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Environmental Management on Farmland

An integrated ecological, social and physical approach to monitoring environmental change and land management effects: the Wales Axis II Monitoring and Evaluation Programme

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Summary

The Welsh Government has commissioned a comprehensive new ecosystem monitoring and evaluation programme to monitor the effects of Glastir, its new land management scheme, and to monitor progress towards a range of international biodiversity and environmental targets. A random sample of 1 km squares stratified by landcover types will be used both to monitor change at a national level in the wider countryside and to provide a backdrop against which intervention measures are assessed using a second sample of 1 km squares located in areas eligible for enhanced payments for advanced interventions. Modelling in the first year will forecast change based on current understanding, whilst a rolling national monitoring programme based on an ecosystem approach will provide an evidence-base for on-going, adaptive development of the scheme by Welsh Government. To our knowledge, this will constitute the largest and most in-depth ecosystem monitoring and evaluation programme of any member state of the European Union.

Key words: Agri-environment, biodiversity, climate change mitigation, soil and water quality, cultural services, economics, ecosystem services

Introduction

This project will provide a scientifically-rigorous approach to the monitoring and evaluation of the new sustainability land management scheme, Glastir. The scheme replaces a fragmented array of existing schemes and pays for the delivery of specific environmental goods and services aimed at combating climate change, improving water and soil management, maintaining and enhancing biodiversity, managing and protecting the Welsh landscape including the historic landscape and creating new opportunities to improve access and increasing the area and management of woodlands. It adopts an ecosystem approach recognising the potential co-benefits and trade-offs individual intervention measures may have on our Natural Capital and the Ecosystem Services that it delivers. Specific elements of the work include monitoring change in biodiversity, soil and water quality, diffuse pollution, climate change mitigation, landscape including historic landscape, access and economics, combined with modelling work to both forecast likely outcomes and help integrate and upscale results. Benefits from the scheme need to be rigorously evaluated to comply with the EC Common Monitoring and Evaluation Framework (CMEF) for the Rural Development

Plan (RDP) for Wales 2007–2013 within one of its four key areas (known as Axes) called "Our Environment and Countryside". A particular emphasis of this Axis and Glastir is to encourage actions that increase environmental sustainability. The project will assess the cost-benefit of impact of specific measures within an ecosystem framework and the wider benefits to society.

It is a novel and highly ambitious project, which will bring together monitoring from different sectors within a hypothesis-led modelling framework that captures our current understanding. The aim is to provide a robust evidence base as an on-going part of the scheme, to allow for fast iterative assessment of outcomes and thus timely adaptation of scheme payments to maximise benefits.

Materials and Methods

Within any ecosystem monitoring programme, there are multiple measures of specific interest and it is essential that the designed survey is good value for money and has sufficiently power and spatial scale to detect changes and trends in these measures and their inter-dependence, enabling trade-offs and co-benefits to be quantified. It is also desirable to develop a sampling unit which will be robust to potential future changes in scheme design from field to farm to catchment to community-based schemes (and back again), depending on political and/or societal pressures. We have selected a 1 km sampling unit which meets these criteria through and also exploits and builds on past survey investments which have used the same sampling unit. In addition, we will exploit the rich array of national datasets to contextualise these 1 km squares where this is required, e.g. using the Land Cover Map to quantify connectivity to landscape features outside the squares, such as woodland and hedgerows, and Digital Elevation Maps and River Flow Networks for catchment boundaries and water resource assessments etc.

One difficulty with investigating the sample size of the 1 km squares required to statistically quantify change statistically and impact of interventions is that the metrics vary over differing scales. Some metrics will have high spatial yet low temporal variability, whereas for others the opposite may apply. Thus, designing a survey to enable detection of changes across time and space for multiple metrics is challenging. We have developed a rolling survey so that we can maximise the number of sites we visit across the national spatial scale whilst at the same time monitoring year-on-year at the national scale, such that changes and trends can be detected cost-effectively. In addition, we maximise the efficiency of field teams by covering as wide a number of ecosystem characteristics as possible within a single visit To ensure sufficient statistical power for most efficient cost we have undertaken a power analysis of the existing 30 year data record from the UK ecosystem-level, integrated monitoring programme called Countryside Survey (Carey *et al*., 2008) using the Wales-only data record (Smart *et al*., 2009). There are little or no data available to test the results of the proposed Glastir intervention measures specifically. The power analysis indicated that a rolling programme of 45 1 km squares per year, revisited every 4 years, should deliver sufficient statistical power to identify stock and change of ecosystem indicators on a 4-year reporting cycle, if the powerful statistical modelling approaches developed for CS are employed. We will repeat this activity within areas specifically targeted by Welsh Government for enhanced payments resulting in a total sample size of 90 1 km squares surveyed each year.

