (i.e. not flow in rivers) could be considered as important particularly for climate resilience going forward.

3.4 FINAL ES, INDICATORS AND DEFRA PRIORITIES

A set of proposed indicators to track change were also provided by Defra to the review teams. The teams were able to provide some suggestions to ES and indicators provided by Defra. The table below outlines the final agreed Theme, ES and Indicators for each ES and the priority placed on each by Defra.

Table 2 Themes, ES, indicators and Defra identified priority level

Theme	ES	Indicator for service (colours indicating priority)	Defra Priority
All/Other	Bio risks	Reduced faecal indicator organisms	M
	Chemical pollutants	Reduced inputs of pesticides	H
	Energy use/use renewables	Number of farms taking action	L
	Food and fibre production	Area under production or management intensity outside of ELM (red action coding indicating increased intensity i.e. displacement of production)	M
Air	Air Pollution	Reduced emissions of NH ₃	H
		Reduced PM _{2.5}	L
	Air Quality	Air pollutants removed	M
Biodiversity	Biodiversity	Biodiversity adaptation - maintaining / enhancing biodiversity under a changing climate	M
		Atmospheric deposition of N and exceedance of critical loads	H
		Connectivity of small 'feature' habitats	M
		Enhance abundance and species richness of wider farmland biodiversity	H

Theme	ES	Indicator for service (colours indicating priority)	Defra Priority
		Enhance abundance and species richness of semi-natural habitat	H
		Favourable condition of SSSIs	H
		Maintain abundance and species richness of wider farmland biodiversity	H
		Maintain abundance and species richness of semi-natural habitat	H
		Presence of rare (red list) species Presence of priority species	H
	INNS*	National species occurrence	H
	Pest and disease control	Evidence of outbreaks of pests and disease	H
	Pollination and seed dispersal	Increased abundance, distribution & species richness of pollinators & seed dispersers	M
Carbon/GHG	Global, regional & local climate regulation	Above ground carbon sequestration	H
		Below ground Carbon sequestration	H
		Recapturing carbon on Farms	L
		Reduction in greenhouse gasses (agriculture)	H
Soil	Mass stabilisation & control of coastal erosion	Improved sediment stabilisation	H
	Nutrient pollutants	Reduced inputs of N and P	H
		Reduced inputs of organic fertilisers (manure)	H
	Soil conservation	Extent of erosion	H
	Soil health	Increased organic matter & biodiversity, reduced contamination & compaction, improved structure	H
Water	Flow variability	Frequency of high and low flows outside previous 20 year record	H
	Control of river erosion	Fine grain sediment load	L
	Flood protection	Improved regulation of flow regime for peak events	L
		Reduced inundation from coastal flooding	L
	Resilience to Drought	Frequency of low flow	H
	Water Quality	Improved ecological and chemical (bacterial, viral and suspended sediment) quality of coastal waters	H
		Improved ecological and chemical (bacterial, viral and suspended sediment) quality of freshwater	H
Water Supply	Increased water supply for non-drinking purposes	H	
Cultural services	Recreation	Visits to natural environment and green spaces	M
		Public rights of way and open access areas	L
		Health and well-being benefits – physical	L
	Mental health	Health and well-being benefits – mental	M
	Education	Environmental attitudes and behaviours	M
	Volunteering	People engaged in social action for environment	M

Theme	ES	Indicator for service (colours indicating priority)	Defra Priority
	Tourism	Tourism visits	L
	Cultural heritage	Awareness of cultural heritage	L
		Condition of scheduled monuments	L
		Number of designated heritage assets	L
	Awareness of diversity – geodiversity	Condition of geological and geomorphological heritage features	M
	Awareness of diversity – wildlife	Perceived increased biodiversity in the environment	L
	Landscape character	Changes in landscape and waterscape character	L
		Enhancement of green/blue infrastructure	L
	Sense of place	Quantitative survey about sense of place	L
Regulating	Noise mitigation	Health and well-being benefits of noise	M
	Local temperature regime	Health and well-being benefits temperature	M

*(INNS) - Invasive and non-native species

Defra agreed due to the potential for overlap and uncertainty in definitions the following ES would not be scored and it was deleted from the IA Table:

- Landslips

3.5 EVIDENCE REVIEW APPROACH

The teams first reviewed the evidence base for all actions proposed by Defra to produce 10 'Evidence Reviews' following a standard approach and template agreed with Defra. This template included a request for assessment of:

- the strength of the evidence;
- the magnitude and timescale of potential change;
- the contextual dependencies as to whether an action may work;
- the risk of displacement of production to other land not in scheme;
- potential impact of future climate change on the impact;
- co-benefits and trade-offs to other services and to the farmer / land manager.

A cost-benefit analysis was not included in the requirement from Defra as this was being covered by a different team.

All reviews are an expert assessment by the team. A systematic review of the evidence base has not been possible within the tight time constraints of the project. The team have instead relied on expert judgment and a light touch review of the evidence base building. The use of multi-author and organisation teams for each review ensures some challenge was present for all reviews. These reviews then provided the basis for the IA using an agreed scoring system.

An external review by community experts of these Evidence Reviews was carried out to provide additional quality assurance. This included 1 to 3 external reviewers for each review. The teams then responded to the comments received.

3.6 IA APPROACH AND SCORING SYSTEM

These evidence reviews were then used to inform the IA. A traffic light, or Red-Amber-Green (RAG), scoring approach has been used in the IA to efficiently capture and communicate high level assessments of each action supported by the Evidence Reviews. The teams developed an additional coding system within this approach to capture the complexity of many issues including:

- magnitude of outcome (indicated by 1* (low) to 3* (high));
- contextual dependencies (indicated by a 'T'. This could include outcomes depend on spatial location and/or actions need to be carried out on contiguous land parcels to be effective);
- if the evidence basis follows a well understood logic chain but current evidence has significant limitations (indicated by a 'L')
- variability in outcome within a single ecosystem service or outcome which includes a dis-benefit (indicated by a 'D' e.g. some taxa will benefit but some will be disadvantaged by a specific action).

A two-day physical meeting involving all review teams and authors was held to ensure consistency across teams for the coding and scoring system for the IA.

The final agreed IA scoring and coding system developed is presented in Table 3 and was applied to all actions and is embedded within the IA Table excel sheet.

Table 3: The Integrated Assessment scoring and coding system

Cell Code		
R	Already covered by regulation; not assessed further	
B or S	Too big to review so split and reviewed under individual actions	
M	Merged actions can be reviewed together for a specific outcome as evidence does not support more granular approach	
N or no letter	No impact on ES was expected by review teams	
X	The action is linked to a theme that was not included in the review team's original remit	
Colour Code	Magnitude score (*)	Contextual issues (Letters)
Green		
Well tested at multiple sites with outcomes consistent with accepted evidence logic chain. No reasonable dis-benefits or practical limitations relating to successful implementation. Plus:	*** Action can have major benefit if done well ** Action can have moderate benefit if done well * Action has limited benefit even if done well	'T' only used for two types of action: <ul style="list-style-type: none"> • Creation of plans • Monitoring and measurement
Amber		
Evidence is currently limited for the impact on this ES indicator and / or there may be some disbenefits embedded within this indicator (e.g. different taxa response differently) and /or it is contextually dependent for each specific ES indicator	*** Action can have major positive benefits on this ES indicator if done well ** Action can have moderate positive benefit on this ES indicator if done well * Action has limited impact on this ES benefit even if done well	'L' Limited evidence for benefit but is consistent with evidence logic chain 'T' Contextually dependent benefits and / or requires targeting to be effective 'D' There are some disbenefits to some services within this ES indicator. <i>Note: no impact does not make a box an amber if all other sub-</i>

		indicators for this ES indicator are green – it should then be a green if nothing disbenefits.
Red		
A disbenefit known for this action for this ES indicator and / or limited evidence but evidence logic chain suggests a highly likely disbenefit.	<p>*** Action can have major disbenefit on this ES indicator</p> <p>** Action can have moderate disbenefit on this ES indicator</p> <p>* Action has limited impact disbenefit on this indicator</p>	'T' Only used where there was a context dependency for the Food and Fibre ES.

3.7 ASSUMPTIONS AND SCALING ISSUES

All actions were scored on the assumption the actions would be carried out following good practice and on land usually considered appropriate for the intervention. See the individual reviews for further assumptions made for each evidence review and resulting scores for the IA Table.

No single definition of 'magnitude' of change was possible as different outcomes operate at different scales. For example, with respect to carbon and GHG, magnitude of change was scored according to the magnitude per unit of land and the extent of likely uptake as outcomes are additive wherever the action takes place. However, for many water quality outcomes, actions were scored on the likelihood that location and scale could be configured to impact at the local level to achieve the desired outcome for a specific local water course. See individual evidence reviews for more information.

Timing of outcomes are known to be highly variable and may take many years if not decades to be fully realised. This is specifically relevant for habitat creation actions and for many other ecological and carbon sequestration outcomes. Air quality and greenhouse gas emission reductions can be more rapid, whilst soil and water flow / quality outcomes are variable depending on the specific outcome and indicator – some outcomes can be rapid (e.g. control of erosion), others more long term (e.g. overall soil health). In assessing actions, this variability was not scored within the IA although the timing of expected outcomes is often captured in the reviews. For the IA, it was assumed ongoing support would allow for the intended outcomes to be fully realised. This is a very brave assumption as many actions (and their intended outcomes) are reversible i.e. permanence and longevity cannot be assumed without ongoing management and support. This issue is emphasised again in Section 5.

4 IA RESULTS

4.1 METHOD FOR ANALYSIS OF SCORES AND POTENTIAL BIASES

The final IA table includes 741 actions, 8 Themes, 33 ES and 53 ES-indicators. A total possible matrix of 39,273 scores. Of these 39,273 possible scores, the team provided 6480 colour coded scores (16% of the total possible scores). The remaining scores are where actions were not considered relevant to an ES indicator (of which a very small number were already covered by regulation) or where actions were merged with, or split into, other actions.

Of the 741 actions a total of 10 actions were not considered relevant or of sufficient potential impact to be assessed by any team. These were:

- ECPW-050C
- ECPW-0595EM
- ETPW-072
- ECPW-160
- EHAZ-036
- EHAZ-086C
- EHAZ-086EM
- ETPW-164
- ECCA-002
- ECCA-004

This suggests the Defra team had identified actions which were likely to have some impact on at least some ES and that most actions did not have impact across the full spectrum of ES and ES indicators.

Analysis of these scores by theme or ES needs to be standardised to account for the variable number of total scores provided by the teams for each theme. As an illustration of this issue, the total number of scores by theme (Figure 1a) and scores which are amber or green and 2* or 3* (Figure 1b) have been converted to control for the different total number of scores across the themes (Figure 1c). (This analysis of amber and green 2* and 3* was requested by Defra to identify the most potentially impactful actions.)

Figure 1a Total counts of scores by theme

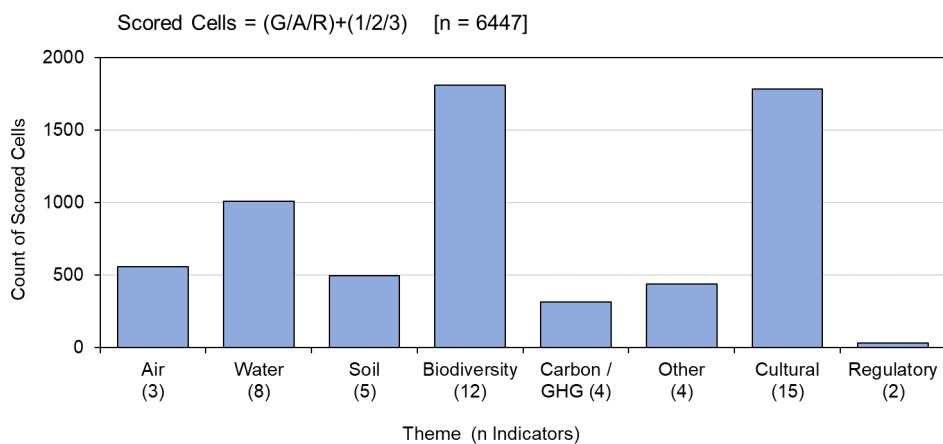


Figure 1b Total counts of amber and green scores with 2* and 3* (i.e. potentially more impactful actions)

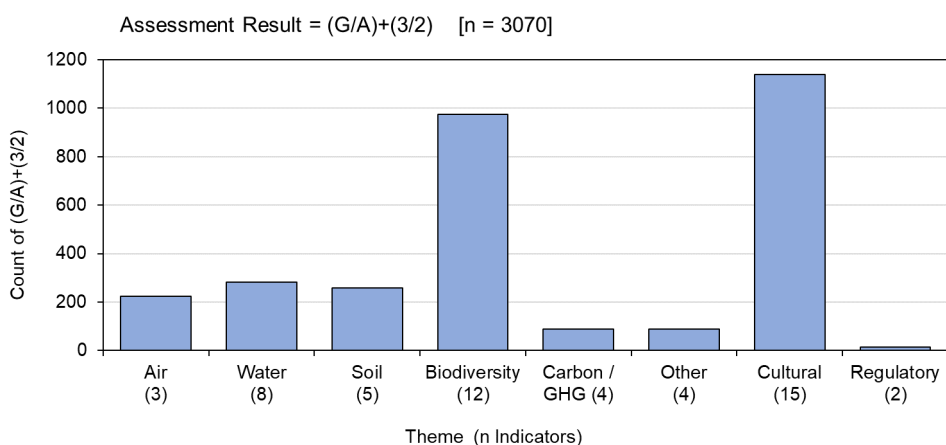
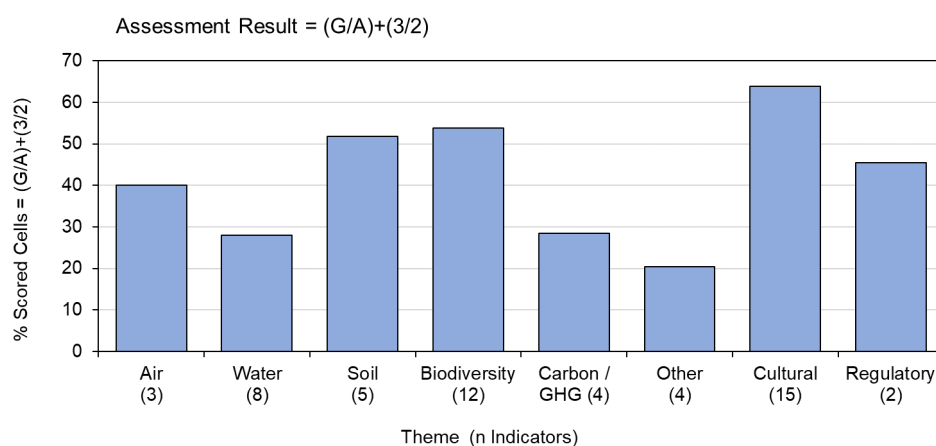


Figure 1c Total counts of amber and green scores with 2* and 3* (i.e. potentially more impactful actions) (Figure 1a) expressed as a percentage of total scores for each Theme (Figure 1b)



Whilst there are more total amber and green scores with 2* and 3* for Biodiversity and Cultural themes (Figure 1b), this is due to a higher scoring rate by these teams (Figure 1a). When controlled for this issue, these two themes are not as different to the other themes as originally indicated (Figure 1c).

Whilst this approach provides some standardisation to enable assessment of the final IA table there remain various potential important biases and issues which should be considered alongside all score analysis reported below:

- Variance in number of actions scored:
 - The evidence base is highly variable across the different ES. This is partially reflected in the use of the code 'L' but may also limit the number of scored provided by some teams.
 - Another reason for variable number of scores provided across ES could be the team's attitude to scoring for actions with nominal or low impact (i.e. 1*). This potentially biases results to more impactful outcomes for some ES where only the most impactful actions were scored.
- Variance in scoring:
 - Teams may be more likely to score higher than others or take a more precautionary approach. This is a particular risk when comparing the scores for the environmental services theme with the cultural services theme as the teams never worked together with only the project management team providing training and guidance to try to ensure a common approach.

