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GLASTIR MONITORING & EVALUATION PROGRAMME

FIRST YEAR ANNUAL REPORT

Prepared by CEH on behalf of the Glastir Monitoring & Evaluation Programme Team

Canolfan Ecoleg a Hydroleg
CYNGOR YMCHWIL YR AMGYLCHEDD NATURIOL

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NATURAL ENVIRONMENT RESEARCH COUNCIL

NERC SCIENCE OF THE ENVIRONMENT

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Further copies of this report are available from: GMEP Office, Centre for Ecology & Hydrology, Environment Centre Wales, Deiniol Road, Bangor, Gwynedd, LL57 2UW.

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Glastir yw'r prif gynllun sydd gan Lywodraeth Cymru ar gyfer talu am nwyddau a gwasanaethau amgylcheddol. Pwrpas Rhaglen Monitro a Gwerthuso Glastir (GMEP) yw gwerthuso llwyddiant y cynllun. Drwy gomisiynu'r rhaglen monitro ochr yn ochr â lansio cynllun Glastir, mae modd cael adborth buan ac addasu taliadau i wneud y cynllun yn fwy effeithiol. Mae cynllun Glastir yn cael ei ariannu ar y cyd gan Lywodraeth Cymru (drwy'r Cynllun Datblygu Gwledig) a'r UE, a fydd yn derbyn adroddiad blynyddol am allbynnau GMEP. Bydd GMEP yn rhoi cymorth hefyd i gyflawni amrywiaeth eang o ofynion cenedlaethol a rhyngwladol am ddarparu cofnodion ar gyfer bioamrywiaeth, allyriadau nwyon tŷ gwydr, pridd ac ansawdd dŵr.

Beth yw gwaith y rhaglen?

Mae'r rhaglen yn casglu tystiolaeth ar gyfer pob un o'r pum canlyniad arfaethedig yng nghynllun Glastir: lleihau effeithiau'r newid yn yr hinsawdd; gwella ansawdd dŵr; atal y dirywiad mewn bioamrywiaeth; rheoli coetiroedd yn well; a mwy o fynediad at dirweddau Cymru a chyflwr nodweddion hanesyddol. Cyflawnir llawer o'r gwaith hwn drwy arolwg maes o 330 o sgwariau 1km ledled Cymru, hanner ohonynt mewn ardaloedd â blaenoriaeth lle y mae taliadau uwch ar gael. Caiff y sgwariau 1km eu dewis ar hap o 26 o ddosbarthiadau tir, fel bod cynrychiolaeth dda o dirweddau Cymru. Archwilir y sgwariau dros gyfnod o bedair blynedd ac ailymwelir â nhw wedyn dros y pedair blynedd dilynol. Drwy wneud hyn, cesglir tystiolaeth o newid a bydd yr effeithiau ar fesuriadau o dywydd eithafol mewn un flwyddyn yn cael eu lleihau. Bydd arwynebedd y 'tir Glastir' ym mhob sgwâr a archwilir yn amrywio a chaiff hyn ei ystyried wrth ddadansoddi data. Byddwn hefyd yn cynnwys data o raglenni monitro arbenigol parhaol yn ein dadansoddiadau lle bynnag y bo modd er mwyn defnyddio'r holl adnoddau sydd ar gael. Defnyddir modelau i amcangyfrif canlyniadau disgwyliedig yn y dyfodol fel y gellir addasu'r cynllun yn ôl blaenoriaethau Llywodraeth Cymru (lleihau effeithiau'r newid yn yr hinsawdd ac adnoddau dŵr ym mlynyddoedd un a dau) a sicrhau'r effaith fwyaf posibl o'r cynllun.

Beth yw'r dulliau arloesol?

Rydym yn defnyddio offer moleciwlaidd newydd i ymchwilio i effeithiau cynllun Glastir ar organeddau mewn pridd a thechnolegau lloeren i fonitro cyflwr mawndiroedd, niferoedd y nodweddion coediog bach ac arwynebedd a chyflwr cynefinoedd yng Nghymru. Datblygir dulliau newydd o asesu ansawdd gweledol tirweddau ac o ddiffinio Tir Ffermio sydd o Werth Mawr i Natur, ac adeiledir systemau mesur symudol sy'n cofnodi fflycsau nwyon tŷ gwydr er mwyn mesur allyriadau carbon deuocsid, ocsid nitrus a methan o laswelltiroedd ledled Cymru.

Beth y mae GMEP wedi'i gyflawni yn y flwyddyn gyntaf a beth yw'r prif ganfyddiadau?

Roedd y gwaith yn y flwyddyn gyntaf yn cynnwys treialu dulliau newydd a chwblhau'r arolwg maes cyntaf. Mae modelwyr wedi ymchwilio i'r effaith bosibl o rai taliadau penodol ar ansawdd a llif dŵr, allyriadau nwyon tŷ gwydr a chysylltedd rhwng coetiroedd. Mae'r canlyniadau'n awgrymu bod yr effaith ddichonol o wahanol ymyriadau'n amrywio rhwng 0.1 a 10% o newid ar y raddfa genedlaethol a bod targedu taliadau'n ofodol yn ymddangos yn fwy effeithiol, ond bod llawer yn dibynnu ar y rhagdybiaeth ynghylch arwynebedd y tir ar bob fferm a newidiadau gwirioneddol sydd wedi'u cyflwyno gan ffermwyr. Bydd arolwg o ffermwyr a gynhelir yn 2016 yn darparu mwy o ddata am hyn. Bydd arolygon pellach o ffermwyr yn ymchwilio i'r manteision ehangach o geir o Grantiau Effeithiolrwydd Glastir, i'r rhwystrau rhag derbyn taliadau Coetir Glastir ac yn asesu ôl traed carbon. Bydd gwefan GMEP yn cael ei lansio yn Ebrill 2015 a bydd canlyniadau arolygon maes a rhediadau modelu yn cael eu cyhoeddi arni.

Citizen Summary

What is the purpose of Glastir Monitoring and Evaluation Programme?

Glastir is the main scheme by which the Welsh Government pays for environmental goods and services whilst the Glastir Monitoring and Evaluation Programme (GMEP) evaluates the scheme's success. Commissioning of the monitoring programme in parallel with the launch of the Glastir scheme provides fast feedback and means payments can be modified to increase effectiveness. The Glastir scheme is jointly funded by the Welsh Government (through the Rural Development Plan) and the EU, to whom outputs from GMEP are reported annually. GMEP will also support a wide range of other national and international reporting requirements for biodiversity, greenhouse gas emissions, soil and water quality.

What does it do?

The programme collects evidence for all five intended outcomes from the Glastir scheme; climate change mitigation, improvement to water quality, a halt in the decline of biodiversity, improved woodland management and greater access to the welsh landscape and condition of historic features. Much of this is achieved through a field survey of 330 1km squares across Wales, half of which are focussed on areas prioritised for advanced payments. The 1km squares are selected at random from 26 land classes, ensuring good coverage of the Welsh landscape. Squares will be surveyed over a four year period and then revisited over the following four years, meaning evidence of change will be collected and the effects of a single year's weather extremes are reduced. The area of 'Glastir land' within each surveyed square will vary and this is taken into account during analysis. Data from ongoing specialist monitoring programmes is also included in analysis wherever possible to maximise use of all resources. Models are being used to estimate expected future outcomes so that adjustments can be made to match Welsh Government priorities (climate change mitigation and water resources in years one & two) and scheme impact can be maximised.