Overall there are three main elements to the evidence-gathering components of the project set within this rolling programme: (a) a modelling framework to forecast changes under low, medium and high uptake scenarios by farmers for selected Glastir measures for priority outcomes, and integrate and upscale results as they are delivered, (b) a national monitoring surveillance programme to quantify on-going change in the countryside and impacts of the All Wales Element (AWE) of Glastir, and (c) a targeted survey to ensure sufficient population of data are obtained from within the areas identified by Welsh Government to receive targeted element (TE) payments for specific agri-environment measures for which a holistic evidence base is lacking (Fig. 1).

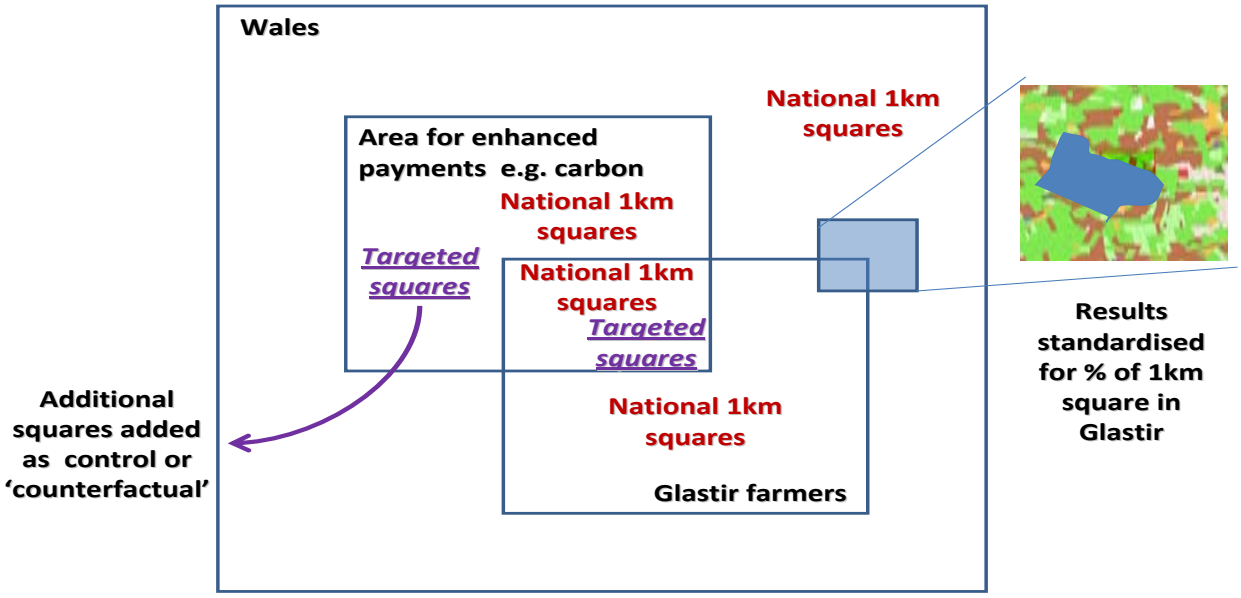

Fig. 1. Schematic illustrating the relationship between the national monitoring scheme and our targeted survey within Wales, targeted areas for enhanced payments and farmers in the Glastir scheme.

For the national monitoring element, a statistically robust, rolling national surveillance programme has been developed, building on methodologies and data from NERC's Centre for Ecology and Hydrology's ecosystem-level monitoring programme called Countryside Survey (CS), which started in 1978 (Carey *et al*., 2008; Norton *et al*., 2012). A Wales-only report was published in 2010 including 30-years of trend information for some aspects of the Welsh environment with implications for ecosystem services reported at a UK level (Smart *et al*., 2009). It is globally unique in adopting an ecosystem approach recording change in plant species, freshwater plants and invertebrates, stream and pond water quality, habitat area, soil quality and linear features, such as stream banks, hedges and walls. This is achieved through a statistically robust sampling design of 1 km squares by a dedicated field team , trained by specialists, with state-of the-art data capture systems, combined with earth observation techniques. We are building on this wealth of data and programme methodology to develop a bespoke, rolling programme for Wales, integrating a range of new social perception and appreciation indicators, visual and historic landscape and access and adding bird and invertebrate monitoring. At the same time, we will ensure full exploitation of a range of other monitoring, modelling and inventory scheme to reduce costs and enhance analysis.