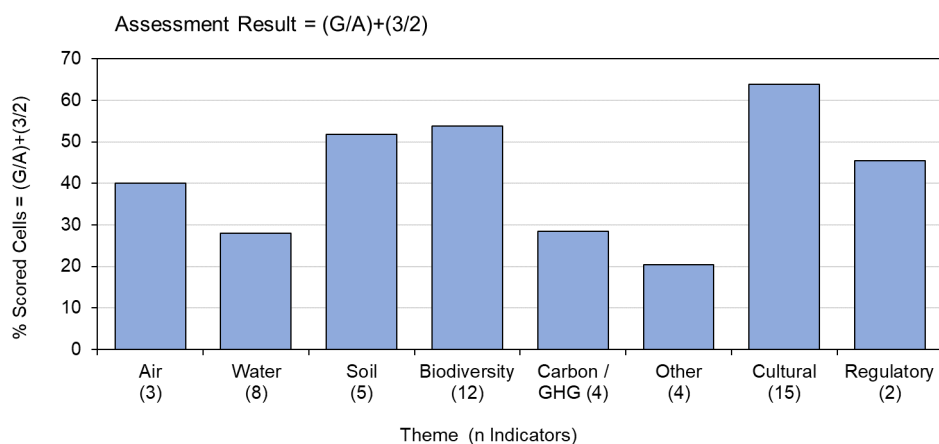
Finally, it should be noted that whilst all scores are based on the evidence base captured in the evidence reviews, all scores are somewhat subjective and whilst based on a team approach with external review and challenge by Defra there may remain inconsistencies due to the rapid nature of the assessment.

4.2 NUMBER OF ACTIONS SCORED WITH POSITIVE OUTCOME OF MODERATE TO HIGH MAGNITUDE BY THEME, ES AND MANAGEMENT BUNDLES

An analysis of the final scores were made at the request of Defra of those scored amber or green and 2* or 3* which were considered the 'potentially more impactful' actions. Of the 6480 colour coded scores created by the teams, 3070 (48%) were scored amber or green and 2* or 3*.

These have been separately plotted and analysed by Themes (Figure 2), ES (Figure 4) and Management Bundles Tier-1 (Figure 5) and Tier-2 (Figure 6).

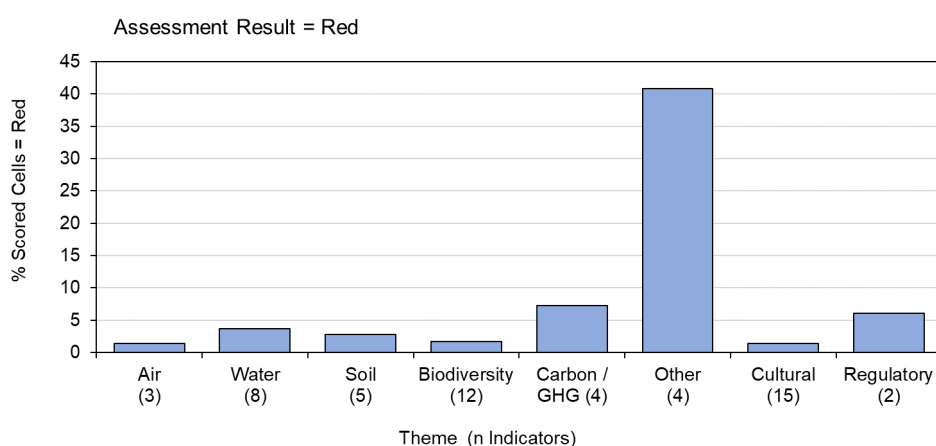
Figure 2 The proportion (%) of amber and green scores with 2* and 3* (i.e. potentially more impactful actions) expressed as a percentage of total scores for each Theme. (Note this is a repeat of Figure 1c in previous section)



The proportion of the more potentially impactful scores expressed as a percentage of total scores made for each theme were highest for the Cultural, Biodiversity and Soil themes (all > 50%). This reflects the high priority given to many ES by Defra within these themes with the exception of the Cultural theme which was not in general prioritised highly by Defra.

Low numbers of potentially impactful scores were observed for the Other Theme which included the 'Food and Fibre production ES'. This not unexpected as many actions are known to reduce productivity levels due to reduced intensity of management practices or land conversion for habitat creation. Payments are made to land managers recognising this potential loss of productivity as well as their cost for implementation. This can be seen in total scores which are red i.e. a known or likely negative outcome or disbenefit) for the Other Theme (Figure 3 and see also section 4.5).

Figure 3 The number of red scores for each Theme expressed as a percentage of total scores for each Theme.



This overall picture of potentially impactful scores by theme however hides a more complex set of scores for the ES embedded within each theme (Figure 4a). For examples, ES scored as potentially impactful within the Biodiversity theme which includes biodiversity, INNS and pollination and Seed Dispersal were scored between 40-60%. For regulatory services, the two individual ES were scored very differently local temperature regulation scored at >70% as potentially impactful whilst noise regulation was ca. 35%.

A 100% score was noted for stabilisation and control of coastal erosion. Very few actions were targeted for this very specific ES and few scores were made with most teams considering it not relevant for their topic / theme. These few actions were scored a potentially impactful. This illustrates the caution with which these scores should be analysed as this should not be interpreted as an ES which is easily improved.

Overall, the cultural services theme generally scored higher than the environmental services theme with the majority of cultural services (83%) scoring above 50% for actions which were potentially impactful. This contrasts with only four of the services in the environmental services theme (24%) which had 50% of their actions scored as amber or green 2* or 3* i.e. potentially more impactful.

Again, within ES within each theme variability was observed between individual ES indicators (Figure 4b).

Figure 4a The proportion (%) of amber and green scores with 2* and 3* (i.e. potentially more impactful actions) expressed as a percentage of total possible counts for each of the 33 ES.

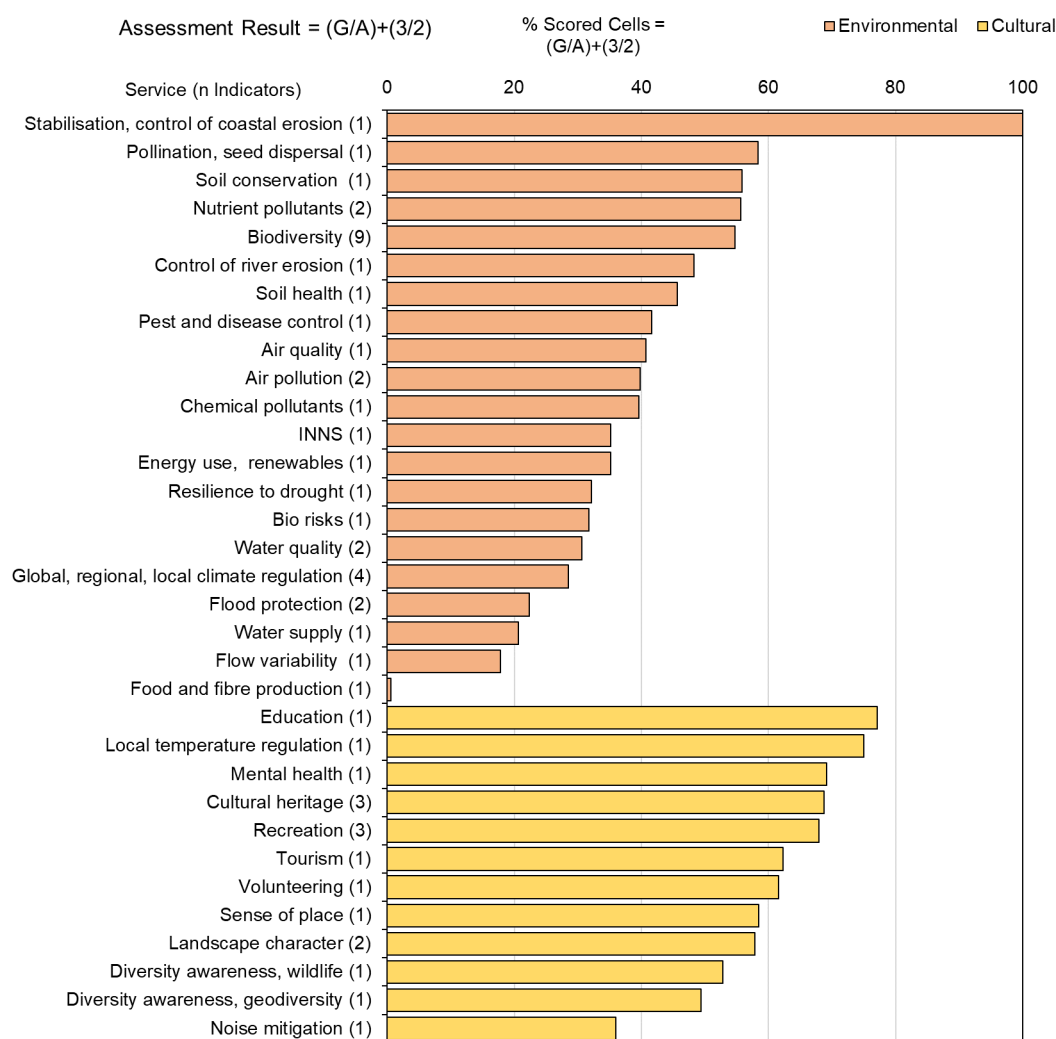
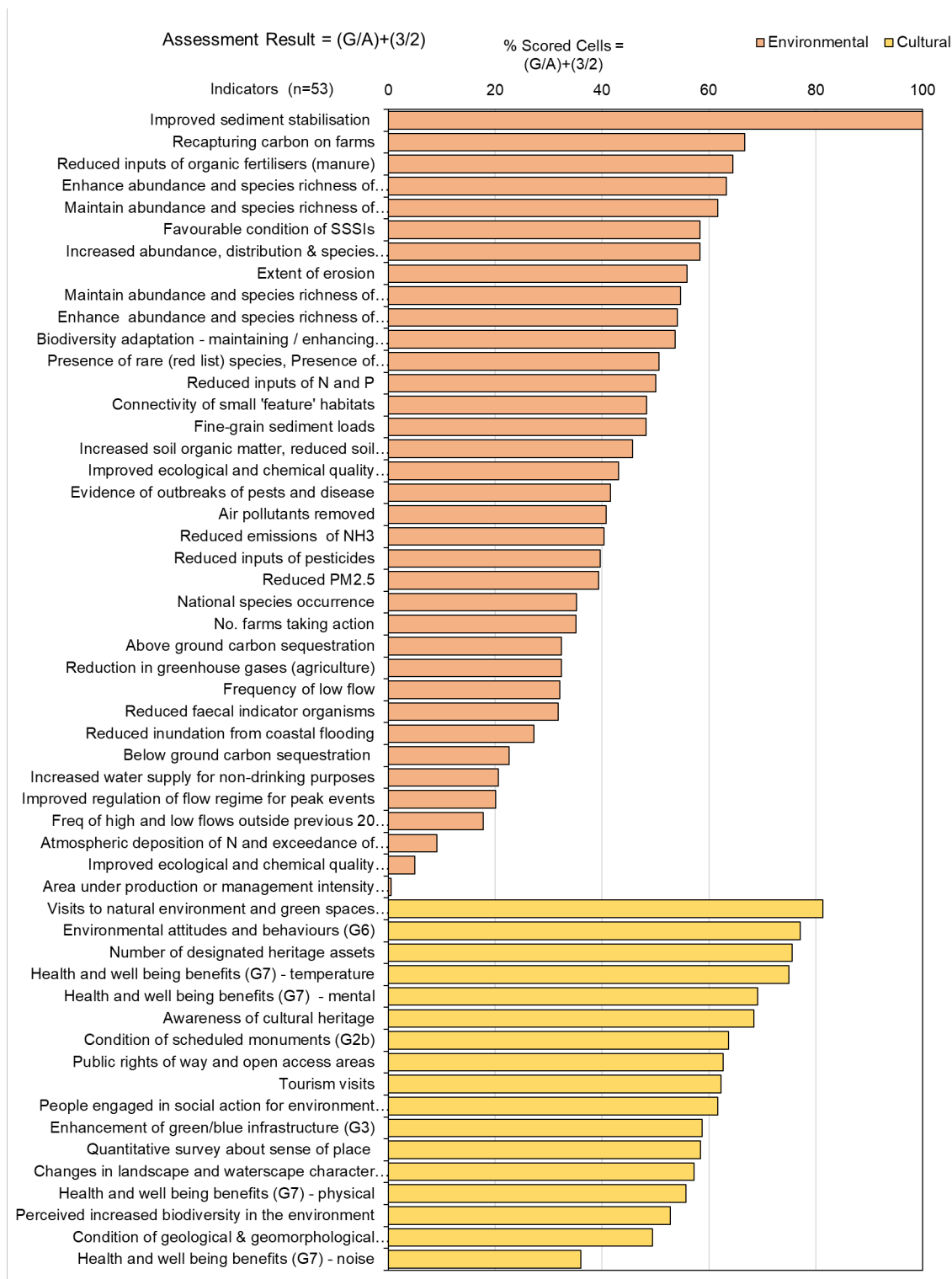


Figure 4b The proportion (%) of amber and green scores with 2* and 3* i.e. potentially more impactful actions expressed as a percentage of total possible counts for each of the 53 ES indicators.



When explored by management bundles, the percentage of actions in Management Bundle Tier-1 with potentially moderate to high positive outcomes varied between ca. 20 and 80% if environmental and cultural services themes were combined (Figure 5a). Overall, ‘Maintain and restore heritage sites’ and ‘Natural regeneration’ bundles scored the highest (> 60%).

For the environmental services themes, actions with potentially impactful actions scores ranged from 5-40% of those scored (Figure 5b). However the lower values were for bundles not targeted to environmental outcomes or for the management bundle.

The ‘Monitor, plan, databases, consultation and resulting action’ which were consistently all scored T* due to the concern from the teams that, whilst these were critical to good practice, they did not in themselves deliver real change. When these two groups were excluded all management bundles were scored ca. 20-40%.

For the cultural services theme, potentially impactful outcome of between 5 – 60% were observed but again low values were observed for bundles not targeted to these cultural services with one exception, natural regeneration (Figure 5c). When bundles targeted at environmental outcomes were excluded, the proportion of impactful outcomes were 20 - 65% i.e. higher than for the environmental services theme.

Figure 5a The proportion (%) of amber and green scores with 2* and 3* i.e. potentially more impactful actions expressed as a percentage of total scores for Management Bundle Tier-1 for environmental and cultural services themes combined.

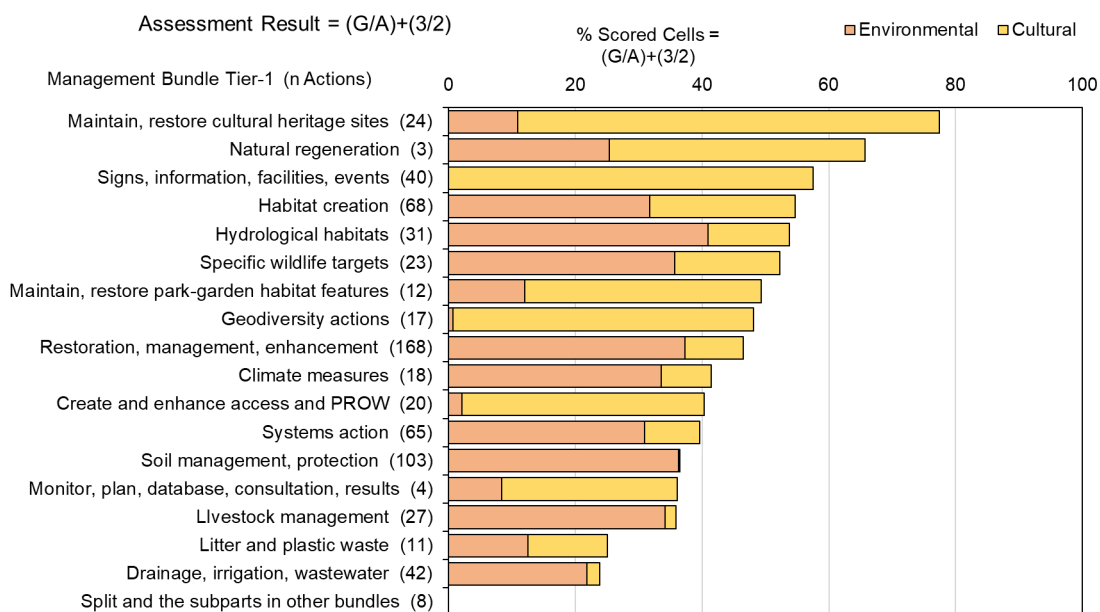


Figure 5b The proportion (%) of amber and green scores with 2* and 3* (i.e. potentially more impactful actions) expressed as a percentage of total scores for Management Bundle Tier-1 for the environmental services themes.