What is innovative?

We are using new molecular tools to explore the effects of Glastir on soil organisms and satellite technologies to monitor the state of peatlands, numbers of small woody features and areas and condition of habitat in Wales. New approaches to assess visual quality of landscape and defining High Nature Value Farmland are being developed and mobile measurement systems for recording greenhouse gas fluxes are being built to measure carbon dioxide, nitrous oxide and methane emissions from grasslands across Wales.

What has GMEP achieved in its first year and what are the main findings?

Work in the first year included piloting new methods and completion of the first field survey. Modellers explored the potential impact of some selected payments on water quality and flow, greenhouse gas emissions and connectivity of woodlands. Results suggest the potential impact of different interventions range from 0.1 – 10% change at the national scale and spatial targeting of payments appear to be more effective but much depends on the assumption made about land area per farm and actual changes put in place by farmers. A farmer survey being conducted in 2016 will provide further data on this. Additional farmer surveys will explore the wider benefits of the Glastir Efficiency Grants, the barriers to uptake of the Glastir Woodland payments and will assess carbon footprinting. A GMEP website will be launched in April 2015 where the field survey results and model runs will be published.

Crynodeb Gweithredol

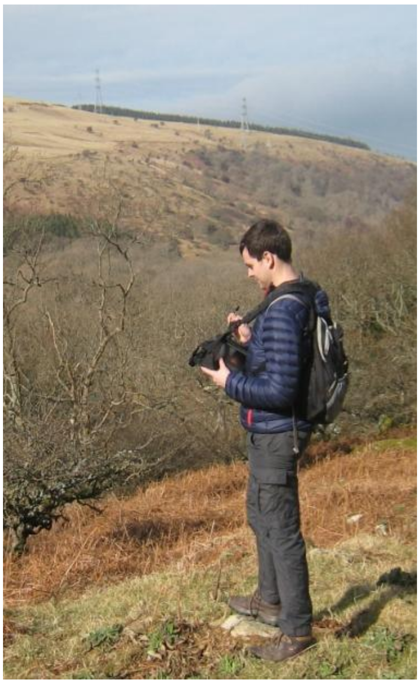
1. Cyflwyno Rhaglen Monitro a Gwerthuso Glastir a'i thîm

Mae Llywodraeth Cymru wedi comisiynu Rhaglen Monitro a Gwerthuso Glastir (GMEP) newydd gynhwysfawr i fonitro effeithiau cynllun Glastir, ei chynllun rheoli tir newydd, ac i gyfrannu, os bydd modd, at fonitro cynnydd tuag at gyrraedd nifer o dargedau cenedlaethol a rhyngwladol ar fioamrywiaeth a'r amgylchedd. Mae hyn yn cyflawni ymrwymiad Llywodraeth Cymru i sefydlu rhaglen fonitro i gyd-redeg â lansio cynllun Glastir. Mae'n gam mawr ymlaen o raglenni monitro blaenorol sydd wedi cyflwyno eu hadroddiadau wedi i'r cynlluniau ddod i ben. Bydd y prosiect yn sicrhau cydymffurfiaeth hefyd â'r gofynion ymestynnol yn Fframwaith Monitro a Gwerthuso Cyffredin (CMEF) y Comisiwn Ewropeaidd ar gyfer y Cynllun Datblygu Gwledig (CDG) i Gymru yn un o'r pedwar maes allweddol (a elwir yn Echelau) sef "Ein Hamgylchedd a Chefn Gwlad". Bydd y canfyddiadau cynnar o GMEP yn darparu adborth buan ar gyfer negodiadau ynghylch cam nesaf y CDG. Bydd y data, y modelau a'r offer a gaiff eu casglu a'u datblygu gan GMEP yn cyfrannu hefyd at gynllunio adnoddau naturiol Cymru mewn ffordd gydgysylltiedig yn y dyfodol er mwyn datblygu economi werdd a gwireddu dyheadau Bil yr Amgylchedd. Bydd y rhaglen ddwy flynedd bresennol yn cael ei hymestyn am ddwy flynedd ychwanegol os cwblheir tasgau'r ddwy flynedd gyntaf yn llwyddiannus.

Mae tîm GMEP yn cynnwys amrywiaeth o sefydliadau sydd ag arbenigaethau gwahanol ar gyfer gweithgareddau, amcanion a chanlyniadau amrywiol y cynllun. Mae'r rhaglen yn cael ei harwain gan Ganolfan Ecoleg a Hydroleg Bangor sy'n cael ei noddi gan Gyngor Ymchwil yr Amgylchedd Naturiol, corff ymchwil cyhoeddus annibynnol. Aelodau consortiwm y prosiect yw ADAS, APEM, Prifysgol Bangor, Biomathematics and Statistics Scotland, Bowburn Consultants, Arolwg Daearegol Prydain, Ymddiriedolaeth Adareg Prydain, Butterfly Conservation, ECORYS, Edwards Consultants, Ymddiriedolaeth Cynefinoedd Dŵr Croyw, Prifysgol St Andrews, Prifysgol Swydd Stafford, Prifysgol Aberdeen, Prifysgol Southampton, a Phrifysgol Victoria yn Wellington, Seland Newydd.

2. Dull gweithredu GMEP

Prif elfen y rhaglen yw arolwg blynyddol treigl a gynhelir ledled Cymru gan ddefnyddio dull ar lefel yr ecosystem. Ymysg pethau eraill, mae'n mesur nifer o agweddau ar ansawdd pridd a dŵr, nodweddion tirwedd, amrywiaeth planhigion a dŵr croyw, a chyflwr nodweddion hanesyddol, ac yn cynnal dau arolwg o bryfed peillio a phedwar o adar, y cwbl wedi'i fapio ar sail mesurau ymyrryd Glastir a'r pum canlyniad lefel uchel sydd wedi'u rhagnodi gan Lywodraeth Cymru. Rhan ganolog o weithgareddau'r rhaglen ar ddadansoddi data a thystiolaeth yw ystyried data o'r gorffennol sy'n dangos effeithiau cynlluniau amaeth-amgylchedd a thueddiadau parhaus. Rhai enghreifftiau o ddata a thystiolaeth o gylch ehangach sydd wedi'u defnyddio yw: data hanesyddol sy'n cael eu dal gan y Ganolfan Cofnodion Biolegol, Ymddiriedolaeth Adareg Prydain ac Arolwg Cefn Gwlad y Ganolfan Ecoleg a Hydroleg. Bydd y defnydd o dystiolaeth a data o gylch ehangach yn hyrwyddo'r gallu i werthuso a hefyd yn darparu cyd-destun hanesyddol hirdymor. Cynhelir rhagor o weithdai gydag amrywiaeth o sefydliadau monitro arbenigol a Cyfoeth Naturiol Cymru ym mlwyddyn 2 i sicrhau bod yr holl dystiolaeth a data a gasglwyd drwy raglenni monitro cyfredol a blaenorol mewn cylchoedd ehangach yn cael eu defnyddio.