For the targeted survey, additional squares will be selected from areas identified by Welsh Government for enhanced payments for specific measures, e.g. enhanced carbon sequestration, diffuse pollution interventions, habitat creation or protection for specific habitats or species. This will include squares both inside and outside the Glastir scheme to ensure sufficient counterfactuals are available. Monitoring in these squares will be based on the same 4-year rolling programme as for the national monitoring survey and critically, the same full ecosystem level monitoring approach will be followed, by the same survey teams, to enable the full population of both national monitoring and targeted squares to be utilised in any subsequent data analysis.

Data analysis

Rigorous statistical testing of the impact of specific measures and thus scheme impact will be made for the All Wales Element (AWE) as part of the national monitoring surveillance programme comparing change within squares within or outside the AWE scheme against a national average or 'backdrop' and subsets of that data, plus evolution of that change over time (Fig. 2). For the Targeted Element (TE) where enhanced payments are available, statistical comparisons will

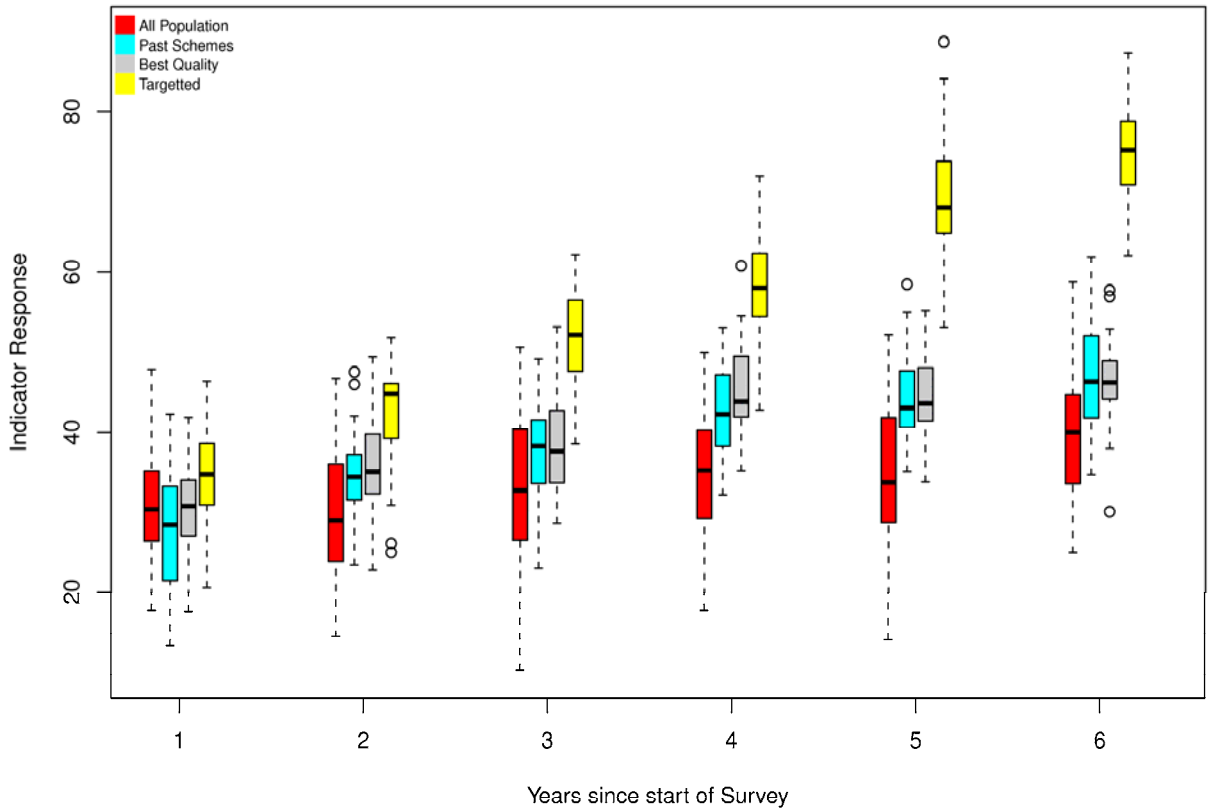

Fig. 2. Potential 'before-after' comparison of hypothetical indicator response from factual and counterfactual monitoring squares in the Wider Wales Countryside (WWC) and Targeted (TS) surveys.