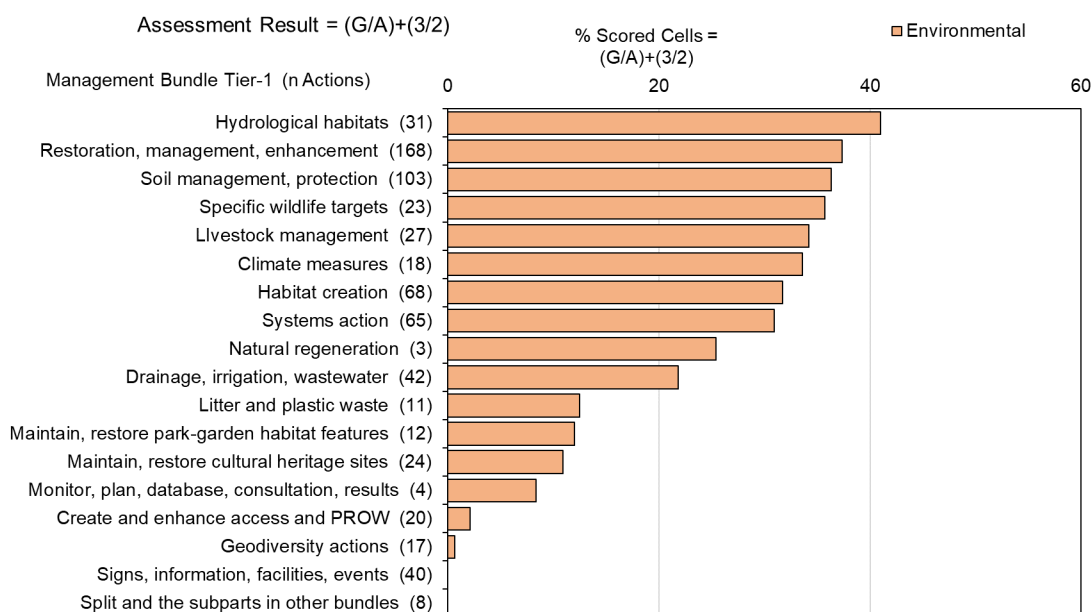
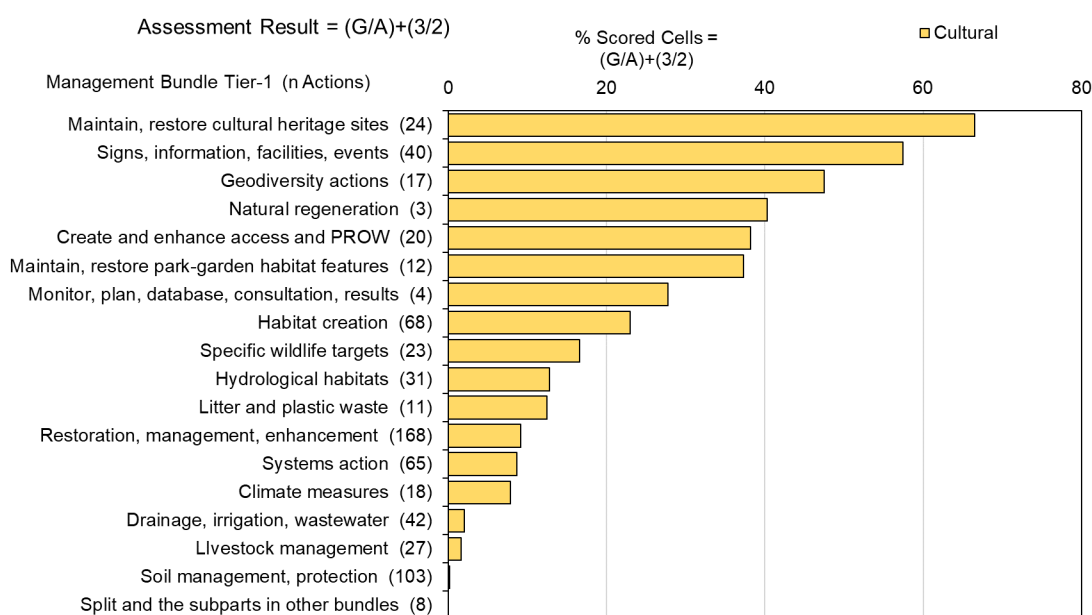


Figure 5c The proportion (%) of amber and green scores with 2* and 3* (i.e. potentially more impactful actions) expressed as a percentage of total scores for Management Bundle Tier-1 for the cultural services themes.



For Management Bundle Tier-2, when the environmental and cultural services themes were combined (Figure 6a), ‘Habitat creation’ actions represent 6 of the top 10 bundles with the highest proportion of scores (ca. 60-80%) with potentially more impactful actions.

For the environmental services theme, the top three Tier-2 bundles were: ‘Habitat creation/ scrub’; ‘Restore, manage and enhance / riparian’; ‘Restore, manage and enhance / mountain, moor and heath’ (Figure 6b).

For the cultural services theme, the top three Tier-2 bundles were: ‘Maintain, restore and manage cultural heritage sites’; ‘Signs, information, facilities and events’; and ‘Geodiversity’ actions (Figure 6c).

Figure 6a The proportion (%) of amber and green scores with 2* and 3* i.e. potentially more impactful actions expressed as a percentage of total scores for Management Bundle Tier-2 for environmental and cultural services themes combined.

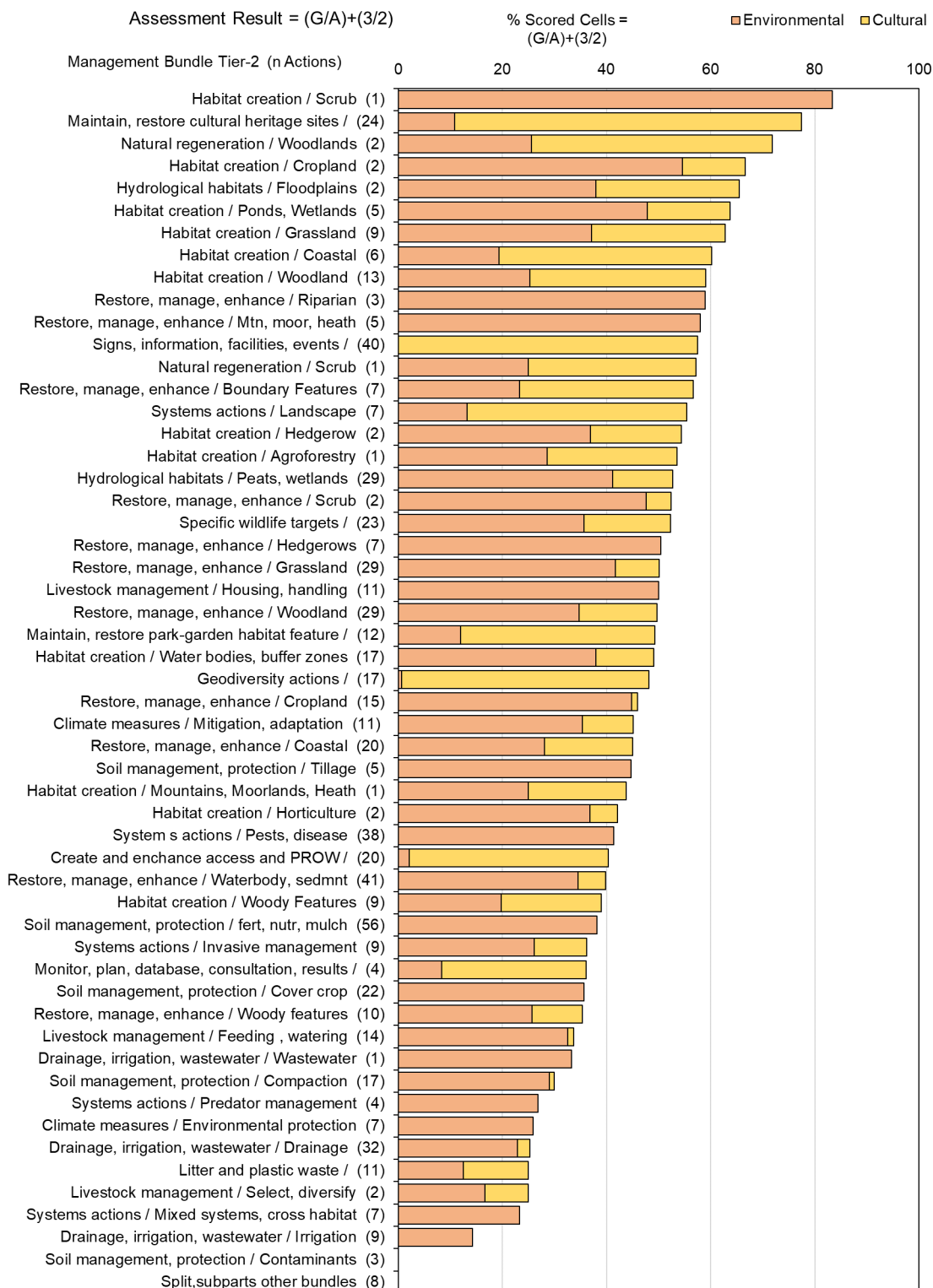


Figure 6b The proportion (%) of amber and green scores with 2* and 3* i.e. potentially more impactful actions expressed as a percentage of total scores for Management Bundle Tier-2 for environmental services themes.

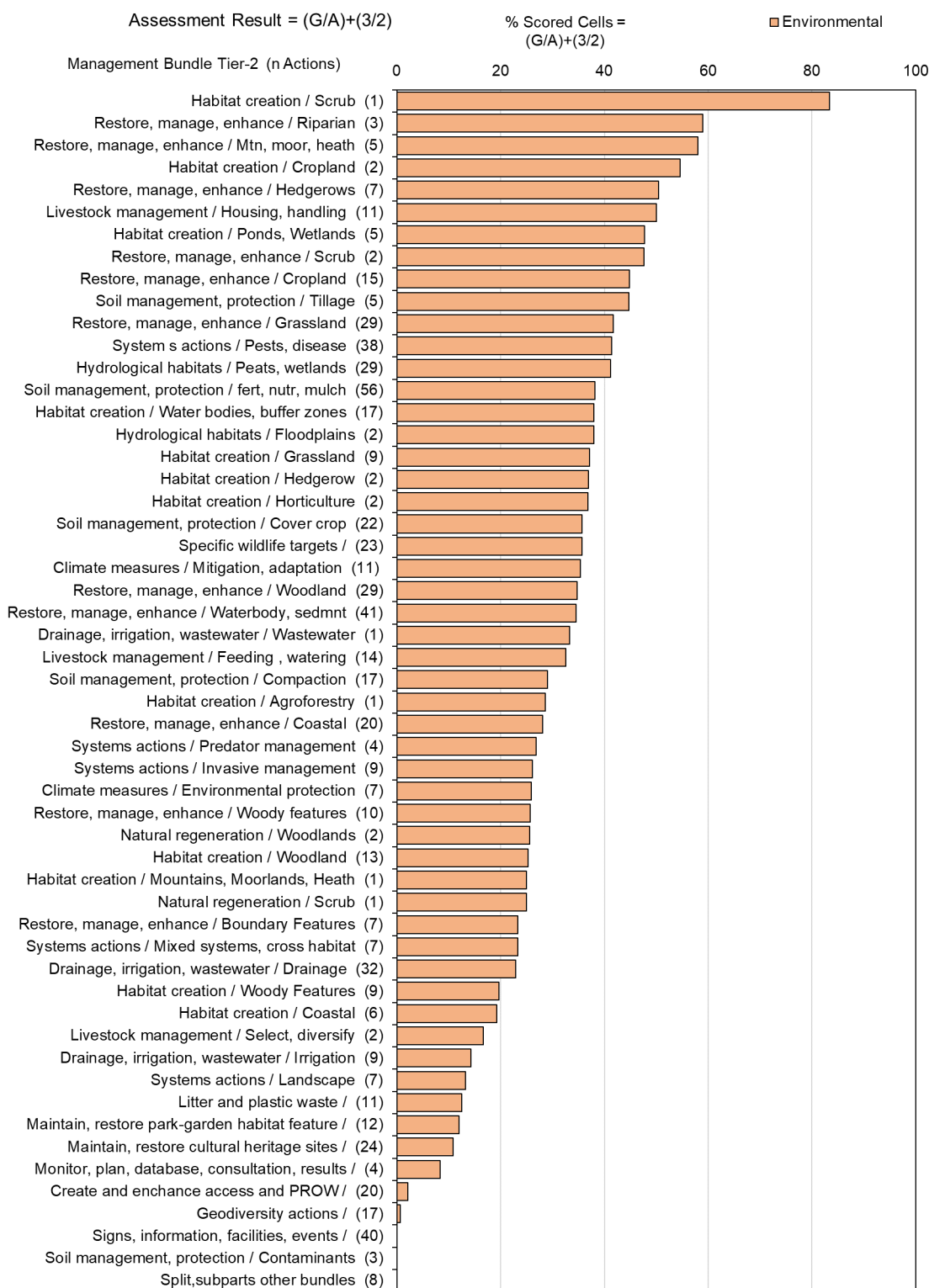
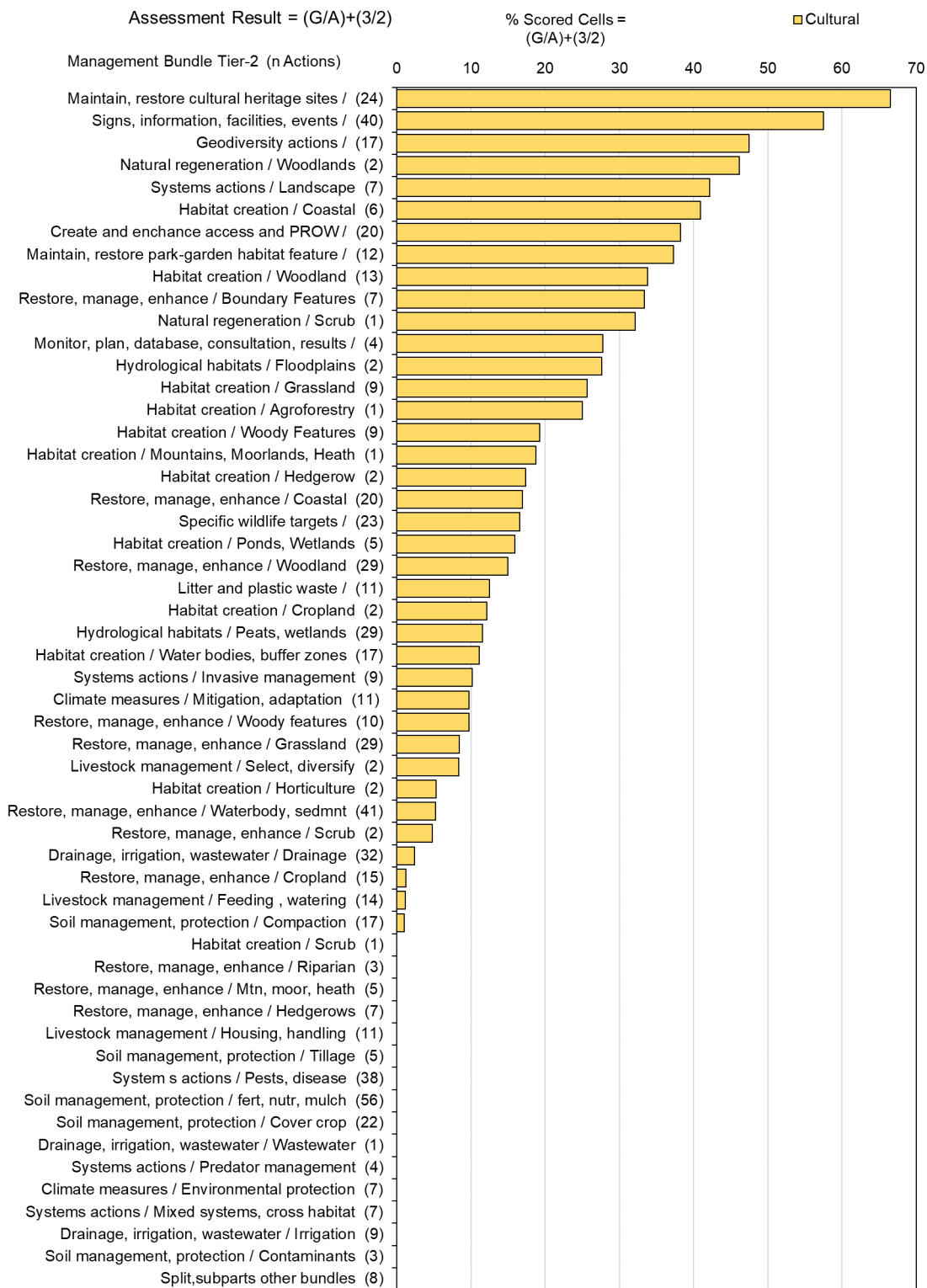


Figure 6c The proportion (%) of amber and green scores with 2* and 3* i.e. potentially more impactful actions expressed as a percentage of total scores for Management Bundle Tier-2 for cultural services themes.