Hyd y gwyddom, hon fydd y rhaglen fwyaf a manylaf ar gyfer monitro a gwerthuso ecosystemau yn holl Aelod-wladwriaethau ac Awdurdodau Rheoli'r Undeb Ewropeaidd. Ymhlith y nifer mawr o elfennau newydd y mae: dull monitro ar lefel yr ecosystem fel y gellir dadansoddi effeithiau gwrthbwyso a chyd-fuddion; rhaglen monitro dreigl sy'n rhedeg ochr yn ochr â'r cynllun i roi adborth buan; cyfraniad o bwys drwy fodelu; cynnwys dadansoddiadau cymdeithasol ac economaidd; cymhwyso dulliau newydd, e.e. techneg foleciwlaidd i fesur bioamrywiaeth mewn pridd, data lloeren i fonitro cyflwr mawndiroedd a thyrau fflwcs symudol i fesur nwyon tŷ gwydr. Bydd pob un o'r rhain yn helpu i hybu effeithlonrwydd a gwella ansawdd data, a sicrhau bod pob math o effeithiau o gynllun Glastir ar dirwedd Cymru, ffermwyr a chymdeithas ehangach yn cael eu cofnodi.

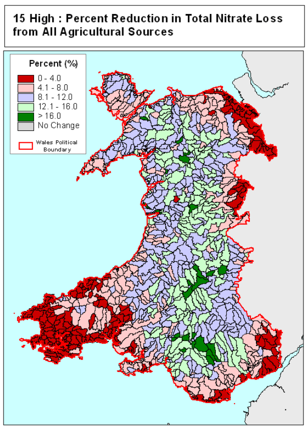
Mae'r adroddiad hwn yn disgrifio prif gyflawniadau tîm GMEP ym mlwyddyn ei sefydlu rhwng Medi 2012 ac Awst 2013, ac mae prif ganlyniadau'r flwyddyn gyntaf wedi'u dangos isod. Mae cyflwyniad mwy helaeth i waith GMEP ym Mhennod 1.

3. Canlyniadau Blwyddyn 1 a sylwadau

3.1 Gwaith modelu i ymchwilio i ganlyniadau ar gyfer y dyfodol o gynllun Glastir

Canlyniadau'r flwyddyn gyntaf:

- Pennu paramedrau ar gyfer pedwar model sy'n ymdrin â'r effeithiau o fesurau ymyrryd y cynllun ar lygredd gwasgaredig, cysylltedd cynefinoedd, dal a storio carbon, amrywiaeth planhigion ac erydu a'r effeithiau gwrthbwyso a'r synergeddau ar eu cyfer.
  - Ymchwiliwyd i chwe mesur ymyrryd gwrthgyferbyniol sy'n cynnwys ymyriadau 'eang a bas' a rhai 'cyfyng a dwfn'. Y rhain oedd: tir pori parhaol heb fewnbynnau (AWE15), plannu coridor ar lan nant (AWE9b), rheoli pori ar dir agored (AWE41a), ymestyn ymyl coetir (AWE 24), rheoli rhedyn (AWE 44) a chadw sofl dros y gaeaf (AWE 28).
  - Edrychwyd ar dri senario lle'r oedd derbyniad isel, canolig ac uchel i'r ymyriadau a chymerwyd bod y ffermydd a oedd yn cymryd rhan yn gweithredu'r opsiynau i'r graddau mwyaf posibl h.y. ar yr holl dir perthnasol ar y fferm. Dylid nodi bod hyn yn debygol o roi goramcangyfrif arwyddocaol o'r canlyniadau. Nid oedd data ar gael ar y pryd am arwynebedd y tir a oedd wedi'i gynnwys mewn cytundebau. Hefyd, ni aseswyd maint yr allyriadau y gellid bod wedi'u dadleoli i wledydd eraill.
- Rhai o'r canlyniadau yw:
  - At ei gilydd, roedd rhagnodiadau unigol o dan Glastir sy'n arwain at ostyngiad ym mewnbynnau'r fferm a niferoedd cyffredinol y da byw mewn cynefinoedd ar ffermydd (h.y. AWE 9b, AWE 28, AWE 41a, AWE 24) yn sicrhau gostyngiadau cenedlaethol bach (<1%) mewn allyriadau o lygryddion o ewtroffeiddio a llygryddion gorfodi hinsawdd.
  - Mae hyn yn gwrthgyferbynnu â chanlyniadau ar lefel safleoedd sy'n dangos bod modd cyrraedd 80%. Gyda'i gilydd, mae'r lefelau cyfranogi disgwyliedig yng nghynllun Glastir ac arwynebedd y tir addas sydd ar gael ar gyfer ymyriadau yn cyfyngu canlyniadau ar raddfa genedlaethol. Er enghraifft, roedd maint y gostyngiad lleol mewn llygryddion sawl gwaith yn fwy mewn Dalgylchoedd â Blaenoriaeth lle y mae arwynebedd eang o dir perthnasol sydd wedi'u targedu ar gyfer ymaelodi â'r cynllun. Gan nad yw'r ffigurau ar gyfer y dalgylchoedd hyn yn uwch na'r cyfartaledd cenedlaethol, mae'r effaith gyffredinol ar ganlyniadau cenedlaethol yn fach.
  - Cafwyd gostyngiadau cenedlaethol o ran trwytholchi nitradau ac allyriadau o ocsid nitrus a methan o 5 i 10% hefyd drwy atal gwrteithiau nitrogen a lleihau'r gyfradd



Modelu ADAS WDP-EMF o'r gostyngiad yng nghanran allyriadau nitradau o dan y senario ar gyfer cyfranogi 'Uchel' yn y cynllun ar gyfer effaith 'Tir Pori Parhaol heb Fewnbynnau' stocio ar yr arwynebedd mwy o laswelltir wedi'i wella (AW15).

- Roedd y canlyniad ar gyfer ansawdd dŵr o'r ddau fodel a oedd yn modelu llygredd gwasgaredig wedi rhoi canfyddiadau tebyg ac roedd hyn yn ategu ein hyder yn y canlyniadau.
- Gall y newid yn yr ôl troed carbon cyffredinol (sy'n cynnwys allyriadau nwyon tŷ gwydr corfforedig) ar gyfer ffermydd penodol fod yn gymaint â 24%.
- Roedd y ddau opsiwn ar gyfer coetir (ymestyn ymyl coetir a phlannu coridor ar lan nant) ill dau'n cynyddu'r tir a oedd ar gael i rywogaethau ffocol llydanddail 'generig' rhwng 3 a 12%, yn lleihau'r potensial ar gyfer llifogydd oddi ar dir rhwng 1 a 9%, yn cynyddu'r gyfradd storio genedlaethol ar gyfer carbon 0.4%, ac yn lleihau maint y pridd a erydir a'r ffosfforws a gyflenwir o gymaint â 15% am fod llai o gysylltedd rhwng tir sy'n agored i erydu ac afonydd a llynnoedd.
- Cafwyd rhagamcan o newidiadau cadarnhaol yn addasrwydd cynefinoedd ar gyfer 75% o'r 21 o rywogaethau planhigion a fodelwyd a chynnydd sylweddol tuag at gyrraedd sgorau arfaethedig ar gyfer addasrwydd cynefinoedd o fewn 10-23 blynedd ar ôl ymgymryd â'r opsiynau.