again be made with the national trend data plus with appropriate subsets of this population. If additional control sites have been established to allow a more experimental approach, these will also provide a 'control' (i.e. counterfactual) situation for statistical assessment. We will develop counterfactuals that provide a suitable backdrop against which within scheme measures can be compared, net impact assessed and value for money quantified using a two tier approach:

Development of a national baseline and trend analysis over time

For the biophysical measures, this will be achieved through our national monitoring element that we have termed the 'Wider Wales Countryside' monitoring or WWC rolling programme, extending the sampling approach developed for Countryside Survey and its 30-year data record. This will provide a general assessment of a robust national average or 'backdrop' against which comparisons can be made, as it will include some sites within and outside the AWE of Glastir, as well as sites with contrasting management within Glastir. Due to the stratified random sampling of the WWC survey, there will be no bias as to which habitat types or other environmental or social-economic heterogeneity exists among the sites surveyed within and outside AWE options. Thus fair comparisons can be made (a) against national averages i.e. a generic comparison, (b) between sites with and without given management and (c) by an approach using 'before-after' comparison following the evolution of the two groups over time in our rolling programme.

Research will take into account knowledge of past agri-environmental policy measures, as well as current and possible future changes in policy (particularly in CAP) and the impact of measures flowing from policy arenas as diverse as the Climate Change agenda, rights of way and rural planning regulations. Such contextual information contributes to the definition of baseline conditions and provides a framework around which to build indicators of perceptual change against background flux in a wide ranging policy environment. Identification of counterfactual scenarios must take such baseline and contextual conditions into account as well as accommodating changes in those conditions over time.

Targeted element

For assessment of the Targeted Element (TE) of Glastir, additional targeted squares in our Targeted Survey (TS) will ensure as far as possible, there is a sufficient population of squares to identify the impact of the TE. The WWC monitoring will again provide a broad counterfactual scenario and also a comparison between the AWE and TE components of Glastir. Because of this wide-scale monitoring, counterfactuals can be chosen so that within-scheme measures can be compared directly against national averages, or effectively against averages from corresponding subsets or habitat types. For rare components of the targeted elements of Glastir, the WWC survey may not contain sufficient suitable counterfactuals, e.g. when designing a nationwide unbiased survey, these rare habitats are missed because they represent such a small proportion of the national mosaic. In these instances we will survey additional counterfactual sites. These counterfactual sites will be chosen to be as representative as possible of the targeted sites, hence achieving an adequate control. We propose to do this by choosing a site closest to the targeted site in question in an environmental/social ordination space. This ordination space will be based on, amongst other things, land cover, population density, climate, geographic location, geology, road network density and footpath density. For all of these, data are available nationally across Wales, so every 1 km square can be added to the ordination space. This would ensure that any targeted site has sufficient counterfactuals either from specific additional monitoring or from a subset of the WWC.

Measures, changes and trends between the counterfactual scenarios and the Glastir uptake options will be compared using a generalised linear mixed modelling (GLMM) approach. This allows us to compare non-normally distributed data (e.g. Poisson count data), unlike the more simplistic ANOVA methods, and can also account for non-independence resulting from spatial or temporal autocorrelation. Methods ignoring such dependence would underestimate standard errors leading to false inference on any hypothesis testing. The GLMM approach also allows for the inclusion of both main effects of management and interaction terms, allowing for inter-dependence of management effects and background environmental variation. The significance of individual terms in such models is assessed using standard methods, such as likelihood-ratio tests, comparing information criteria or using the non-parametric bootstrap to resample under the null hypothesis. An example potential interaction arises because the societal benefits from changes in habitat quality will depend on whether access rights permit the public to experience the habitat. Delivery of these robust estimates of change are essential for the economic efficiency, cost effectiveness and distributional effect to be undertaken.