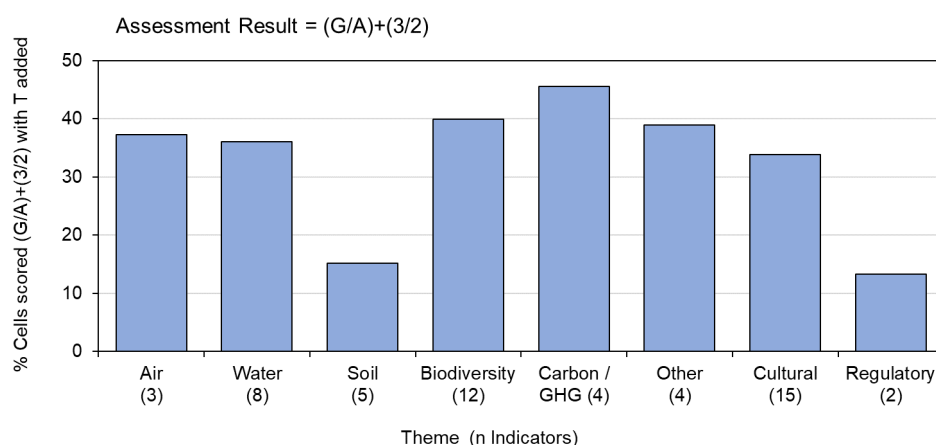
4.3 THEMES WHERE ACTIONS ARE CONTEXTUALLY DEPENDENT (T)

Exploring where the high impact scores were most contextually dependent (i.e. were scored amber or green, 2* or 3* and with a letter T), all themes had values between 30-45% with the exception of 'Soil' and 'Regulatory' services which were only 10-15% contextually dependent (Figure 7). Thus for most themes, there are important considerations to be taken into account for many actions about their placement in the landscape and/or whether the actions taken are contiguous with land where the same actions are being undertaken.

For 'Soil' and 'Regulatory' services, the low context dependency suggest actions explored are location specific and are purely additive. As the soil theme also had a high number of high impact scores, this suggests the proposed actions may have one of the most certain and positive outcomes for a theme.

It is worth noting that for 'Carbon and GHG', there were relatively few high impact scores (ca. 30%), and of these, 45% were contextually dependent suggesting many actions proposed may have the least certain outcomes.

Figure 7 The proportion (%) of amber and green scores with 2* and 3* (i.e. potentially more impactful actions) which are also scored as a 'T' i.e. contextually dependent.



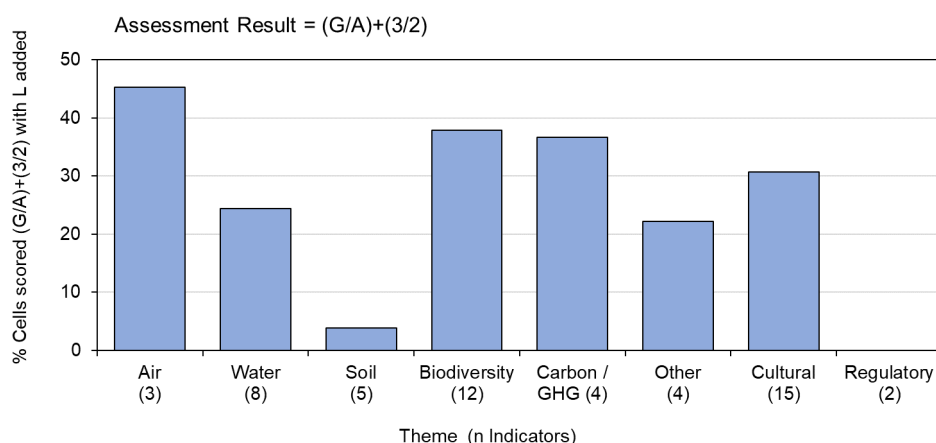
4.4 THEMES WHERE EVIDENCE IS MORE LIMITED (L)

Some scores were noted as having a limited evidence base (i.e. 'L') (Figure 8). Scores were given on the basis of expert knowledge but where this is limited by the evidence base this is shown to comply with the need for transparency.

Of the total number of potentially impactful scores within each theme, the evidence limitation was greatest for the Air theme (ca. 45%) with Biodiversity, Carbon/GHG and Cultural services all with ranges between 30-40%. Soil and Regulatory were the themes least impacted by this lack of evidence at < 5%.

This information may help guide future priorities with respect to research and evidence requirements for the actions proposed.

Figure 8 The proportion (%) of amber and green scores with 2* and 3* (i.e. potentially more impactful actions) which are also scored as 'L' i.e. limited evidence.



4.5 NUMBER OF ACTIONS WITH NEGATIVE OUTCOMES OR DISBENEFITS (RED)

As discussed in section 4.1, the most negative outcomes or disbenefits were scored for the 'Food and fibre production' ES (Figure 9a) – a total of 80% of all scores made. A notable number of negative outcomes were also noted for 'Biodiversity', 'Global, regional and local climate regulation', 'Biorisks' and 'Resilience to drought' ES.

When Management Bundles Tier-1 are explored for negative outcomes (Figure 9b), 'Livestock measures' and 'Climate measures' had ca. 10-15% levels of scoring.

In the cultural services theme (Figure 9c), a surprising number of negative outcomes were scored for the 'Creation of public rights of way (PROW)' and 'Geodiversity' actions.

For Management Bundles Tier-2 in the environmental services theme (Figure 9d), 'Livestock management / feeding and watering' had a particularly high level of negative scores (23%). This reflects the high risk of a potential trade-off which increases efficiency of agriculture create for other ES.

When exploring individual actions (Figure 9f), the following 4 actions had more than 50% scores showing as disbenefits:

ETPW-043 – restrict beach cleaning to hand cleaning of inorganic waste

ECAR-020 – extend grazing season for cattle

ECPW-243 – drill double heads into arable crops

EHAZ-056 – modify or remove in channel structures (weirs and sluices).

In some cases, these are down to a single score being made which was coded as red (ETPW-043) whilst in others there are multiple red scores (12 for ECAR-020). Each action and their scores should be checked individually as both single and multiple disbenefits could be relevant depending on the specific location and context.

Figure 9a The proportion (%) of red scores of the total actions scored for environmental and cultural services theme.

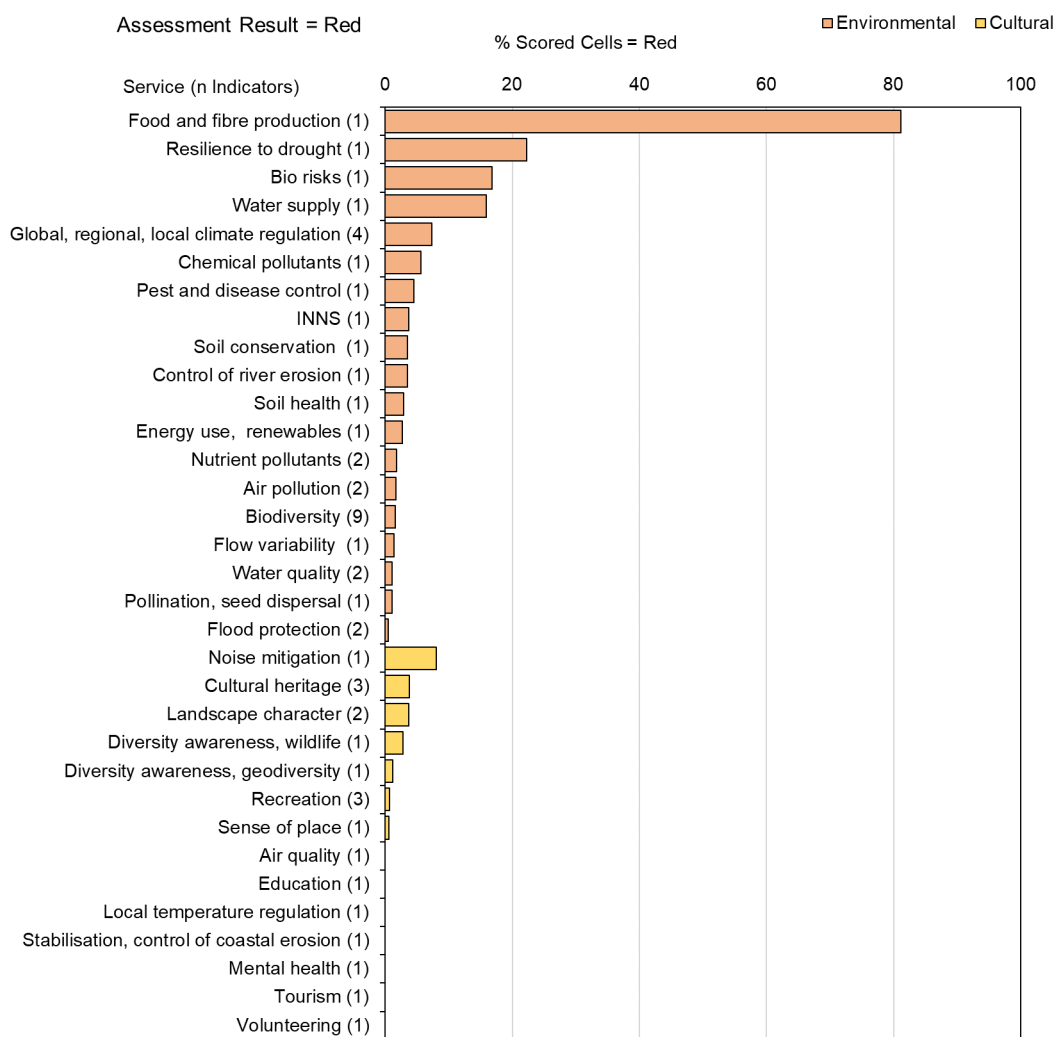


Figure 9b The proportion of total scores which are red (%) for Management Bundle Tier-1 for environmental services themes

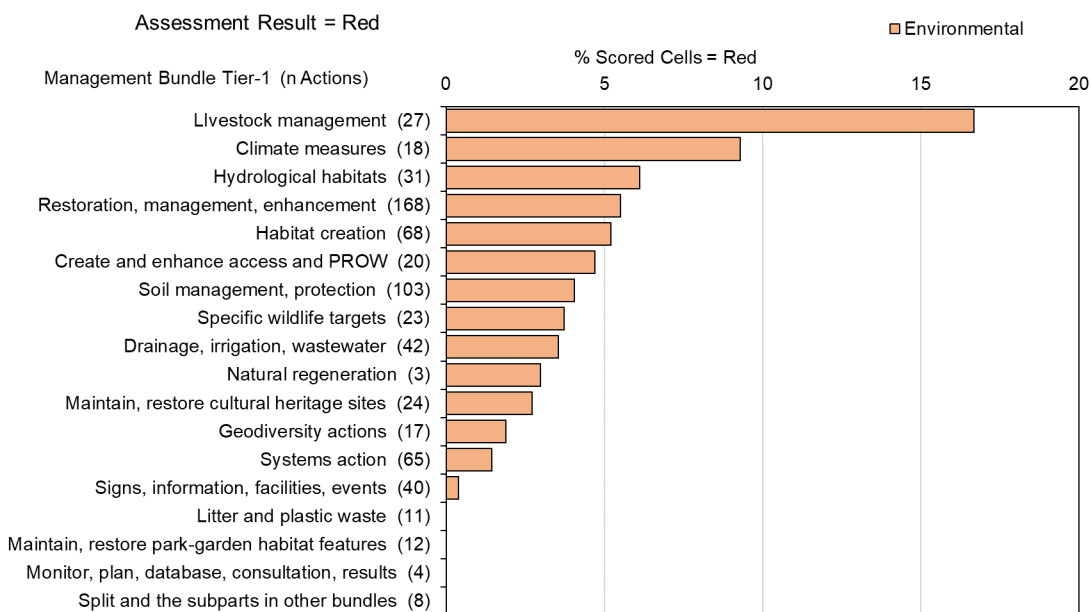


Figure 9c The proportion of total scores which are red (%) for Management Bundle Tier-1 for cultural services themes

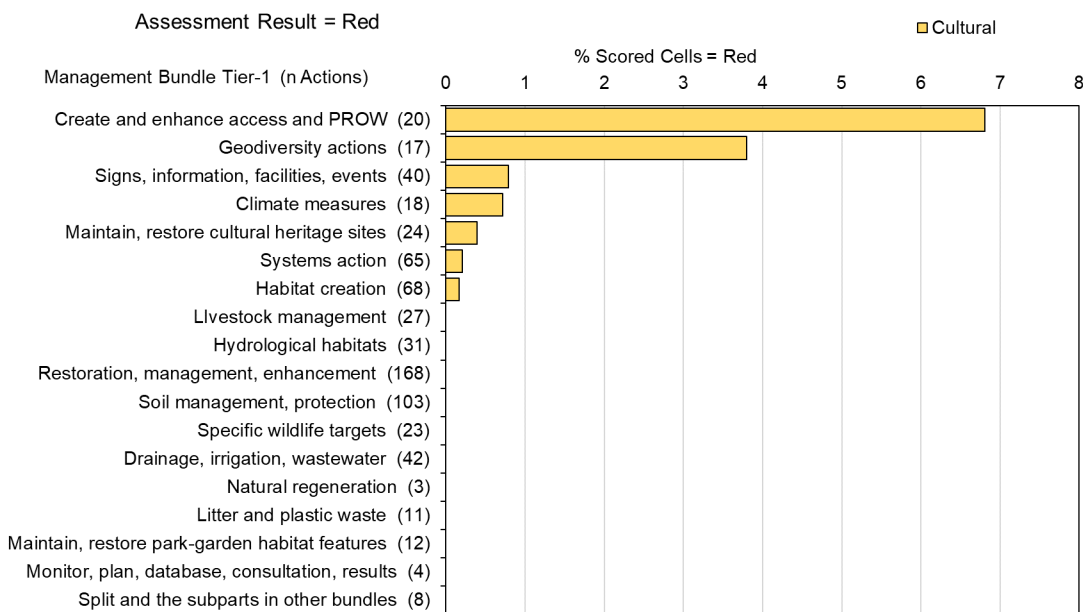


Figure 9d The proportion of total scores which are red (%) for Management Bundle Tier-2 for environmental services themes

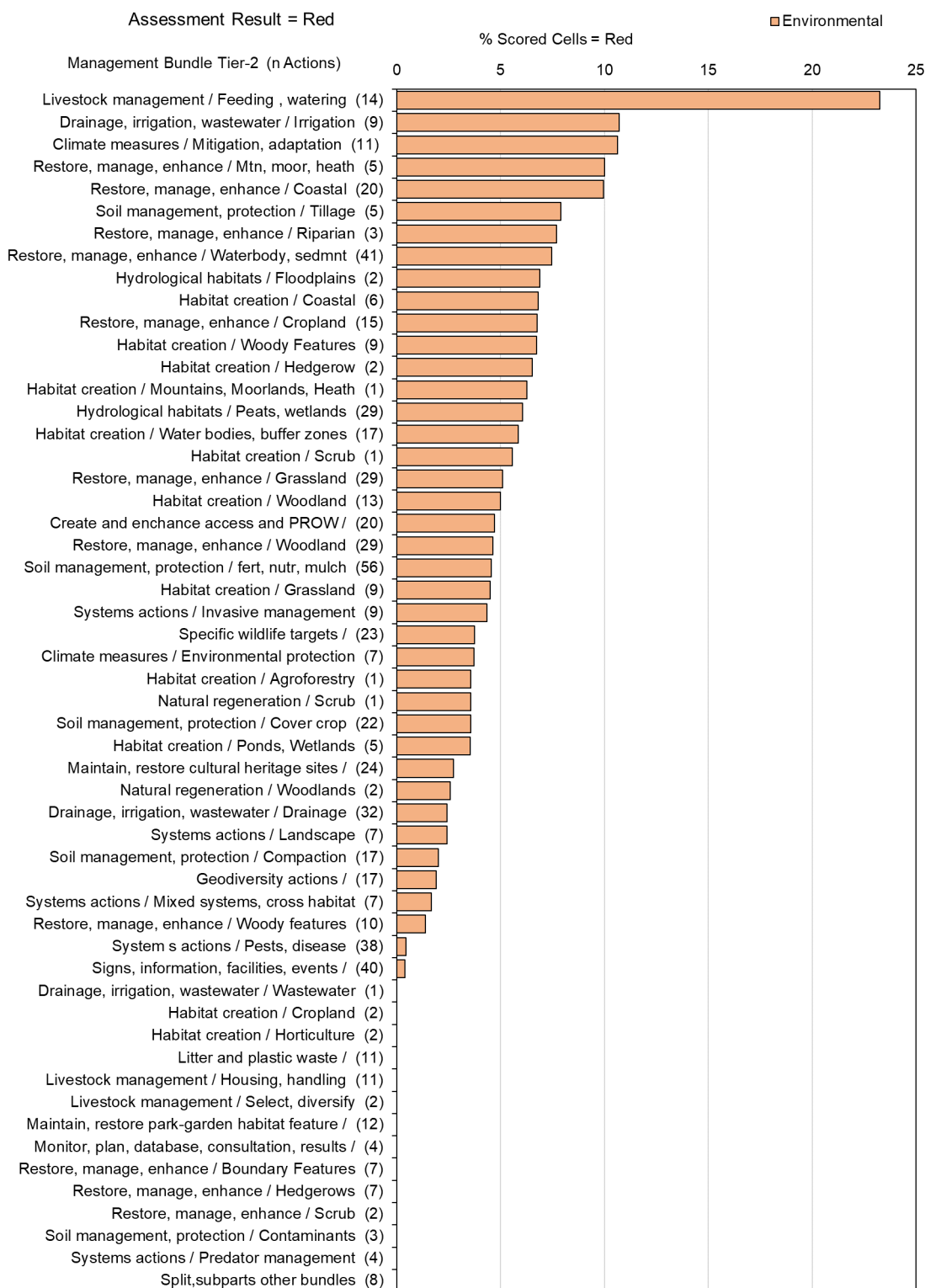


Figure 9e The proportion of total scores which are red (%) for Management Bundle Tier-2 for cultural services themes