Mae'r defnydd hwn o fodelau'n elfen newydd iawn yn GMEP. Maent yn werthfawr o ran ymchwilio i'r newidiadau y gallwn eu disgwyl o ymyriadau Glastir ar sail ein gwybodaeth bresennol, a'r cyfnodau ar gyfer y newidiadau hynny, oherwydd gellir cael oedi sylweddol ar lawr gwlad. Defnyddir modelau hefyd i asesu newidiadau anodd eu mesur fel allyriadau nwyon tŷ gwydr, ac i gynyddu graddfa neu ddehongli canfyddiadau o arolygon maes fel rhai ar gyfer ansawdd dŵr o fewn y dirwedd/dalgylch ehangach. Yr hyn sy'n hollbwysig i sicrhau dull trwyadl wyddonol o ymchwilio yw bod y modelau hefyd yn rhoi fframwaith damcaniaethol wedi'i seilio ar y ddealltwriaeth wyddonol orau sydd ar gael er mwyn rhoi prawf ar ddata o'r arolwg maes. Yn fyr, roedd y gwaith modelu cychwynnol ar senarios yn dangos:

- Y buddion cymharol fach o rai ymyriadau o'u hystyried ar raddfa genedlaethol, a hynny'n gwrthgyferbynnu â buddion mawr ar lefel y safleoedd.
- Bod lleoliad yr ymyriadau yn y dirwedd yn hollbwysig.
- Mae'r allbynnau o'r modelau hyn hefyd yn dangos y cyd-fuddion dichonol o ymyriadau fel plannu coed os byddant wedi'u lleoli'n addas ar gyfer bioamrywiaeth, ansawdd dŵr a charbon.
- Dylid nodi bod y canlyniadau o natur hirdymor, yn enwedig ar gyfer bioamrywiaeth. Mae hyn yn awgrymu bod angen posibl am ymrwymiad hirdymor i ymyriadau i wireddu'r holl ganlyniadau.
- Y gwerth posibl mewn modelau ar gyfer diwallu amrywiaeth o anghenion o ran cofnodi a datblygu polisi, yn amrywio o'r rhestr nwyon tŷ gwydr i gynllunio gofodol, yn ogystal â Glastir.

Yn olaf, dylid nodi bod canlyniadau'r modelau'n dibynnu ar nifer o ragdybiaethau ynghylch ymgymryd ag ymyriadau a'u gweithredu. Rhagwelir y bydd y canlyniadau a geir yn rhoi goramcangyfrif mawr o'r effaith lle y mae rhwystrau rhag gweithredu opsiwn penodol, e.e. colli cynhyrchiant o ganlyniad i atal gwrteithio neu droi tir pori yn goetir. Drwy ddatblygu ac adeiladu'r modelau tra chymhleth hyn, bydd modd cynnal efelychiadau pellach i ymchwilio i'r potensial mewn ymyriadau newydd ar gyfer rhaglenni yn y dyfodol gan gynnwys y data o'n Harolwg Arferion Ffermydd a fydd yn rhoi mwy o wybodaeth i ffermwyr am y ffordd orau o weithredu ymyriadau ar lawr gwlad a gwybodaeth fwy manwl am gytundebau gan Lywodraeth Cymru. Cyflwynir y canlyniadau ym mhenodau 2 a 5.

3.2 Yr arolwg maes

Canlyniadau'r flwyddyn gyntaf:

- Dylunio arolwg cenedlaethol hyblyg ar sail ystadegol gadarn, wedi'i seilio ar raglen dreigl ac uned samplu a ddewiswyd fel ei bod yn cynnwys yr Elfen Cymru Ehangach (WWC) a ddefnyddir i amcangyfrif llinellau sylfaen, tueddiadau cenedlaethol ac ar gyfer adroddiadau cenedlaethol ar gynllun Glastir, ac Elfen wedi'i Thargedu (TC), sydd â chysylltiad penodol â'r meysydd a nodau â blaenoriaeth yng nghynllun Glastir.
- Cwblhawyd yr arolwg yn llwyddiannus yn y flwyddyn gyntaf. Archwiliwyd 60 o sgwariau 1km ar gyfer amrywiaeth eang o briodweddau ecosystem gan gynnwys adar a phryfed peillio, priddoedd a rhagnentydd, nodweddion hanesyddol a chyflwr llwybrau troed, gwrychoedd a choetiroedd. Rhai enghreifftiau o raddfa'r arolwg yw:
  - 1726 o leiniau botanegol wedi'u harchwilio.
  - 1500 o samplau pridd wedi'u codi o 300 o leiniau i gyd-fynd ag arolwg botanegol parhaol sy'n defnyddio dulliau addas ar gyfer dadansoddi ffisegol, microbaidd, cemegol, carbon ac infertebrata.
  - 2043 o nodweddion pwynt wedi'u pennu a'u hasesu.
  - 4 arolwg ar wahân o adar (Ebrill – Gorffennaf).
  - 2 arolwg ar wahân drwy gerdded trawsdoriad 120km o hyd i gyfrif rhywogaethau o loynnod byw, grwpiau o wenyn a phryfed hofran ynghyd ag archwiliadau wedi'u hamseru o fewn 9000m^2.
  - 790 km o nodweddion llinol (gwrychoedd, glannau nentydd etc).
  - Yr arolwg cyntaf o'i fath i fonitro'r canlynol yr un pryd: infertebrata dŵr croyw, diatomau (mewn nentydd yn unig), macroffytau, cynefinoedd ffisegol, cyfansoddiad cemegol dŵr, mewn pyllau a nentydd.
  - 47 o nodweddion hanesyddol i asesu eu cyflwr.
  - 960 o luniau tirwedd wedi'u tynnu.
- Roedd perchnogion tir wedi rhoi caniatâd i fynd ar 82% o'r arwynebedd tir cyfan (daliadau sydd o fewn y cynllun a daliadau eraill) o fewn y 60 sgwâr 1km. Ym mlynyddoedd 2-4 bydd 90 o sgwariau'n cael eu harchwilio bob blwyddyn er mwyn cael arwynebedd samplu cyfan o 330km^2. Erbyn blwyddyn 4, y rhaniad rhwng daliadau sydd o fewn y cynllun a daliadau eraill o fewn yr arwynebedd samplu hwn fydd tua 50 / 50 a disgwylir y bydd tua 4500 o ffermydd wedi ymaelodi â chynllun Glastir. Bydd hyn yn sicrhau bod sail wrthffeithiol gadarn i werthuso effaith y cynllun.
- Cafodd 13 o syrfewyr maes eu recriwtio a'u hyfforddi a datblygwyd meddalwedd bwrpasol ar gyfer arolygon maes.
- Darparwyd rheolaeth ar ansawdd gan syrfewyr annibynnol a groeswiriodd 12% o holl sgwariau'r arolwg.
- Roedd syrfewyr wedi casglu data drwy ddefnyddio llechen ddurol a oedd yn mewnforio, yn trosglwyddo, ac yn cwblhau data'r arolwg yn awtomatig gan greu copïau wrth gefn.
- Rhoddwyd mesurau bioddiogelwch trwyadl ar waith i ddiogelu rhag clefydau planhigion ac anifeiliaid. Holwyd ffermwyr hefyd i weld a oeddent yn gwybod am unrhyw glefydau mewn planhigion neu goed ac nid oedd y syrfewyr yn mynd ar dir a oedd wedi'i heintio.