Results

Our legacy datasets and trend analyses from past and on-going monitoring programmes will provide an evidence base for Baseline, Result and Impact indicators. A unique strength of our approach is that messages about the causes and consequences of ecosystem and landscape change can be powerfully expressed based on the integrated links between indicators. For example, simultaneously quantifying change in habitat area with the ecological condition of the area by reference to vegetation, soil and waters indicators provides insights into the ecological 'quality' of the newly recruited versus lost area, as well as the possible driving variables of which just one driver may be Glastir. Planned work will extend this approach into the landscape, social and economic issues. Thus individual work packages will be relevant for a range of Results and all Impact indicators which will be integrated into an ecosystem services framework. Examples of activities, indicators and outcomes are listed below:

Species

Work will involve: recording plant species within random permanently marked vegetation plots and additional random plots for eligible Glastir features; bird territory mapping and

site-map based invertebrate transects; stream kick sampling; stream macrophytes; diatom sampling; topsoil mesofauna and microbial diversity assessments. This will provide Results and Impacts measures indicative of improvement of biodiversity likely to be impacted by agri-environment measures in the wider countryside and their coincidence. This will support reporting for a range of conservation commitments and biodiversity targets, including the Habitats Directive and the Wales Biodiversity Action Plan (which aim to deliver targets set in the Strategic Plan agreed by the Convention on Biological Diversity for 2011–2020). Tested plant species metrics can also be used to quantify impacts of reductions in NO_x and ammonia emissions (estimated from the diffuse pollution work), which cause eutrophication of vegetation and again compromise delivery of biodiversity and conservation targets. This links through to a range of linked policy targets including the National Emission Ceilings Directive and the Gothenburg Protocol 2010 under the Convention on Long Range Transboundary Pollution. More broadly, co-ordinated sampling of such a broad range of biodiversity is unusual and opens many opportunities for investigating co-variation between different groups and the identification of potential proxy indicators.

Habitats

This work package will quantify the creation and loss of habitats both on-going and resulting from Glastir interventions. We will collect data on the extent and condition of habitats (e.g. broad and priority habitats) and landscape features (e.g. hedges) using an existing, GIS system developed for Countryside Survey. Metrics assessing the permeability and functionality of the landscape (e.g. habitat connectivity, habitat diversity) will be derived from field data and using remotely sensed data, e.g. Land Cover Map, Welsh habitat map and aerial photographs. Data from previous Welsh Agri-environment Schemes (AESs) and past Welsh CS data will be used to assess the fit of the proposed data collection system to report on previous AESs. A field-based pilot phase will determine where additional functionality is required for Glastir. By combining data of cover and quality metrics from across other WPs we will also identify High Nature Value areas of farmland and forestry and maintenance of these areas over time and impacts of interventions. Integrating indicators of habitat cover with other biophysical, social and economic metrics will also provide information on avoidance of marginalization and land abandonment and the role of agri-environment measures and payments in this change. Additional datasets on annual and average change forest cover including new planting from the Forestry Commission will also be exploited if available.

Landscape, historic landscape and access

This workpackage will work closely with the Habitats team and focus on physical and historic aspects of landscape quality. Photographs will be taken from pre-selected positions in all sample squares and an assessment of the current status of selected historic features located in sample squares carried out. Integration of a large number of metrics reported by the survey teams including land use, hedgerow length and condition, other linear features and a range of nationally available data, e.g. digital elevation maps, will enable us to develop 3D ‘viewsheds’ from ‘Rights of Way’ to explore the impact and additionality of interventions on accessibility of the landscape, including historic features, to Welsh society, the importance of seasonal change and its overall attractiveness.

Diffuse pollution and climate change mitigation

Activities will exploit a range of modelling, inventory and database tools to report on impacts of interventions on greenhouse gas emissions and diffuse pollution. The main primary dataset will come from a survey of farmer practice with benefits in response to Glastir payments compared to benefits realised from previous AESs that have already quantified using the same survey and modelling approach (Anthony *et al*., 2012). In addition, two greenhouse gas (GHG) accounting tools, a process-based model and the current UK GHG inventory approaches will be compared to

explore their commonalities, suitability and relevance for a range of Welsh Government interests. We will take account of updates in methodologies currently in progress linking through to IACS data and the new rolling Land Cover Map. Data will also provide an evidence base that will contribute towards river basin management planning and reporting under the Water Framework Directive and to the on-going developments of the UK Land Use, Land Use Change and Forestry (LULUCF) and Agricultural Greenhouse Gas Inventories. As there is a critical issue of data limitation in this field, new real-time measurements using eddy covariance equipment will be carried out across Wales on a number of typical farming systems to identify net fluxes of GHG into and out of the systems under a range of soil types, climatic conditions and management.