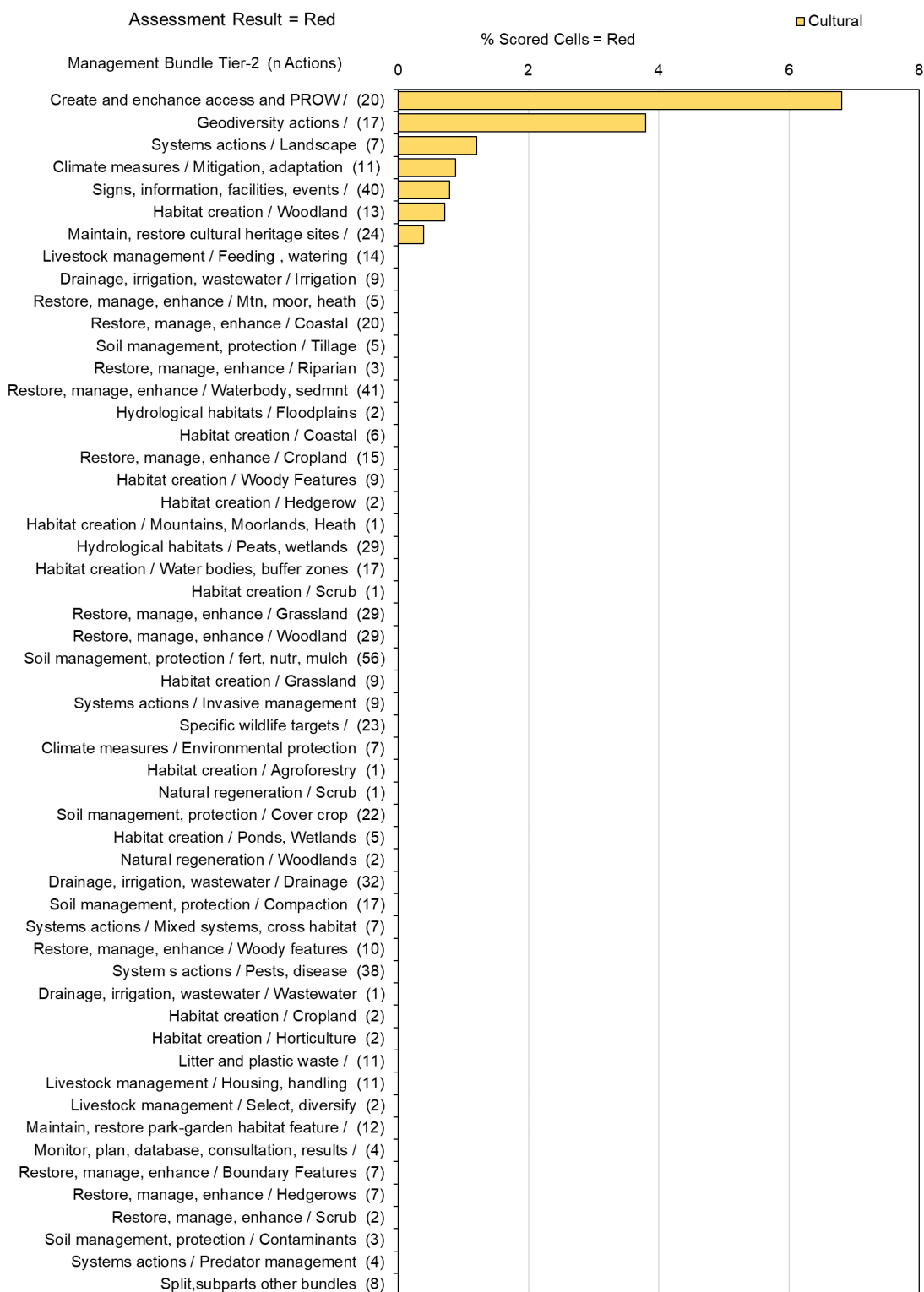
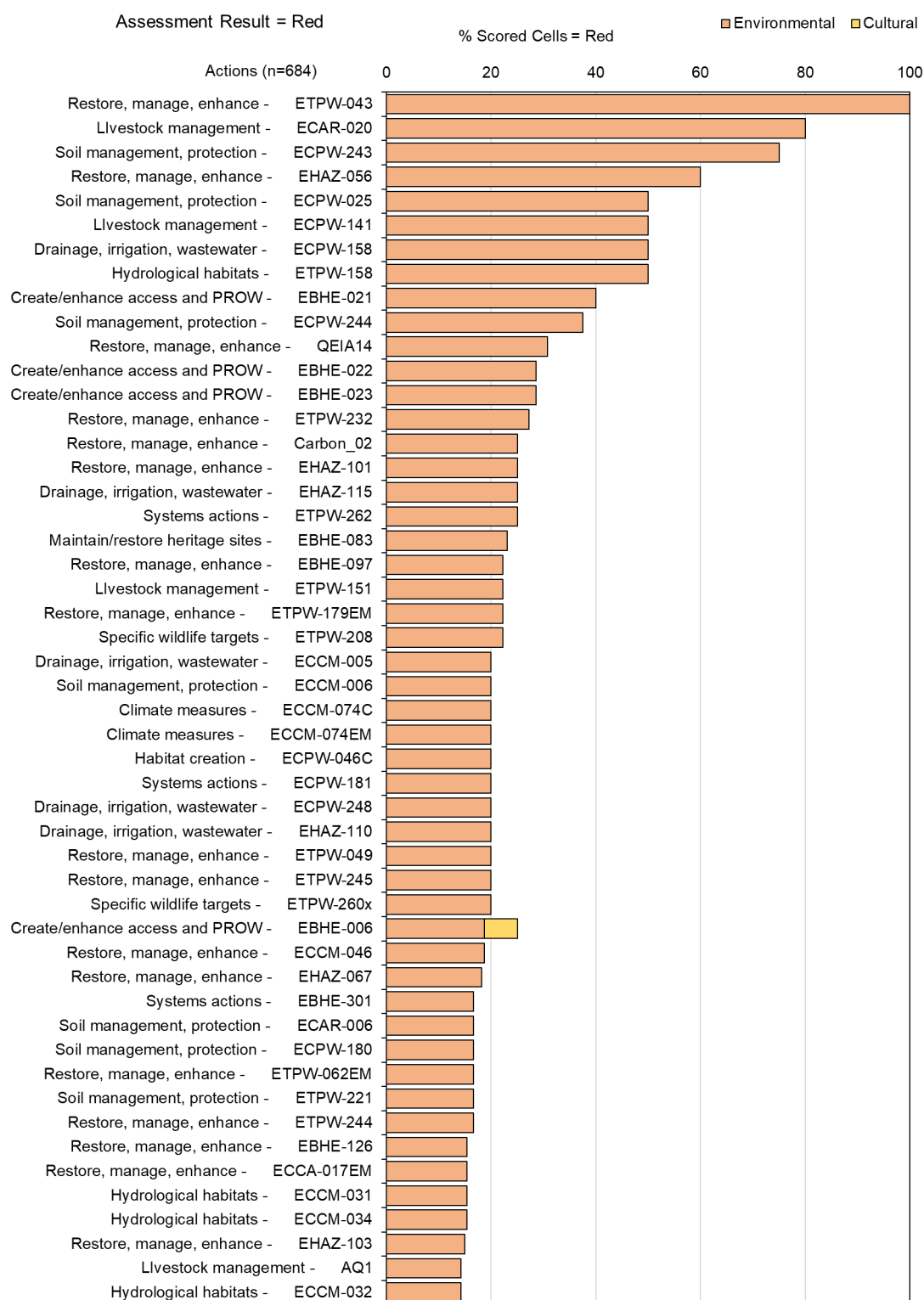


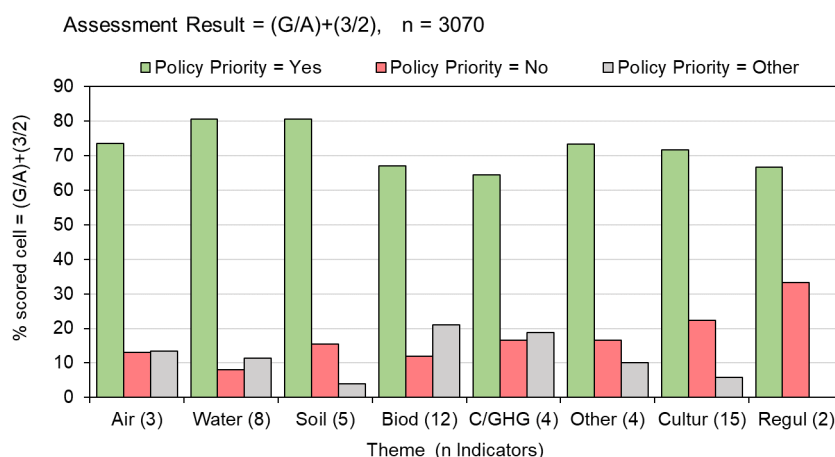
Figure 9f The proportion of total scores which are red (%) by action for both environmental and cultural services themes (top 50 only shown).



4.6 THEMES AND DEFRA PRIORITIES

Of the potentially high impactful actions, 72% were in themes prioritised by Defra (Figure 10) with little difference between the different themes. This suggests that actions proposed by Defra for priority areas were in general scored as potentially impactful.

Figure 10 The proportion (%) of amber and green scores with 2* and 3* (i.e. potentially more impactful actions) which were also scored as a policy priority category (green), not a policy priority (red) or policy priority other (grey).



4.7 A COMPARISON OF KEY ACTIONS PROPOSED BY THE ENVIRONMENTAL SERVICES TEAMS AND TOP SCORING ACTIONS IN THE IA TABLE

Defra requested key actions to be identified by the environmental services teams which they considered fundamental for reversing environmental degradation (including restoration and improvement).

The teams identified a total of 154 actions (Table 4a) representing c.20% of the original list of actions provided by Defra (which were further enhanced by the teams). These identified actions are provided in full in Annex-A of this report.

An analysis of overlap between these actions across the thematic teams indicate that of these 154 actions identified by the thematic teams as fundamental to reverse environmental degradation (including restoration and improvement):

- No actions were identified by more than 3 thematic teams
- 2 actions were identified by 3 thematic teams. These were:
 - ECCM-025C – Plant Hedgerows (Habitat Creation/Hedgerows). Teams were Carbon &GHG, Soil and Biodiversity
 - ECPW – 171 – Use very low inputs on permanent grassland (Soil Management and Protection). Teams were: Air Quality, Carbon & GHG and Biodiversity.
- 15 actions were identified by 2 teams. The combinations of themes in which these actions sit were perhaps unexpected with actions identified by Biodiversity and Soil and Carbon & GHG the most co-identified whereas perhaps Water and Soil would have been more expected to co-identify the same actions (Table 4b).

Table 4a Table of actions identified by the environmental services teams which they considered were fundamental to reverse environmental degradation (including restoration and improvement).

Environmental Services Themes								
Air Quality	Carbon/GHG		Water*	Soil*	Biodiversity			
	Carbon	GHG			Systems-based	Semi-Natural	Grassland	Cropland
ECAR-001	Carbon_01	ECAR-001	ECPW-002	EBHE-164C	EBHE-182	EBHE-196	EBHE-214EM	Arable01
ECAR-020	Carbon_04	ECAR-004	ECPW-042	ECCM-025C	EBHE-187	EBHE-198	ECCM-014	Arable01
ECAR-024	ECAR-032	ECAR-006	ECPW-103	ECCM-028	ECCM-025C	EBHE-203C	ECCM-038	Arable02
ECAR-027	ECCA-024	ECAR-015	ECPW-170	ECCM-030	ECCM-025EM	EBHE-203EM	ECPW-022C	EBHE-117
ECAR-033C	ECCM-024C	ECCM-013	ECPW-232	ECCM-039	ECCM-048	EBHE-205	ECPW-022EM	EBHE-117
ECAR-035	ECCM-024EM	ECCM-014	EBHE-212	ECPW-002	ECPW-071	EBHE-205C	ECPW-039	EBHE-303
ECCM-006	ECCM-025C	ECCM-061	ECCA-008	ECPW-022C	ECPW-071C	EBHE-214C	ECPW-083	ECAR-015
ECCM-010	ECCM-030	ECCM-063	ECPW-202	ECPW-044	EHAZ-010	EBHE-226	ECPW-171	ECCM-071
ECCM-011	ECCM-038	ECPW-115	EBHE-164C	ECPW-044C	EHAZ-010X	EBHE-307	ECPW-237	ECPW-031
ECCM-077	ECCM-048	ECPW-131	ECPW-059	ECPW-095	ETPW-198	ECAR-034	ECPW-237Cx	ECPW-032
ECCM-078	ETPW-019	ECPW-137	EHAZ-052	ECPW-232	ETPW-205C	ECAR-036	ECPW-237Cy	ECPW-231
ECPW-115	ETPW-081C	ECPW-141	ECCA-014	ECPW-249	ETPW-260	ECCA-028	ECPW-237EMx	ECPW-264
ECPW-123	ETPW-081CX	ECPW-146		ECPW-270	ETPW-260x	ECCM-033	ECPW-237EMy	EHAZ-007
ECPW-152		ECPW-171		ECPW-271	ETPW-260y	ECCM-051	ECPW-245	EHAZ-024
ECPW-156		ECPW-173		ECPW-279	ETPW-271	ECCM-051C	ECPW-249	ETPW-116
ECPW-156C		ETPW-156		EHAZ-007		ECCM-053	ECPW-257	ETPW-200
ECPW-171				ETPW-038		ECCM-054	EHAZ-010	ETPW-200x
				ETPW-205C		ECCM-056	EHAZ-010Y	ETPW-202
				ETPW-223		ECPW-291	EHAZ-010Z	ETPW-205C
				ETPW-251		ECPW-291C	ETPW-098	ETPW-205EM
						ETPW-016	ETPW-101	ETPW-207
						ETPW-016C	ETPW-104	ETPW-229
						ETPW-036EM	ETPW-105	ETPW-233
						ETPW-142	ETPW-106	ETPW-238
							ETPW-115	ETPW-240
							ETPW-150	ETPW-260
							ETPW-156	ETPW-260x
							ETPW-157	
							Grassland_01	

* Includes assessment for chemicals and biorisks which were in the Other theme.

Table 4b The thematic teams and number of occurrences where two teams co-identified the same actions as fundamental to reverse environmental degradation (including restoration and improvement)

Teams	No. of times 2 actions were co-identified by both thematic teams
Carbon & GHG and Biodiversity	5
Soil and Biodiversity	4
Water and Soil	3
Air quality and Carbon & GHG	2
Carbon & GHG and Soil	1

- The Management Bundle Tier-1 with the greatest number of co-identified actions was 'Soil management and protection' (Table 4c) which was also one of the Management Bundles Tier-1 which was co-identified by three thematic teams or more. This suggests soil actions are considered by several of the teams as some of the fundamental to take to reverse environmental degradation.
- The remaining actions were identified by 1 team only.