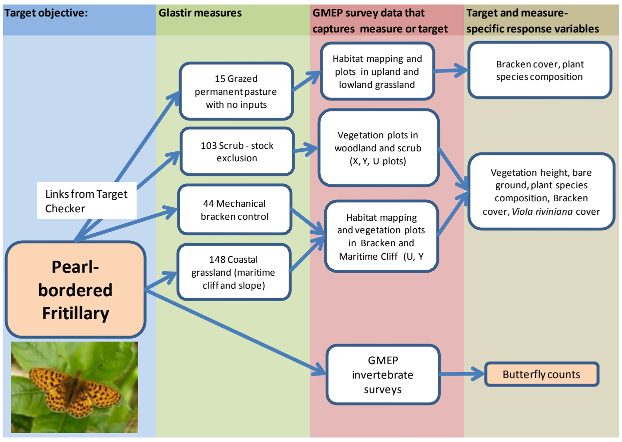
Mae’r arolwg maes yn rhan ganolog o raglen GMEP. Y nod yw darparu’r brif sylfaen dystiolaeth ar gyfer newid sy’n digwydd yng nghefn gwlad (Elfen Cymru Ehangach) y gellir ei defnyddio i werthuso effaith ymyriadau o dan gynllun Glastir drwy Elfen wedi’i Thargedu (TC). Dewisir ardaloedd samplu’r Elfen wedi’i Thargedu ar sail y strwythur pwyntiau ar gyfer Glastir Uwch, felly maent yn adlewyrchu’r blaenoriaethau ar gyfer canlyniadau Glastir. Drwy ddefnyddio’r dull hwn, ynghyd â dull integredig o gasglu data wedi’i seilio ar yr ecosystem, gall yr arolwg newid dros amser yn ôl y newid ym mlaenoriaethau Llywodraeth Cymru yn ystod 4 blynedd cyntaf y rhaglen. Dewiswyd uned samplu gyffredin o 1km x 1km ar gyfer y ddwy elfen er mwyn cael uned samplu ymarferol a fyddai’n rhoi’r gallu i werthuso canlyniadau rhwng lefel y rhywogaeth a lefel y dirwedd. Nid ydym wedi defnyddio dull sy’n paru ffermydd ag unedau oherwydd y cyfyngiadau a fyddai’n codi, gan gynnwys tra-dyblygu a bias. Archwilir y sgwariau 1km ar sail rhaglen dreigl ac ailymwelir â nhw bob 4 blynedd. Mae nifer o fanteision ynglŷn â hyn: (i) defnyddio adnoddau yn y ffordd fwyaf effeithlon, (ii) canfod amrywiadau o flwyddyn i flwyddyn, (iii) darparu data yn gynnar er mwyn profi a phennu paramedrau modelau fel bod modd darparu adborth buan i Lywodraeth Cymru, a (iv) sicrhau bod effeithiau gwrthbwyso a chyd-fuddion yn cael eu cofnodi gan na fyddai hynny’n digwydd pe na byddai arolygon ar wahân e.e. o adar, planhigion a phridd, yn cael eu cynnal yn yr un lle. (Canlyniadau ym mhennod 3)

3.3 Tueddiadau parhaus o ran bioamrywiaeth, datblygu dangosydd ar gyfer Tir Ffermio sydd o Werth Mawr i Natur a chipio data o’r tu allan i raglen GMEP

Canlyniadau’r flwyddyn gyntaf:

- Drwy ddadansoddi data o gofnodion biolegol o rywogaethau a gasglwyd yn ôl y cyfle gan y Ganolfan Cofnodion Biolegol, cafwyd bod 10 o blith 18 o grwpiau tacsonomig wedi dirywio o 1970 ymlaen a bod yr 8 grŵp tacsonomig sy’n weddill wedi cynyddu. Mae’r ffigurau ar gyfer rhywogaethau cyffredin yn well na’r rheini ar gyfer rhywogaethau prin o ran y newid yn y tebygolrwydd o arsylwi ar rywogaeth rhwng 1990 a 2000. Mae dadansoddi o’r math hwn yn darparu data ar gyfer adrodd ar nifer o dargedau cenedlaethol a rhyngwladol ar gyfer bioamrywiaeth, ond yr unig ddata a gesglir yw’r rheini lle y mae cofnodi gan wirfoddolwyr yn cynnwys sampl ddigon manwl. Aseswyd is-set ddethol o rywogaethau â blaenoriaeth lle’r oedd digon o ddata ar gael, a’r rheini wedi’u rhestru o dan Ddeddf yr Amgylchedd Naturiol a Chymunedau Gwledig 2006. Roedd hyn yn cynnwys rhywogaethau y credwyd eu bod o bwysigrwydd rhyngwladol i gadwraeth, h.y. wedi’u rhestru’n rhywogaethau o dan fygythiad ar Restr Goch Fyd-eang IUCN (IUCN 2013), ar fwy na 50% o Restrau Coch rhanbarthol yr UE neu ar restrau dibynadwy eraill. Roedd rhywogaethau wedi’u cynnwys os oedd Cymru’n cynnwys mwy na 25% o’i phoblogaeth yn yr UE neu drwy’r byd a bod eu poblogaeth wedi dirywio 25% neu fwy yn y 25 mlynedd diwethaf. Hefyd roedd rhywogaethau sydd wedi dirywio o fwy na 50% yng Nghymru yn y 25 mlynedd diwethaf wedi’u cynnwys. Yn olaf, roedd rhywogaethau wedi’u cynnwys os oedd amgylchiadau eithriadol yn eu bygwth, e.e. bod eu cwmpas yn gyfyngedig iawn, yn ôl gwybodaeth a gafwyd gan arbenigwyr tacsonomig.