Soils

Measurements will identify impacts of interventions on a range of topsoil (0–15 cm) quality measures such as soil structure, nutrient status, organic matter, acidity, and biodiversity (mesofauna and microbial). Soil carbon data will also contribute to the evidence base for LULUCF greenhouse gas inventory reporting, with the full suite of measures potentially providing an evidence base should an EU Soils Framework Directive become a reality.

Streams and ponds

Biodiversity assessment of macroinvertebrates, diatoms, macrophytes, and chemical composition of ponds and streams will be integrated with streamside vegetation data, modelled diffuse pollution data and a wide range of national data on landcover, agricultural land-use and water chemistry data within the wider catchment beyond the 1 km square, to identify causal links to a range of drivers including the Glastir interventions. The biological reference condition will be derived using the abiotic environmental data collected in the field entered into existing models: e.g. RICT for stream macro-invertebrates, and LEAFPACS for stream macrophytes. Trends and spatial patterns for ecological quality ratios will be quantified using standard CS statistical methods and integrated with other data.

Economics

This workpackage will focus on economic benefits of intervention measures, with a focus on the impacts of woodlands and capital investments by farmers on their surrounding communities in year 2 and access and recreation in year 4. Linking cost-benefit work to outputs from other work packages will enable the benefits of farmland and forestry payments for ecological quality and function to be assessed. Outputs from the Ecosystem Services workpackage related to changes to a service quantified from the change we record from our monitoring work (both biophysical and social) will provide a basis for establishing benefits, including economic and thus cost-benefit of the additionality of measures. Probability modelling approaches (i.e. Bayesian Belief Networks) will also be adopted, so that further knowledge and uncertainty linking a change we observe to the delivery of the ecosystem service can be included.

Ecosystem services

The aims of this workpackage are to integrate information from all WPs into an ecosystem service framework by linking measurements to service production, and their use, to the likely beneficiaries and whether these are local (e.g. agricultural production), national (e.g. water services) or global (e.g. greenhouse gas emission). To explore the importance of the spatial positioning of measures within the landscape down to a sub-field scale and to enable scenario testing (climate and land management), an ecosystem service analysis tool originally developed in Wales called Polyscape (Jackson *et al*., 2013), now adapted to include climate change scenario and water quality capabilities and called LUCI will be used. The model will be further developed over time to include GHG accounting, improved biodiversity capabilities by inclusion of the Multimove biodiversity modelling tool (Smart *et al*., 2010) and cultural service measurement incorporating valuation, thereby providing a tool that can be used for a range of purposes by end users.

Quality assurance, data security, outreach and reporting

All data, trend analysis and reports will be made available through a web portal and a stakeholder liaison group who will meet with the project management team once every 6 months to help the team understand farmer perceptions of Glastir and how to best communicate the findings from the project to landowners and the wider community. Data security will be a priority, as will effective and rigorous project management, quality assurance and control.

Discussion

The aims of Glastir are focussed on combating climate change, improving water and soil management, maintaining and enhancing biodiversity, managing and protecting the Welsh landscape including the historic landscape and creating new opportunities to improve access and increasing the area and management of woodlands. Through the Glastir interventions, Welsh Government will subsidise farmers for a change in land management practice for goods and benefits to be realised by both current and future generations at local, national, and, in a minor way, global scales. Welsh Government recognize through their spending commitment that the actions of farmers and land owners have value to society, in terms of public goods and services beyond the value received by the farmer in terms of profit derived from maximizing production. Many of these goods and services do not currently have markets or they have markets that are only just emerging. Thus Glastir interventions can substitute and 'purchase' greenhouse gas emission mitigations and biodiversity protection whilst compensating farmers for the reduction in crop or livestock productivity. The key question this monitoring and evaluation programme will ask is: how successful is the Glastir scheme in achieving these public goods and services for the costs incurred? Then, what is the likely outcome in the future and what is the relative effect compared with e.g. other on-going drivers, past schemes in Wales and similar AES elsewhere?

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