Table 4c The Management Bundles Tier-1 in which actions were located where two teams co-identified the same actions as fundamental to reverse environmental degradation (including restoration and improvement)

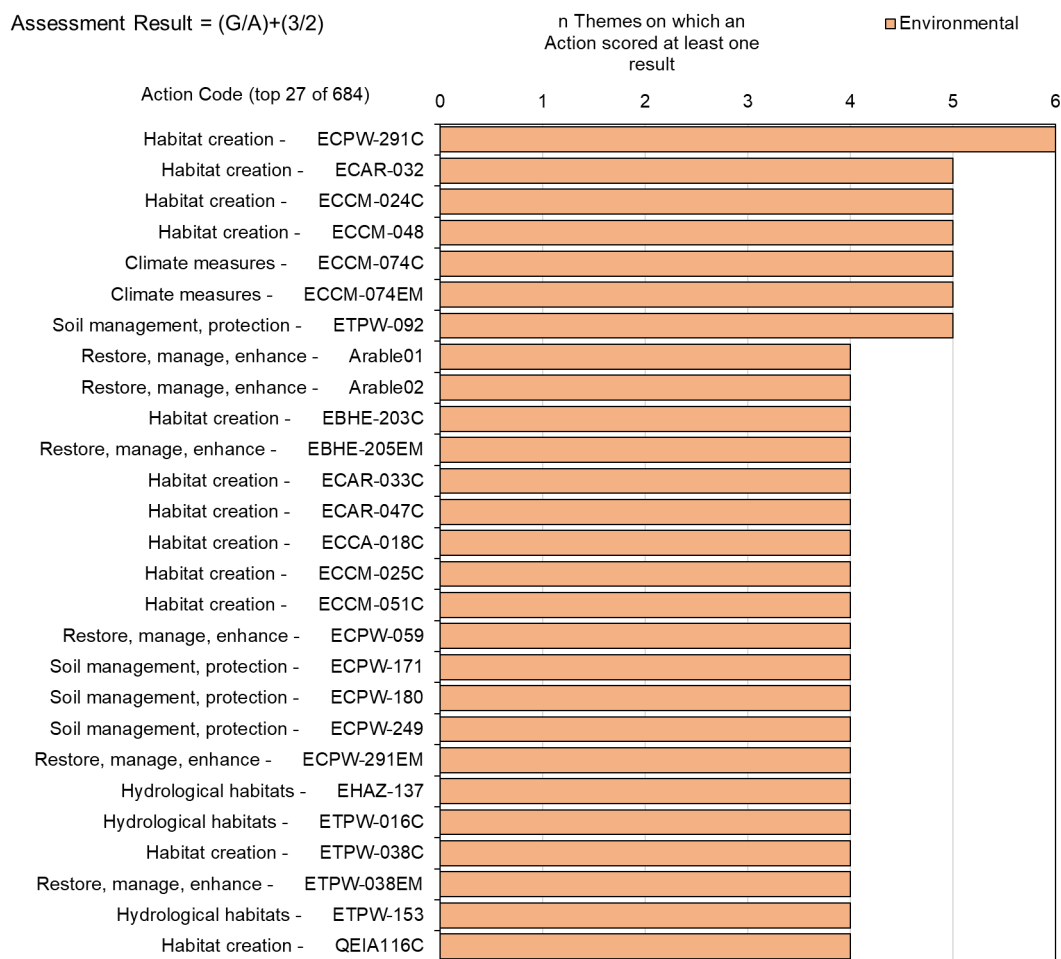
Management Bundles Tier-1	No. of times 2 actions were co-identified by two thematic teams
Soil management and protection	6
Habitat creation	3
Restoration, management and enhancement	3
Actions for habitats with specific hydrological characteristics	3

The selection of actions by the environmental services thematic teams contrasts with the evidence of the most impactful actions across multiple ES identified in the IA table in section 3.1.1. This indicates that many actions (83 in total) have high potential impact (amber or green 2 or 3 *) across 3 or more environmental services themes (Figure 11a).

Furthermore, a total of 20 actions were identified in the IA as having potentially high impact across 4 or more environmental services themes, 6 actions for 5 themes and 1 actions for 6 environmental services themes (Figure 11a). A total of 239 actions had no scores indicating potentially high impact.

This apparent disconnect between the selection of actions by the expert teams and the most impactful actions across ES identified in the IA suggests that expert teams focus on actions which particularly target specific issues relating to their topics when asked to do so without moderating their assessment to take account of the more generalised high impact i.e. co-benefits across multiple themes. This should be taken into consideration when asking experts for their advice going forward i.e. the question asked should be explicit as to whether co-benefits should be taken into account.

Figure 11a The top scoring actions in the IA with potentially impactful outcomes for 4 or more of the 6 environmental services themes.



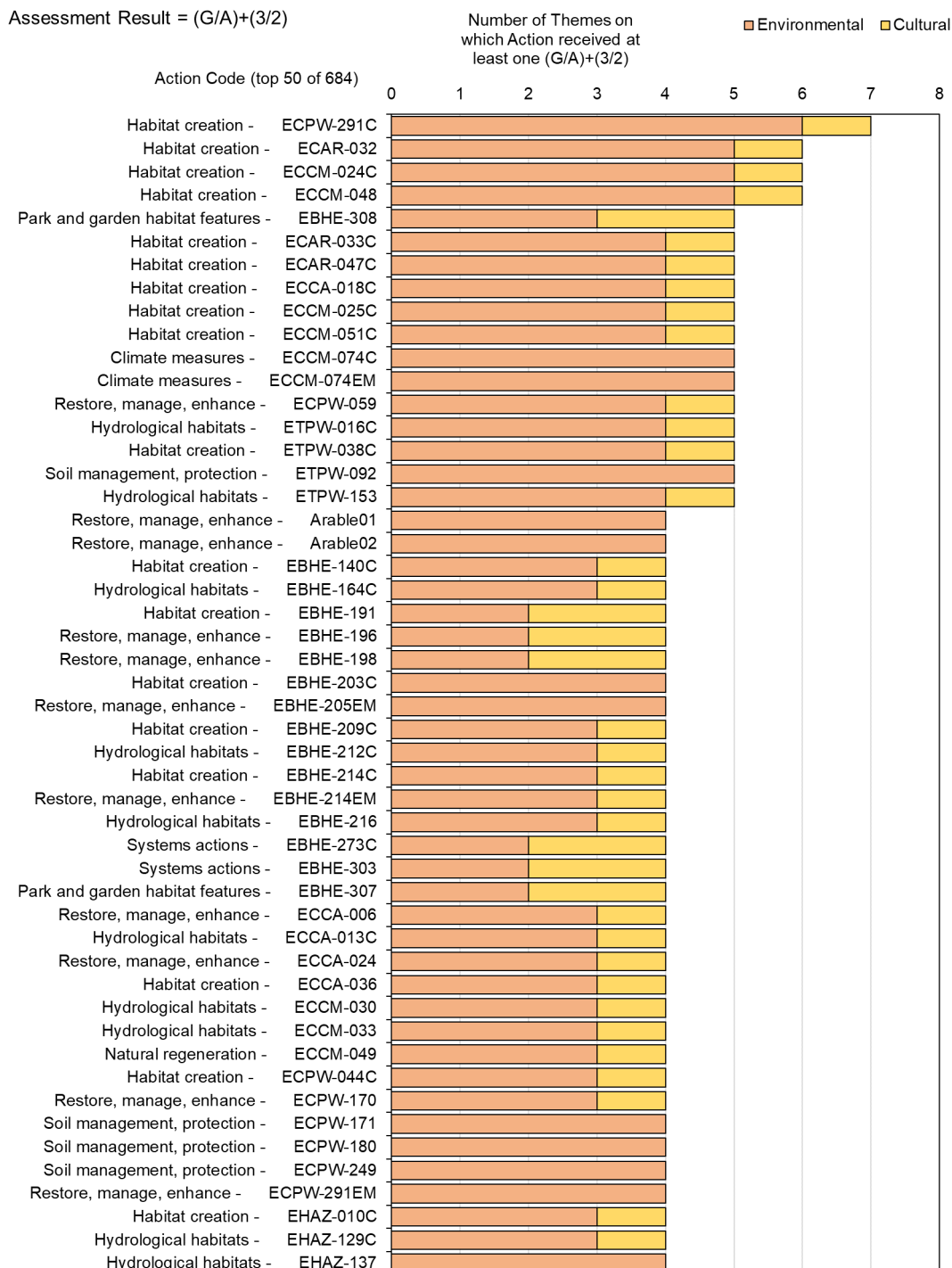
The top scoring actions in the IA (Table 11a) with the highest potential impact across 5 or all 6 of the environmental services themes are listed below together with the number of potential dis-benefits in parentheses (i.e. the number of red colour codings).

Action code	Management Bundle Tier 1 / Tier 2
ECPW-291C	Habitat creation / water bodies and buffer zone (2 reds)
ECAR-032	Habitat creation / agroforestry (1 red)
ECCM-024C	Habitat creation / woody features (3 reds)
ECCM-048	Habitat creation / woodland (2 reds)
ECCM-074C	Climate measures / climate change and adaptation (Plant bioenergy crops) (4 reds)
ECCM-074EM	Climate measures / climate change and adaptation (Enhance or manage bioenergy crops) (4 reds)
ETPW-092	Soil management and protection / tillage (no reds)

The list is clearly dominated by actions which sit in the Management Bundle Tier-1 of 'Habitat creation' involving woody species or new bodies and buffer zone within the freshwater system. Whilst creation of bioenergy crops scored highly for multiple theme delivery, there was also significant number of trade-offs as indicated by the high number of red scores.

When cultural services are included, more than 139 (compared to 83 for environmental actions alone) delivered potentially positive impactful outcomes for more than 3 themes (Figure 11b). A total of 128 actions had no amber or green 2* or 3* scores (compared to 239 for environmental services alone).

Figure 11b The top scoring actions in the IA with potentially impactful outcomes for the environmental and cultural services themes combined.



4.8 KEY FINDINGS

4.8.1 The ambition of the IA approach

1. The final IA table includes 741 actions, 8 Themes, 33 ES and 53 ES-indicators. A total possible matrix of 39,273 scores. This was a massive undertaking to face the project team and is a more ambitious integrated assessment of agri-environment actions than any previously carried out for the UK to our knowledge. The benefit is the rich information captured which recognises that many actions may have consequences beyond their primary targeted outcome of either, equal or positive magnitude (co-benefits), or a potentially negative trade-off.
2. The team have followed the requirements and best practice when providing policy advice and have made clear uncertainties, assumptions and limitations of the approach and findings.
3. Of the 39,273 possible scores, the team provided 6480 colour coded scores (16% of the total possible scores). The remaining scores are where actions were not considered relevant to a ES indicator (or are) already covered by regulation – a very small number - or where actions were merged or split. Of the 741 actions a total of 10 actions were not considered relevant or of sufficient potential impact to be assessed by any team. This suggests the Defra team had identified actions which were likely to have some impact on at least some ES but that most actions did not have impact across the full spectrum of ES and ES-indicators.

4.8.2 Most impactful actions

4. Of the 6480 colour coded scores created by the teams, 3070 (47%) were scored amber or green and 2* or 3*. Defra indicated these scores were of most interest as they identified actions which were the potentially most impactful actions to be considered for inclusion in the ELM schemes. In this category of potentially more impactful actions, scores for the environmental services themes (20-40%) were generally lower than for the cultural services theme (20-65%). This could reflect the time required to reverse environmental degradation compared to cultural services or possibly a different perception within the two quite different research disciplines.
5. The proportion of the more potentially impactful scores expressed as a percentage of total scores made for each theme were highest for the Cultural, Biodiversity and Soil themes (all > 50%). This reflects the high priority given to many ES by Defra within these themes with the exception of the Cultural theme which was not in general prioritised highly by Defra.
6. Low numbers of potentially impactful scores were observed for the 'Other' Theme which included a mix of issues including 'Food and fibre production' ES. Low impact, or indeed negative impact, for this ES is not unexpected as many actions are known to reduce productivity levels due to reduced intensity of management practices or land conversion for habitat creation. Payments are made to land managers recognising this potential loss of productivity as well as their cost for implementation. This issue is also reflected in the number of scores which are coded red with 80% of all actions scored coded red.
7. This overall picture however hides a more complex set of scores for the ES embedded within each theme. For examples, ES within the biodiversity theme which includes 'Invasives & non-native species', 'Pollination' and 'Seed dispersal' were scored between 40-60%. For regulatory services, the two individual ES were scored very differently 'Local temperature regulation' scored at >70% whilst 'Noise regulation' was ca. 35%. This emphasises the potential for quite variable outcomes with a theme for different ES.

8. Overall, the cultural services theme generally scored higher than the environmental services theme with the majority of cultural services (83%) scoring above 50% for actions which were potentially impactful. This contrasts with only four of the services in the environmental services theme (24%) which had 50% of their actions scored as potentially more impactful.
9. When explored by management bundles, the percentage of actions in Management Bundle Tier-1 with potentially impactful scores varied between ca. 20 and 80% when environmental and cultural services themes were combined.
10. For the environmental services themes, proportions of actions with potentially impactful actions scores ranged from 5-40%. However the lower values were for bundles not targeted to environmental outcomes, or for the management bundle, 'Monitor, plan, databases and results' which were consistently all scored T* due to the concern from the teams that, whilst these were critical to good practice, they did not in themselves deliver real change. When these two groups were excluded all management bundles scored ca. 20-40% for the environmental services theme.
11. For the cultural services theme, potentially impactful outcome of between 5 – 60% were observed but again low values were observed for bundles not targeted to these services with one exception 'Natural regeneration'. When bundles targeted at environmental outcomes were excluded, the proportion of impactful outcomes were 20 - 65% i.e. higher than for the environmental services theme.
12. Overall, when ES from the environmental and cultural services theme were combined, the management bundles of 'Maintain and restore cultural heritage sites' and 'Natural regeneration' scored the highest (> 60%) for most impactful scores. It is interesting to note the potential value for both environmental and cultural services themes of 'Natural regeneration' which may not be a well-recognised phenomenon and deserves further exploration.
13. Exploring management to the more detailed Tier-2 level for the environmental services theme, the top three Tier-2 bundles with the most impactful scores were:
 - Habitat creation/ scrub;
 - Restore, manage and enhance / riparian;
 - Restore, manage and enhance / mountain, moor and heath.

For the cultural services theme, the top three Tier-2 bundles were:

 - Maintain, restore and manage cultural heritage sites;
 - Signs, information, facilities and events;
 - Geodiversity actions.
14. When the environmental and cultural services themes were combined, 'Habitat creation' actions represent 6 of the top 10 management bundles with the highest proportion of scores (ca. 60-80%) with potentially more impactful actions. As habitat creation is one of the most fundamental changes which can be made this is perhaps not surprising but interesting to note the overall high scores across both the environmental and cultural services themes.

4.8.3 Context dependency, limited evidence and trade-offs

15. Exploring where the high impact scores were most contextually dependent (i.e. were scored amber or green, 2* or 3* and with a letter T), all themes had values between 30-45% with the exception of Soil and Regulatory services which were only 10-15% contextually dependent. Thus for most themes, there are important considerations to be taken into account for many actions about their placement in the landscape and/or whether the actions taken are contiguous with land where the

same actions are being undertaken. For Soil and Regulatory services, the low context dependency suggest actions proposed are location specific and are purely additive. As the Soil theme also had a high number of high impact scores, this suggests the proposed actions may have one of the most certain and positive outcomes for any theme which are not dependent on their landscape context. Note they still be specific for individual soil types.

16. It is also worth noting that for the 'Carbon and GHG' ES, there were relatively few high impact score (ca. 30%), and of these 45% were contextually dependent suggesting many actions proposed may have the least certain outcomes.
17. Of the potentially high impactful actions, 72% were in themes prioritised by Defra. This suggests that actions proposed by Defra for priority areas were in general scored as potentially impactful.
18. Some scores were noted as having a limited evidence base (i.e. 'L'). Scores were given on the basis of expert knowledge but where this is limited by the evidence base this is shown to comply with the need for transparency. Of the total number of potentially impactful scores within each theme, the evidence limitation was greatest for the air theme (ca. 45%) with biodiversity, carbon/GHG and cultural services also relatively highly scored (30-40%). 'Soil' and 'Regulatory' services were the themes least impacted by this lack of evidence at < 5%. This information may help guide future priorities with respect to research and evidence requirements for the actions proposed.
19. The most negative outcomes or disbenefits (scored red) were scored for the 'Food and fibre production ES'. A notable number of negative outcomes were also noted for 'Biodiversity', 'Global, regional and local climate regulation', 'Biorisks' and 'Resilience to drought' ES.
20. When Management Bundles Tier-1 are explored for these negative outcomes, 'Livestock measures' and 'Climate measures' had high level of negative scores (10-15%).
21. In the cultural services theme, a surprising number of negative outcomes were scored for the 'Creation of public rights of way (PROW)' and 'Geodiversity' actions. This suggests important trade-offs to be considered when considering adoption of these actions.
22. These results can be explored further by examining the results for Management Bundles Tier-2. For the environmental services theme, 'Livestock management / feeding and watering' had a particularly high level of negative scores (23%). This reflects the high risk of a potential trade-off which increases efficiency of agriculture create for other ES and should be considered when applying at scale in the landscape.
23. When exploring individual actions, the following 4 actions had more than 50% scores showing as trade-offs / disbenefits:
 - ETPW-043 - restrict beach cleaning to hand cleaning of inorganic waste
 - ECAR-020 - extend grazing season for cattle
 - ECPW-243 - drill double heads into arable crops
 - EHAZ-056 - modify or remove in channel structures (weirs and sluices).