- Cwblhau'r fersiwn gyntaf o Ddangosydd Rhestr Gwylio ar gyfer tueddiadau mewn rhywogaethau yng Nghymru.
- Cafwyd nifer o gyfarfodydd â rhanddeiliaid i drafod y cysyniad o Dir Ffermio sydd o Werth Mawr i Natur a sut y gallem ddatblygu dangosydd yn Rhaglen Monitro a Gwerthuso Glastir. O ganlyniad i hyn, cafwyd nifer o benderfyniadau ar gwmpas y gwaith a thermau a chynigion ar gyfer gwaith yn y dyfodol. Cynullwyd gweithgor bach a oedd yn cynnwys CEH, BTO, RSPB a CNC a chytunwyd ar y camau nesaf, gan gynnwys coladu setiau data a chynnal profion ar safleoedd adnabyddus, a chwblau dadansoddiad wedyn i ymchwilio i gyd-ddigwyddiad gwasanaethau ecosystemau eraill a chyfalaf naturiol.



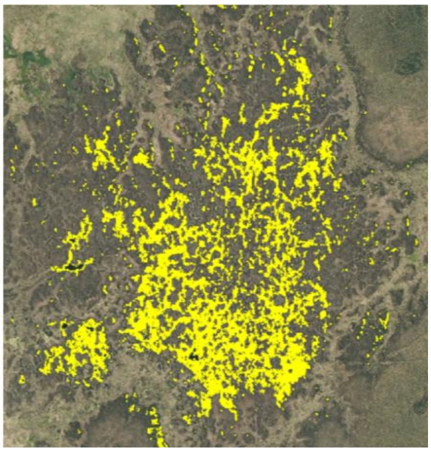
Gwahanol ddulliau a ddefnyddir gan GMEP i fesur effaith ymyriadau ar y fritheg berlog

- Cychwyn gwaith i allosod data o'r sgwariau 1km gan ddefnyddio data BRC a dulliau synhwyro o bell.
- Mae CEH wedi cydweithio â Llywodraeth Cymru i drwyddedu a chaffael nifer o'r > 50 o setiau data sylfaenol presennol gan wahanol sefydliadau a chyrff llywodraeth gan gynnwys CNC, CCGC, Asiantaeth yr Amgylchedd, yr Arolwg Ordnans, NSRI, Cadw, Defra, Intermap ac eraill. Gellir disgrifio'r data hyn o dan yr 8 pennawd canlynol: Cyd-destunol; Cynefinoedd; Priddoedd; Ardaloedd Dynodedig; Hydroleg; Hanesyddol; Daliadau Fferm; Glastir a Chynllluniau Blaenorol. Mae'r data hyn yn rhoi mwy o wybodaeth am y cyd-destun ar gyfer dadansoddi yn y dyfodol ac, o'u hychwanegu at y data sydd gan dîm GMEP (e.e. Arolwg Cefn Gwlad ac Arolwg BTO o Adar Nythu), maent yn darparu tystiolaeth ychwanegol o newid parhaol. Un elfen bwysig yn y gwaith ym Mlwyddyn 2 fydd cwrdd â grwpiau cadwraeth arbenigol i ddod o hyd i ddata ychwanegol ar lefel rhywogaethau er mwyn pennu effeithiau o fesurau o dan gynllun Glastir.
- Mae holl setiau data GMEP yn cael eu dal ar rwydwaith diogel mewn ffolderi cyfrinachol, a dim ond nifer bach o staff yn y tîm gwybodeg sydd â'r hawl i'w gweld. Os bydd angen i unrhyw aelod arall o staff weld y setiau data, rhaid iddo gyflwyno cais i reolwyr data a llofnodi cytundeb trwyddedu data. Wedyn gellir caniatáu iddo weld data gofodol drwy gronfa data ofodol GMEP (SDE), gan roi'r hawl i ddarllen yn unig ar gyfer y setiau data y gofynnwyd am eu gweld. (Pennod 4)

3.4 Data llinell sylfaen newydd ar gyfer allyriadau nwyon tŷ gwydr o laswelltiroedd yng Nghymru ac ar gyfer cyflwr mawndiroedd

Canlyniadau'r flwyddyn gyntaf:

- Prynwyd dau dŵr fflwcs symudol i fesur nwyon tŷ gwydr er mwyn cael mesuriadau amser real ar gyfer carbon deuocsid, ocsid nitrus a methan. Prin yw'r synwyryddion tirwedd amser real eraill o'r fath yn y DU (dim ond un synhwyrydd N_2O arall sydd yn y DU) a, hyd y gwyddom, nid oes yr un arall sy'n cynnwys y tri synhwyrydd mewn un system symudol.
- Yn ogystal â hyn, rydym yn defnyddio'r synwyryddion



Enghraifft o fapio mawn noeth gan BGS drwy dynnu lluniau o'r awyr ar y cyd â synwyryddion newydd arloesol sy'n mesur lleithder priddoedd yn y dirwedd gan fod lleithder mewn pridd yn ffactor mor bwysig o ran sbarduno fflycsau nwyon tŷ gwydr. Mae'r holl gyfarpar wedi'i brynu (sylwer bod cyfnodau arweiniol hir ar gyfer prynu'r eitemau cyfarpar arbenigol hyn) a dechreuwyd comisiynu ac integreiddio'r cyfarpar yn y systemau ôl-gerbyd symudol i'w defnyddio yn y maes yn Ebrill 2014.

- Mae metrigau newydd i fonitro mawn yn cael eu datblygu, gan gynnwys dulliau synhwyro o bell i fesur erydiad mawn a dulliau isotopig. Rydym wedi prosesu delweddau radar o arwynebedd o 4460km^2 yng ngogledd Cymru a oedd yn cynnwys gorgorsydd yn yr ucheldir ar gyfer y cyfnod rhwng 1993 a 2000. Dangoswyd ei bod yn bosibl canfod a mapio symudiadau tir bach ym mhridd mawnogydd yr ucheldir er mwyn darganfod tueddiadau tymor byr a thymor hir. Ail ddull a ddefnyddiwyd oedd dadansoddi lluniau o'r awyr i ddangos arwynebedd o 0.63km^2 o fawn noeth o arwynebedd cyfan o bridd organig o 473km^2; mae hyn yn cyfateb i 0.13% o'r arwynebedd cyfan o fawn a aseswyd. Drwy'r dulliau hyn, ynghyd â dull isotopig newydd sy'n defnyddio llystyfiant yn fesur procsi, y nod yw pennu dull gwrthrychol a gwell o asesu effaith ymyriadau o dan gynllun Glastir ar gyflwr mawn.

Am nad oes data digonol ar gael na chonsensws gwyddonol ynghylch lefelau presennol yr allyriadau o nwyon tŷ gwydr o laswelltiroedd yng Nghymru, mae ansicrwydd o hyd ynghylch pa laswelltiroedd sy'n storio neu'n rhyddhau carbon ar hyn o bryd. Defnyddir y tyrau fflwcs symudol ar dir sy'n rhan o gynllun Glastir a thir nad yw'n rhan ohono i greu sylfaen dystiolaeth newydd gadarn ar gyfer y math pwysig hwn o ddefnydd tir yng Nghymru. Rhagwelir y bydd y data a gaiff eu casglu drwy fonitro drwy raglen GMEP yn rhoi dealltwriaeth well o lawer i ni o ymyriadau'r cynllun a ffyrdd effeithiol o ddylunio polisi er mwyn lliniaru effeithiau'r newid yn yr hinsawdd ac y bydd hyn o gymorth hefyd i ddatblygu dulliau a data gwell ar gyfer Defnydd Tir, Newid Defnydd Tir a'r Rhestr Nwyon Tŷ Gwydr Coedwigaeth. Mae'r sefyllfa'n debyg o ran mawndiroedd gan nad oes methodoleg empirig wrthrychol ar gyfer asesu'r tueddiadau presennol yng nghyflwr mawndiroedd (ac felly diogelwch y carbon y maent yn ei storio). Felly bydd anawsterau ynghylch mesur effeithiau o ymyriadau o dan gynllun Glastir os na ddefnyddir technolegau newydd o'r fath. (Pennod 3)

3.5 Coetiroedd

Canlyniadau'r flwyddyn gyntaf:

- Cytunwyd ar brotocolau maes, a'u rhoi ar waith, ar gyfer cofnodi cynefinoedd a rhywogaethau coetiroedd yn sgwariau arolwg GMEP. Mae hyn yn cynnwys mapio cynefinoedd coetir, y prif rywogaethau, gwybodaeth reoli, defnydd tir, plotiau llystyfiant mewn llecynnau bach a mawr yn y coetir ac ar hyd nodweddion llinol coediog, a chofnodi adar a phryfed peillio.
- Casglu data esboniadol i ddadansoddi newidiadau ym maint a chyflwr coetiroedd ac effeithiau ar newidynnau eraill sy'n dangos ymateb o ran yr amgylchedd a bioamrywiaeth.
- Mapio ymyriadau Glastir ar sail mesuriadau GMEP a Chynllun Coetiroedd Cymru.
- Defnyddio'r 3 model i ymchwilio i ragolygon o effeithiau 2 o ragnodiadau Glastir ar gyfer coetiroedd (sydd wedi'u disgrifio o dan 3(i) uchod).
- Ymchwilio i fetrigau ar gyfer cysylltedd cynefinoedd er mwyn datblygu dulliau o asesu effeithiau mesurau o dan gynllun Glastir ar gysylltedd cynefinoedd mewn coetiroedd.

Cyhoeddwyd strategaeth Llywodraeth Cymru 'Coetiroedd i Gymru' yn 2001 a'i diwygio yn 2012. Mae'n hyrwyddo dulliau o ddylunio a rheoli coetiroedd sy'n darparu amrediad eang a chytbwys o wasanaethau ecosystemau. Datblygwyd set o 23 o ddangosyddion i fesur cynnydd tuag at gyrraedd yr 20 canlyniad lefel uchel sydd wedi'u disgrifio yn y strategaeth 'Coetiroedd i Gymru'. Mae'r rhain yn cynnwys mesurau sy'n ymwneud â chyrhaeddiad, arwynebedd coetiroedd o wahanol fath (trefol, fferm etc.) a'r newid ynddynt, amrywiaeth cynefinoedd a'u rhywogaethau, dulliau cynaliadwy o reoli coetir, cydbwysedd carbon, iechyd coed, buddion lleol o goetiroedd, hygyrchedd, gwerth pren a rheoli dŵr. Mae'r rhain yn cwmpasu amrywiaeth o fuddion cymdeithasol, economaidd ac amgylcheddol. Bydd nifer o'r agweddau hyn yn cael eu disgrifio yn arolwg GMEP a fydd hefyd yn mesur effeithiau o ymyriadau Glastir gan gyfrannu at yr asesiad ehangach o'r strategaeth. Bwriedir cydweithio â Cyfoeth Naturiol Cymru ym Mlwyddyn 2 i gysoni data'r rhaglen GMEP â data am goedwigaeth a choetiroedd o ffynonellau eraill. (Pennod 7)

3.6 Effeithiau ar dirwedd Cymru a'r amgylchedd hanesyddol

Canlyniadau'r flwyddyn gyntaf:

- Adeiladu setiau data 3D manwl ar gyfer pob un o'r 60 sgwâr 1km^2 sy'n cynnwys topograffi tirweddau a nodweddion tirwedd ar raddfa fach sy'n cyfyngu'r gallu i weld y dirwedd (e.e. coed mawr, terfynau fel gwrychoedd, adeiladau, coetiroedd).
- Adeiladu setiau data 3D ar fanylder o 5m ar gyfer arwynebedd 3 x 3km o gwmpas pob un o'r 60 sgwâr 1 km.
- Canfod y rhwydwaith Hawliau Tramwy cyfan ar gyfer gwahanol fathau o ddefnyddwyr (cerddwyr, beicwyr, marchogion, cerbydau bach, cerbydau mawr) ar gyfer pob un o'r 60 sgwâr.
- Coladu cofnod gweledol o bob un o'r 60 sgwâr o luniau o bwynt penodol a dynnwyd yn ystod yr arolwg maes (16 ym mhob sgwâr).
- Adeiladu golygfeydd 3D manwl ar sail yr Hawliau Tramwy ar gyfer pob un o'r 60 safle astudio 1km^2. Rydym hefyd wedi codio'r dulliau o gyfrifo'r golygfeydd o bob safle astudio 1km wrth edrych allan ar yr arwynebedd o 3 x 3km o gwmpas, yn ogystal â chyfraniad y safle astudio 1km i'r olygfa o'r dirwedd wrth edrych i mewn o'r arwynebedd 3 x 3km o gwmpas. Mae hyn yn ffordd o fesur pa mor weladwy yw'r dirwedd hon i'r cyhoedd.
- Canfod holl nodweddion yr amgylchedd hanesyddol ar gyfer y 60 sgwâr.
- Mae dull o asesu cyflwr nodweddion hanesyddol wedi'i gynnwys yn yr arolwg maes, ar sail nodiadau maes a ddarparwyd gan yr ymddiriedolaethau archeolegol. Bydd hyn yn rhoi set newydd, amserol a phwysig o ddata arolwg am gyflwr safleoedd hanesyddol.
- Datblygu Mynegai Ansawdd Gweledol (VQI) unigryw i fesur gwerth tirwedd pob un o'r sgwariau 1km. Mae'n cynnwys pum elfen allweddol: topograffi (pa mor arw / amrywiol yw'r tirffurf); "gofod glas" (nodweddion dŵr yn y dirwedd); "gofod gwyrdd" (amrywiaeth cynefinoedd, cymhlethdod llystyfiant); anthropogenig (elfennau adeiledig); hanesyddol / diwylliannol (gan gynnwys presenoldeb Henebion Rhestredig etc).
- Defnyddir pob un o'r uchod i ymchwilio i effaith ymyriadau Glastir ar ansawdd a hygyrchedd y dirwedd.