In some cases, these are down to a single score being made which was coded as red (ETPW-043) whilst in others there are multiple red scores (12 for ECAR-020). E action and their scores should be checked individually as both single and multiple disbenefits could be relevant depending on the specific location and context.

4.8.4 Defra Priority Themes

25. Of the potentially high impactful actions, 72% were in themes prioritised by Defra with little difference between the different themes. This suggests that actions proposed by Defra for priority areas were in general scored as potentially impactful.

4.8.5 Most impactful actions selected by the Team

26. Defra requested key actions to be identified by the environmental services teams which they considered fundamental for reversing environmental degradation (including restoration and improvement). The teams identified a total of 154 actions representing c.20% of the original list of actions provided by Defra (which were further enhanced by the teams). These identified actions are provided in full in the IA report.
27. An analysis of overlap between these actions across the thematic teams indicate that of the 154 actions identified by the thematic teams as fundamental to reverse environmental degradation (including restoration and improvement):
 - No actions were identified by more than 3 thematic teams
 - 2 actions were identified by 3 thematic teams. These were:
 - ECCM-025C – Plant Hedgerows (Habitat Creation/Hedgerows). Teams were Carbon &GHG, Soil and Biodiversity
 - ECPW – 171 – Use very low inputs on permanent grassland (Soil Management and Protection). Teams were: Air Quality, Carbon & GHG and Biodiversity.
 - 15 actions were identified by 2 teams. The combinations of themes in which these actions sit were perhaps unexpected with actions identified by ‘Biodiversity’ and ‘Soil and Carbon & GHG’ the most co-identified whereas perhaps ‘Water’ and ‘Soil’ would have been more expected to co-identify the same actions (Table 4b).
 - The Management Bundle Tier-1 with the greatest number of co-identified actions was ‘Soil management and protection’ (Table 4c) which was also one of the Management Bundles Tier-1 which was co-identified by three thematic teams or more. This suggests soil actions are considered by several of the teams as some of the fundamental to take to reverse environmental degradation.
 - The remaining actions were identified by 1 team only.
28. The selection of actions by the environmental services thematic teams contrasts with the evidence of the most impactful actions across multiple ES identified in the IA table (see section 4.8.6). The IA indicated that many actions (83 in total) have high potential impact (amber or green 2 or 3 *) across 3 or more environmental services themes. Furthermore, a total of 20 actions have potentially high impact across 4 or more environmental services themes, 6 actions for 5 themes and 1 actions for 6 environmental services themes.
29. This apparent disconnect between the selection of actions by the expert teams and the IA suggests that expert teams focus on actions which particularly target specific issues relating to their topics when asked to do so without moderating their assessment to take account of the more generalised high impact i.e. co-benefits across multiple themes. This should be taken into consideration when asking experts for their advice going forward i.e. the question asked should be explicit as to whether co-benefits should be taken into account.

4.8.6 Top scoring actions across multiple themes and ES

30. The top scoring actions with the highest potential impact across 5, or all of the 6, environmental services themes are listed below together with the number of potential dis-benefits in parentheses (i.e. the number of red colour codings).

Action code	Management Bundle Tier 1 / Tier 2
ECPW-291C	Habitat creation / water bodies and buffer zone (2 reds)
ECAR-032	Habitat creation / agroforestry (1 red)
ECCM-024C	Habitat creation / woody features (3 reds)
ECCM-048	Habitat creation / woodland (2 reds)
ECCM-074C	Climate measures / climate change and adaptation (<i>Plant</i> bioenergy crops) (4 reds)
ECCM-074EM	Climate measures / climate change and adaptation (<i>Enhance or manage</i> bioenergy crops) (4 reds)
ETPW-092	Soil management and protection / tillage (no reds)

31. The list is clearly dominated by actions which sit in the Management Bundle Tier-1 of 'Habitat creation' involving woody species or new bodies and buffer zone within the freshwater system. Whilst 'Creation of bioenergy crops' scored highly for multiple theme delivery, there was also significant number of trade-offs as indicated by the high number of red scores.
32. When cultural services are included, more than 139 actions (compared to 83 for environmental actions alone and 2 actions identified by the teams) delivered potentially positive impactful outcomes for more than 3 themes. A total of 128 actions had no amber or green 2* or 3* scores (compared to 239 for environmental services alone).

4.8.7 Conclusions

The cultural services theme (which includes both cultural and regulatory services) was generally scored as more impactful (20-65% of all scores provided) relative to the environmental services theme (20-40%). Within these themes, the proportion of the more potentially impactful scores were highest for the cultural, biodiversity and soil ES (all > 50%).

When the environmental and cultural services themes were combined, the management bundles at Tier-2 level to 'Maintain and restore cultural heritage sites' and 'Natural regeneration' scored the highest (> 60%) for most impactful scores. It is interesting to note the potential value for both environmental and cultural services themes of 'Natural regeneration' which may not be a well-recognised phenomenon and deserves further exploration.

At the Management bundle Tier-1 level, 'Habitat creation' actions represent 6 of the top 10 bundles with the highest proportion of scores (ca. 60-80%) with potentially more impactful actions.

'Habitat creation' was also found to be the management bundle with the most consistent potentially impactful scores across multiple ES (i.e. the high number of scores were spread across multiple ES) particularly when these included 'woody species' or 'creation of freshwater bodies'. As habitat creation is one of the most fundamental changes which can be made this is perhaps not surprising but it is interesting to note the overall high scores when combining both the environmental and cultural services themes.

Trade-offs or disbenefits were scored highest for management bundles those relating to 'Food and fibre production', 'Livestock management' and 'Climate measures' and for outcomes in the themes of 'Biodiversity', 'Global, regional and local climate regulation', 'Biorisks' and 'Resilience to drought' ES. This suggests important potential trade-offs for other environmental outcomes when climate or agricultural efficiency is being targeted.

Soil actions are the least uncertain and contextually dependent whilst actions for Carbon & GHG are some of the most uncertain and contextually dependent.

Overall, this analysis represents only an initial probe into the richness of the evidence captured by the teams and further analysis is likely to reveal further insights to inform selection of actions for the ELM schemes in future iterations.

5 DISCUSSION, CAUTIONARY COMMENTS AND RECOMMENDATIONS

The outcomes of many actions were identified as being context dependent i.e. it depended where and how the action was carried out. Improved access to independent advice regarding best practice would be beneficial to secure optimum outcomes going forward. To ensure outcomes are realised as intended (and the risk of unintended impacts are reduced) there is a need for more widespread advice and guidance to be made available to land managers as many actions have contextual dependencies and / or need to be done according to best practice for outcomes to be fully realised.

The team noted that whilst localised effects may be small in scale they can be important for specialised species and/or where hotspots of environmental degradation are having a significant impact. Scores reflect this adjustment in many cases.

The issue of connectivity is more complex than often proposed and has conflicting evidence in the literature. For example, creating corridors can create barriers for some species and can also have other dis-benefits e.g. convergence of water runoff can increase flood risk. Spread of disease along corridors is another example of a potential disbenefit.

The team recognised the importance of creating appropriate plans (e.g. the action 'Create a Woodland Plan') but it was also recognised not all plans lead to action and therefore the score for these actions are always scored 'Green' but contextually dependent 'T' as outcomes depend on the plan being implemented. Linked actions should always accompany the creation of such activities.

Most actions result in winners and losers if a full assessment of all outcomes is considered as land is under intense competition for a wide range of outcomes and any change will result in:

- displacement or a shift between agricultural production and environmental outcomes;
- and/or a switch in habitat suitability for different taxa (this issue results in many amber codes and some 'D' codes for the biodiversity ES where different taxa will have different responses for an individual action);
- and/or a change in access or landscape aesthetics which may be perceived differently by different groups.

There is a need for transparency where these trade-offs are likely to happen when future pathways and scenarios are being explored and final decisions made.

Longer term outcomes of improved resilience were not assessed by all teams with the exception of assessment of a few indicators requested for the Water and Biodiversity themes. So many other factors are likely to contribute to this issue in the long term which require a more focussed assessment.

Overall, evidence can take different forms such as comparisons before and after the action has been implemented, comparisons between paired systems and/or comparisons across gradients of variable implementation of an action. In addition, many different indicators are often reported and at variable scale

of the action (within fields, between fields, between farms or across larger spatial survey units, such as 1km grid squares).

The lack of uniformity of ongoing, independent research and monitoring data recording these metrics means that evaluation of the impact of management interventions in practice, in real schemes and at both field and landscape scale, is not universally available. Evidence is often limited to small-scale and short term (i.e. < 4 years) trials and experiments under controlled conditions which limits the assessment of broader landscape outcomes, their variability between years and issues of displacement. Greater effort to create an improved evidence base is urgently needed which is consistently and routinely updated and synthesised using approaches as described here capturing co-benefits and trade-offs across multiple ES.

Finally, the team emphasise that the outcomes of several actions will take many years if not decades to be fully realised. This is specifically relevant for habitat creation actions and for many other ecological and carbon sequestration outcomes. Air quality and greenhouse gas emission reductions can be more rapid. Soil and water flow / quality outcomes are variable depending on the specific outcome and indicator – some outcomes can be rapid (e.g. control of erosion), others more long term (e.g. overall soil health). Long term commitment beyond the usual scope of many land management payment agreements may be needed therefore to realise many outcomes. Indeed, many actions (and their intended outcomes) are reversible: permanence and longevity cannot be assumed without ongoing management and support.

6 RECOMMENDATIONS FOR FUTURE REVIEWS AND ASSESSMENTS

This IA has demonstrated the approach can provide a highly effective approach to create an accessible and integrated approach to the review of many actions and the complexity of their potential impact across multiple services. We recommend Defra adopt the approach and provide a rolling programme to update the evidence it contains.

We also recommend Defra review and potentially consolidate actions across Defra policy teams to increase efficiency of future reviews and implementation as the process moves forward. We recommend that our assignment of all actions into Management Bundles by the team could provide a useful structure to support this process.

Due to the urgency of the evidence review, there was insufficient time for systematic reviews and therefore the reviews relied on the knowledge of the team of the peer reviewed and grey literature with some rapid additional checking of recent reports and papers. This limitation of the review process was clearly explained and understood by Defra.

We recommend the commissioning of regular updates of this review and IA to ensure an adaptive and agile approach can be taken going forward. This should include:

- a) regular updates and improvements to the reference database of over 2,400 sources, expert reviews and the IA. Ideally this should follow a systematic approach rather than rapid expert approach adopted here due to time constraints. This ongoing review process will increase confidence and ensure payments and other incentives are well supported by the whole community
- b) review of new actions also need to be included as new innovative management practices become available
- c) additional commissioning of research to fill evidence gaps identified here

This approach would recognise outcomes may change: as climate change accelerates; ensures early adoption of new technologies; decisions keep pace with land management systems which are in a constant

state of flux; and new evidence is continually becoming available from the research community (although this latter does require a more consistent funding base).

A review and consolidation of actions across Defra policy teams to increase efficiency of future reviews and implementation. Our assignment of all actions into Management Bundles by the team could provide a useful structure to support this process.

Seeking of agreement between the research and policy community of a standard minimum set of indicators for all future studies of actions and their impact on the full range of ES as this would greatly improve the evidence base of future reviews.

ANNEX-A: KEY ACTIONS PROVIDED BY THE ENVIRONMENTAL REVIEW TEAMS WHICH THEY CONSIDERED FUNDAMENTAL FOR REVERSING ENVIRONMENTAL DEGRADATION (INCLUDING RESTORATION AND IMPROVEMENT)

Theme 1: Air Quality

Key actions for improving air quality include:

Whole process tools:

- ECPW-004 Nutrient Management Plan

Farm infrastructure management:

- ECAR-027: Use improved livestock housing+ infrastructure to reduce emissions (e.g. ammonia scrubbers and biotrickling filters to mechanically ventilate housing) unless regulated
- ECPW-152: Keep poultry litter dry (through storage/covering, maintaining drinkers) and regularly removing litter using cleaning belts where not applicable under BAT environmental permitting regs.
- ECAR-024 Wash and scrape fouled collecting yards after each use except where farms are subject to the provisions of the Industrial Emissions Directive
- ECAR-001: Cover slurry, sludge, and digestate stores where business is not regulated under IED,
- ECPW-123: Install/ maintain roofing over livestock yards, manure, slurry and silage stores

Fertilisers use

- ECCM-010 and ECCM-011: Acidify slurry and digestate during spreading where business is not regulated under IED
- ECPW-115: Switch to efficient / precision fertiliser application machinery (e.g. trailing hose, trailing shoe or injection, GPS)
- ETPW-246: Switch to liquid application of fertiliser
- ECPW-171: Use very low inputs on permanent grassland
- ECCM-006: Replace urea and Urease Ammonium Nitrate (UAN) fertiliser with ammonia nitrate fertiliser for nitrogen applications
- AQ-04: Use fertiliser with urease and nitrification inhibitors
- ECCM-077: Use of urease inhibitors with urea fertilisers
- ECCM-078: Use of polymer coated urea (slow release)

Reducing outdoor emissions with vegetation and stock numbers

- ECPW-156C: Plant trees and shrubs around point-source polluters
- ECAR-033C: Create shelter belts (tree, woodland, scrub, and hedgerow) with appropriate species composition near sensitive habitats
- Free range poultry/pigs in woodland (AQ-01)
- Extending cattle grazing season (ECAR-020)
- Reduce stocking density or remove livestock grazing where likely impacts on sensitive habitats and species (aquatic and terrestrial) ECAR-035 (local AQ impact only)

Theme 2: Mitigation of GHG emissions

Strong evidence was found for GHG reduction benefits in the following areas:

- ECAR-004 Increase the capacity of farm slurry and manure stores to improve timing of slurry applications

Evidence clearly shows the seasonal effect on utilisation of slurries on land, driven mainly through changes in plant uptake. This indicates that there can be substantial benefit to storing slurry and applying at appropriate times.

- ECCM-063 Monitor energy consumption and implement targets
- ECCM-061 Create and use an energy consumption optimisation plan

Correct monitoring and management of energy on-farm can significantly reduce energy use (and hence GHG production)

- ECPW-115 Switch to efficient/precision fertiliser application machinery

Precision application reduces GHG emissions through improved resource use efficiency and a reduced overall use of artificial fertiliser.

- ECAR-015 Replace nitrogen fertiliser application by using clover in pasture or arable cropping systems

This factor can substantially reduce GHG emissions associated with artificial fertiliser production, provided that plants receive enough nutrients from clover and animals have enough to eat to maximise growth rate.

- ECCA 033C&M Manage/enhance or create coastal habitats to compensate for losses to climate change as part of a coastal management plan

Evidence shows that certain coastal environments can capture large amounts of carbon. Creating habitat can substantially increase this.

- ECCM-013 Active diet and feed planning management to match animal requirements:

Diets should be optimised for every animal. The overall impact on GHG emissions is very large, assuming that the diet enables the animal to grow quickly to finish.

- ECPW-146 Use phase feeding of livestock

Phase feeding is effective at reducing GHG emissions, but not as effective as active diet planning as it is not as precise.

- Improve Animal Health

High animal health improves feed utilisation and improves speed of growth, reducing GHG emissions to finish.

- Deliver Farm Animal Genetic Improvement

Genetic improvement can have a very large effect on GHG emission through improved efficiency of use of feed resulting in reduced consumption of animal feed.

Evidence was found for a moderate GHG reduction benefit in the following areas:

- ECAR-001 Cover slurry, sludge, and digestate stores where business is not regulated under IED

Covering stores reduces immediate release of GHG factors, but the gases are usually then released at application.

- ECAR-006 Dilute slurry to improve soil infiltration, coupled with irrigation
- ECPW-131 Separate slurry and digestate (liquid and solid) and store separately

Key actions to incorporate in the mitigation of GHG emissions. *Limited to no evidence was found for GHG reduction benefits in the following areas:*

- ECCM-014: Use low-intensity grazing systems using biodiverse sward mixtures
- ECPW-137 Export manure and slurry
- ECPW-141 Use of ad lib feeding systems
- ECPW-171 Use very low inputs on permanent grassland
- ECPW-173 Use no fertiliser
- EHBE-227 Maintain genetic diversity by rearing rare breed livestock
- ETPW-156 Replace grazing of sheep with cattle grazing, particularly on limestone habitats

Theme 3: Soil conservation and soil health

The key actions in the ELMS Sustainable Farming Incentive (SFI) for soil conservation and soil health include:

- ETPW-205C - Create flower-rich and species rich grass margins, field corners, and plots (also ETPW-038 - Create/ manage/ enhance buffer strips)
- ECCM-028 - Manage temporary grassland reseeding frequency (the benefits assume that reseeding frequency is reduced)
- ECPW-249 - Reduce grazing and stocking rates when soils are wet to avoid soil compaction
- Soil management and protection

Soil compaction management

- ETPW-223 - Assess soil structure and plan how to avoid and alleviate soil damage and compaction (soil management plan)

Cover cropping

- EHAZ-007 - Use cover crops (and similar actions: ECPW-279, ECPW-002 and ECPW-095)

Other additional options:

- ECPW-044C - Create targeted woodland
- ECCM-025C - Plant hedgerows

Systems action - Advanced

- ECPW-232 - Avoid growing crops with high risk of nutrient losses (e.g. field vegetables) in fields with high risk of soil erosion or close to sensitive sites

However, consider increasing the flexibility of this action. One option could be to convert the land to permanent grassland at the highest payment rates. An alternative could be to put in mitigation methods such as buffer strips, tied ridges, additional headland tramlines, mulches and grassed waterways if higher risk crops are to be retained, e.g.:

Manure and mulch management

- EHAZ-113 - Use mulches and organic matter to increase the water retention capacity of soil

Cover cropping

- ETPW-251 - Use grass waterways in crops with high risk of soil erosion and run off (e.g., field vegetables)

Drainage, irrigation and wastewater /drainage

- ECPW-270 - Use cultivations / shaping of beds in potatoes and vegetable crops to direct water into beds and reduce run off e.g. angled tines, Creyke roller (also ECPW-271 - Use tied ridges (dammer dykes) in row crops)

Local Nature Recovery:

- EBHE-164C - Create wetland habitats
- ECPW-022C - Create species-rich grassland habitats

Landscape Recovery:

- ECCM-030 - Restore/ manage upland and lowland peatlands including blanket bog and raised bog
- ECCM-030B - Raise water levels in areas of farmed peatland and adapt farming systems accordingly
- ECCM-039 - Restore areas of farmed peatland to wetland

Theme 4: Water

The key actions for water quality include:

- ECPW-170 Fence off rivers, streams, lakes and ponds from livestock to prevent bankside erosion, reduce nutrient input and faecal contamination, and prevent poaching
- ECPW-103 Construct bridges for livestock and machinery crossing watercourses
- ECPW-042 Create/ enhance/ manage riparian buffer strips
- ECPW-002 Minimise bare soil to reduce soil loss e.g. cover crops, crop residues, trees coppice etc
- ECPW-232 - Avoid growing crops with high risk of nutrient losses (e.g., field vegetables) in fields with high risk of soil erosion or close to sensitive sites

The Farming Rules for Water require farmers and land managers to use nutrient management planning, store manures safely and ensure that manures and fertilisers are not spread at times when there is a high risk of water pollution. Compliance with the Farming Rules for Water is a statutory requirement, so it is not appropriate to include duplicate nutrient management actions in SFI.

The following actions have the potential to reduce peak river flows and reduce flooding risk.

- EBHE-212: Create/ maintain raised water level areas by appropriate installation and operation of water level controls
- ECCA-008: Create/ enhance/ maintain high flow storage reservoirs
- ECPW-202: Use controlled drainage system
- EBHE-164C : Create wetland habitats
- ECPW-059: Reconnect rivers with floodplains
- EHAZ-052: Use land for temporary flood storage
- ECCA-014: Create/ enhance/ maintain swales

In addition to reducing peak flows in river systems these actions can provide other benefits including improving bio-diversity and water quality by reducing nitrate, microbial pathogen and sediment and phosphorus losses. However, management practices implemented to slow water movement downstream are likely to increase the risk of flooding upstream which will take land out of agricultural production.

Theme 5A: Biodiversity - Cropland

Key actions to incorporate in land management schemes. *Strong evidence was found for moderate to large biodiversity benefits* across multiple taxa and ecosystem services (e.g. pollination, pest control):

- Sow and manage wildflower / pollen and nectar strips and patches to provide a diversity of flowers with a range of flowering times and seasons (actions ETPW-116, ETPW-205C, ETPW-205EM).
- Create and manage grass buffer / contour strips and beetle banks with diverse vegetation structure (EBHE-117, ETPW-207).
- Create suitable habitats for beneficial insects (crop pollinators, natural enemies of crop pests) to live near cropped land, including sites for overwintering, breeding and feeding (ETPW-238).
- Extended over-winter stubbles followed by a one year fallow left to regenerate naturally or sown with seed mixes rich in pollen and nectar for insects, and seed resources for farmland birds (Arable01, part of ETPW-229).
- Fallows left to regenerate naturally or sown with seed mixes rich in pollen and nectar for insects, and seed resources for farmland birds (Arable02, part of EHAZ-024).
- Plant trees and shrub species appropriate to the region as hedges, in-field strips (agroforestry) and patches (e.g. action EBHE-303).
- Include short-term herbal and legume leys in the arable crop rotation (ECPW-032, ETPW-202).
- Provide unsown fallow plots / areas for ground-nesting birds, invertebrates and rare arable plants (ETPW-200x).
- Leave unharvested cereal headlands (ECPW-264).
- Unvegetated, ploughed fallow (natural regeneration) for one year to promote rare arable plants and support insects, birds and mammals (Arable 02).
- Annually cultivate field headlands and leave unsown to promote rare arable plants (Arable 03).
- Encourage beneficial insects into the centre of arable fields by sowing in-field strips with wildflowers to provide refuge habitat and flower resources (unpublished data from [ASSIST programme](#)).

Key actions to incorporate in land management schemes, with good evidence for moderate biodiversity benefits for some taxa and ecosystem services relating to biodiversity, in Cropland agricultural systems:

- Sow cover crops (EHAZ-007).
- Apply Integrated Pest Management (IPM) (e.g. action ECPW-231).
- Use companion cropping to promote natural pest control, support pollinating insects and wider biodiversity (ECPW-031).
- Use intercropping to promote natural pest control, support pollinators and biodiversity (ECCM-071)
- Establish trap crops to reduce pest prevalence (edge of field) (ETPW-233).
- Reduce nitrogen fertiliser application by undersowing cereal crops with clover or growing arable crops in a permaculture of clover (ECAR-015).
- Use low input cropped margins with reduced inputs of pesticides and fertilisers (ETPW-240).

Strong benefits for Cropland biodiversity but reviewed under Biodiversity 5D Systems:

- Provide feeding areas to support the lifecycles of wild birds (e.g. wild bird seed mix) (ETPW-260x).

Promoting large-scale benefits for biodiversity in arable landscapes

This is particularly important to ensure the right habitat is created in the best location for wildlife within intensively farmed arable landscapes as they are depauperate in semi-natural habitats, with acute competition for land to produce food profitably and efficiently:

- Farm facilitation clusters
- Spatial planning tools
- Monitoring outcomes of habitat creation and knowledge sharing on arable farms

Theme 5B: Biodiversity - Grassland

1. Widespread grazing/livestock management of grasslands

- Create and use a grazing plan including stocking rates; monitor and adjust in line with grass productivity (especially where there are multiple graziers) (ETPW-157)
- Reduce grazing and stocking rates when soils are wet to avoid soil compaction (ECPW-249)
- Graze and cut grass later when fibre content higher (to slow digestion in ruminants) (ECPW-245)
- Relocate sheep veterinary treatment areas and pens to appropriate locations (ECPW-257)

2. Locally targeted grazing/livestock management of grasslands

- Use low-intensity grazing systems using biodiverse sward mixtures (ECCM-014)
- Reduce stocking rate (grazing) to restore structure and flowering, maintain ground cover, and reduce poaching (ETPW-104)
- Manage timing of grazing and select livestock type to allow flowering and seed return, and control competitive and invasive species (ETPW-106)
- Replace grazing of sheep with cattle grazing, particularly on limestone habitats (ETPW-156)
- Use low intensity mixed livestock grazing (ETPW-105)
- Manage localised grazing pressure (ETPW-150)
- Maintain water supplies to support grazing (e.g. during management/restoration of heathland) (ETPW-098)
- Control grazing on sand dunes (ECPW-083)

3. Widespread mowing and soil management of grasslands

- Adapt mowing or first grazing dates on improved or semi-improved grassland (Grassland_01)
- Use mowing techniques to reduce mortality (Grassland_01)
- Enhance/manage wildflower/legume rich swards (ECPW-237EMy)
- Enhance/manage grasslands to benefit invertebrates (EHAZ-010Z)
- On meadows, make field-dried hay and minimise haylage and silage (ETPW-101)
- Enhance or manage permanent grasslands (EHAZ-010Y)
- Use very low inputs on permanent grassland (ECPW-171)
- Aeration of soils in grassland situations to remove surface compaction / capping especially from sheep grazing (ECPW-039)

4. Locally targeted grassland sward/soil/input management

- Enhance and manage locally distinctive flower rich/hay meadows using traditional techniques (EBHE-214EM)
- Enhance or manage species-rich grassland habitats (ECPW-022EM)
- Control cutting of grasslands to promote flowering and structure of target species, where appropriate (ETPW-115)
- Enhance/ manage in-field vegetation including grass, scrub, trees (ECPW-237Cy)
- Raise water levels in areas of farmed peatland and adapt farming systems accordingly (ECCM-038)*

5. Locally targeted grassland creation

- Create species-rich grassland habitats (ECPW-022C)
- Create wildflower/legume rich swards (ECPW-237EMx)
- Create in-field vegetation including grass, scrub, trees (ECPW-237Cx)

* In cases where peatland soils, currently drained and used for arable or grassland are converted to permanent grassland with water levels raised seasonally or permanently and used for appropriate grazing

Theme 5C: Biodiversity - Semi-natural habitats

Many of the actions for semi-natural habitats are quite generic (where specific action numbers are not included below) and further detailed specification is required to achieve successful outcomes.

Habitat Creation/enhancement

Limited to strong evidence was found for moderate to large biodiversity benefits across taxa and ecosystem services for the creation/restoration of the following semi-natural habitats (and the multiple actions associated with these). It should be noted that the 'success' of actions was often highly dependent on land use history and location, and evidence of success was often lacking due to insufficient time for habitats to become established or restored.

- Creation of coastal habitats inter-tidal and saline/specifically saltmarsh (within coastal management plans)
- Creation of heathland (EPCW-176C)
- Creation of species rich/locally distinctive flower rich meadows (EPCW-022C, EBHE-214C)
- Creation of ponds, water bodies and wetlands
- Creation/enhancement of woodland (in particular, targeted, floodplain and ghyll woodland) and by natural regeneration
- Creation of wood pasture (EBHE-205C)
- Create buffer zones around ancient woodland (ECCM-051C)
- Create targeted scrub (EBHE-203C)
- Create woody features (trees outside of woodland, shelter belts, along water courses)
- Create/manage/enhance wetland habitats including fen, blanket bog, wet heath (including creating appropriate hydrological conditions)
- Restore peatland vegetation (ECCM-033)
- Create/enhance/manage floodplain/water meadows (ETPW-016C, ETPW-036EM)
- Create riparian habitats (ECPW-291C)

Habitat management/enhancement/restoration

Limited to strong evidence was found for moderate to large biodiversity benefits across taxa and ecosystem services for the following actions designed to manage semi-natural habitats. As with actions above, the success of actions depends of specific management and context, with sites needing to be managed individually.

- Control grazing on sand dunes (EPCW-083)
- Use rare breeds for conservation grazing (EBHE-226)
- Off-winter livestock or reduce winter grazing on upland and mountain heath (ETPW-142)
- Re-naturalise river catchments (multiple actions)
- Restore/ manage ancient woodland with native broadleaf species (EBHE-198)
- Planted ancient woodland restoration (EBHE-196)
- Manage deadwood (ECCM-053)
- Use of continuous cover forms of woodland management (ECCA-028, ECCM-054)
- Enhance/manage veteran trees (preserve and maintain) (ECCM-056) including in parks and gardens (EBHE-307)
- Enhance/manage targeted scrub (EBHE-203EM)

Locate slurry stores away from sensitive habitats and avoid spreading organic manures close to them (ECAR-034, ECAR-036)

Theme 5D: Biodiversity - Integrated System-Based Actions

Note that these interventions should be considered together with those from Biodiversity Themes 5A-C, because some assignments to categories are somewhat arbitrary and many are considered here because they can be implemented in both arable and pastoral systems, for example. Interventions with landscape-scale outcomes will often depend on local- or farm-scale constituent effects, but will require landscape-scale implementation to achieve full benefits. Farm-scale benefits will also scale up, but not necessarily disproportionately.

Landscape-scale outcomes

6. Coordinated wildlife management planning

- EBHE-187 Create a landscape appraisal of the holding in the context of the local area to identify key characteristics that will inform integrated implementation of actions to conserve and enhance the landscape character; EBHE-182 Create and use a wildlife management plan; ETPW-198 Use targeted habitat management for species with highly specialised requirements.
- Any intervention will benefit some species and be neutral or negative for others, sometimes dependent upon the scale of implementation, so planning within and across land-holdings is critical to optimise outcomes for suites of target species.

7. Creation of woodland and woody features

- ECCM-048 Create woodland on a large scale, ECPW-071 Create, enhance or manage floodplain, woodland, ECPW-071C Create floodplain woodland.
- As the native climax vegetation, broadleaf woodland provides critical semi-natural habitat for native species, as well as landscape connectivity.
- It is important to note that woodland creation needs landscape-level coordination to deliver benefits for woodland specialists, while avoiding negative consequences for open-habitat specialists.

8. Provision of winter bird food

- ETPW-260x Provide feeding areas to support the lifecycles of wild birds (e.g. wild bird seed mix).
- Monitoring and evaluation to preclude unintended negative consequences is critical, but this is nevertheless the most practical general approach for filling the key need for man priority farmland birds, with potential impacts well beyond farm boundaries.

9. Provision of invertebrate habitats

- ETPW-205C Create flower-rich and species rich grass margins, field corners, and plots); ETPW-271 Create/ manage/ enhance buffer strips to encourage natural predators and species diversity; ETPW-260y Provide feeding areas to support the lifecycles of pollinators (e.g. pollinator seed mix).
- Supporting priority invertebrates and those that may provide pollination and pest predation services should have strongly positive impacts both within and across farms.

Farm-scale outcomes

10. Creation of permanent grasslands

- EHAZ-010X Create permanent grasslands
- Increasing habitat heterogeneity and creating a novel habitat that supports a diverse fauna will be strongly positive in arable areas, although less valuable in areas that are already rich in grassland.

11. Creation and management of hedgerows

- ECCM-025C Plant hedgerows; ECCM-025EM enhance/ manage hedgerows.
- Hedgerows provide critical resources for a broad range of taxa, benefits that are multiplied by sensitive and effective vegetation management to enhance structure and to promote flower and berry resources.

Theme 6: Carbon sequestration

Above-ground C sequestration (2 and 3 * amber and green)

ECCM-048	Create woodland on a large scale
ECCM-024EM	Plant or manage trees outside of woodlands, including shelterbelts
ECCM-025C	Plant hedgerows
ECAR-032	Create agroforestry systems
ETPW-019	Use coppice for bank reinforcement
Carbon_01	Conservation of long-established woodlands with existing high carbon stocks
Carbon_04	Enrichment of woodland growing stock for carbon sequestration
ECCA-024	Create new areas of habitat adjacent to existing habitat patches to increase patch size and help sustain more viable species populations.
ECCM-024C	Plant trees outside of woodlands including shelterbelts

Below-ground C sequestration (2 and 3* amber and green)

ETPW-081CX	Create salt marsh
Carbon_01	Conservation of long-established woodlands with existing high carbon stocks
ECCM-030	Restore/ manage upland and lowland peatlands including blanket bog and raised bog
ECCM-038	Raise water levels in areas of farmed peatland and adapt farming systems accordingly

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