Mae nifer o'r mesurau sy'n rhan o'r cynllun Glastir Sylfaenol a'r cynllun Glastir Uwch yn effeithio ar ansawdd gweledol y dirwedd wledig a'r nodweddion hanesyddol o'i mewn a'i hygyrchedd i'r cyhoedd. Byddwn yn ymchwilio i'r effaith hon gan asesu'r cysylltiad rhwng ansawdd ecolegol a chanfyddiad o'r dirwedd ym Mlwyddyn 2. Bwriedir cynnal gweithgareddau ychwanegol i fesur y buddion cymdeithasol ac economaidd ehangach o Glastir Cymdeithasol ym Mlwyddyn 2 yn bennaf. Ymhlith y gweithgareddau bydd: canfyddiad ffermwyr o'r elfen Tir Comin a'r gwerthoedd cymdeithasol ac economaidd ehangach o Grant Effeithiolrwydd Glastir a Glastir Coetir. (Pennod 6)

4. Gwaith allanol ac adroddiad y flwyddyn gyntaf

Cafwyd llawer math o waith allanol gan gysylltu â thua 20 o sefydliadau yng Nghymru, ynghyd â nifer o sefydliadau'r DU a rhai rhyngwladol. Mae hyn wedi cynnwys:

- 2 gyfarfod â rhanddeiliaid a chyfarfod rhwng y grŵp llywio a chynrychiolwyr Llywodraeth Cymru, CNC, NFU, CADW, CLA, Confor a'r RSPB.
- Bod yn bresennol a briffio mewn cyfarfodydd sydd wedi'u trefnu gan sefydliadau eraill: RSPB i drafod dulliau mesur dichonol a gwerth y dull Gwerth Mawr i Natur; Dŵr Cymru i gyflwyno prosiect GMEP i sefydliadau gan gynnwys yr Ymddiriedolaeth Camlesi ac Afonydd, Afonydd Cymru, Cyswllt Amgylchedd Cymru, y Gymdeithas Cadwraeth Forol, Natural England, Parciau Cenedlaethol Cymru, Canolfan Ymchwil Amgylcheddol Cymru, Ymddiriedolaethau Natur Cymru, Cadwch Gymru'n Daclus a Chyngor Defnyddwyr Dŵr Cymru.
- Cynhadledd Cymdeithas Biolegwyr Cymhwysol i gyflwyno'r prosiect i amrywiaeth eang o ymarferwyr gwyddoniaeth a pholisi ym maes ymchwil amaeth-amgylcheddol.
- Ysgrifennwyd erthyglau ar gyfer cylchgrawn Farming Wales yr NFU; a chyhoeddwyd papur ar y fethodoleg gyffredinol yn Aspects of Applied Biology 118, 2013.

Mae adroddiad y flwyddyn gyntaf wedi'i drefnu ar sail y pum canlyniad ar gyfer Glastir, ac mae'n canolbwyntio ar y canlyniadau i ymyriadau penodol o dan gynllun Glastir sydd wedi'u rhag-weld drwy fodelu.

5. Cynlluniau ar gyfer Blwyddyn 2

Mae cynlluniau ar gyfer Blwyddyn 2 wedi'u paratoi eisoes. O dan y cynlluniau, bydd 90 o sgwariau 1km yn cael eu harchwilio rhwng Ebrill a Medi 2014, defnyddir y tyrau fflwcs i fesur nwyon tŷ gwydr, rhoddir prawf ar y dull o fesur ansawdd gweledol tirwedd, ceir mwy o waith modelu, a mwy o ymgysylltu â chyrff anllywodraethol a sefydliadau eraill i gael y defnydd gorau posibl o'r holl ddata sydd ar gael am rywogaethau a choetiroedd. Bwriedir cynnal cyfres o arolygon hefyd i bennu'r buddion economaidd-gymdeithasol ehangach a'r cyfyngiadau ar dderbyn cynllun Glastir. Y cwestiynau penodol a ofynnir yw:

- Beth yw'r buddion economaidd-gymdeithasol ehangach o Grantiau Effeithiolrwydd Glastir?
- Beth yw'r cyfyngiadau presennol sy'n effeithio ar y parodrwydd i dderbyn grantiau Coetir Glastir?

Executive Summary

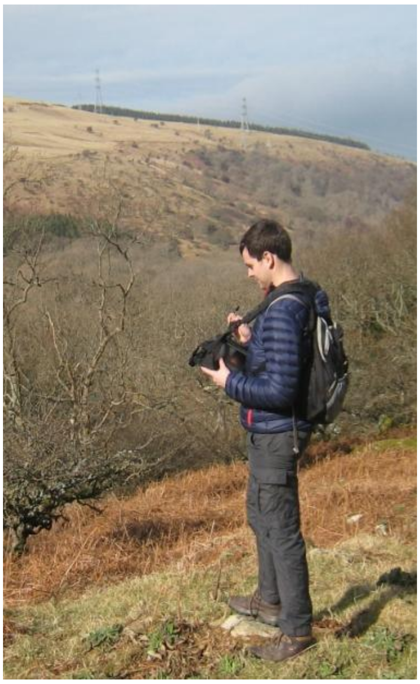
1. Introduction to the Glastir Monitoring and Evaluation Programme and team

The Welsh Government has commissioned a comprehensive new Glastir Monitoring and Evaluation Programme (GMEP) to monitor the effects of Glastir, its new land management scheme, and potentially contribute to the monitoring of progress towards a range of national and international biodiversity and environmental targets. This fulfils a commitment by the Welsh Government to establish a monitoring programme concurrently with the launch of the Glastir scheme. It is a major development from past monitoring programmes which have only reported after schemes have been closed. The project will also ensure compliance with the rigorous requirements of the European Commission Common Monitoring and Evaluation Framework (CMEF) for the Rural Development Plan (RDP) for Wales within one of its four key areas (known as Axes) called "Our Environment and Countryside". The early findings from GMEP will provide fast feedback to inform negotiations for the next phase of the RDP. The data, models and tools collected and developed within GMEP will also help inform future planning of Wales' natural resources in a joined-up way to ensure the development of a green economy and the aspirations of the Environment Bill. The current two year programme will be extended by a further two years subject to successful completion of the first two year deliverables.

The GMEP team compromises a mix of organisations with different specialisations covering the different schemes activities, objectives and outcomes. The programme is led by the Natural Environment Research Councils' Centre for Ecology & Hydrology Bangor, an independent public research body. The project consortium includes ADAS, APEM, Bangor University, Biomathematics and Statistics Scotland, Bowburn Consultants, British Geological Survey, British Trust for Ornithology, Butterfly Conservation, ECORYS, Edwards Consultants, Freshwater Habitats Trust, St Andrews University, Staffordshire University, University of Aberdeen, University of Southampton, and Victoria University of Wellington, New Zealand.

2. The GMEP approach

A major part of the programme involves a rolling annual survey across Wales using an ecosystem approach. Measurements include a range of soil and water quality metrics, landscape features, plant and freshwater diversity, condition assessment of historic features, two pollinator and four bird surveys; all mapped to Glastir intervention measures and the five high level outcomes as prescribed by the Welsh Government. Work to look at past data on impacts of agri-environment schemes and on-going trends is central to the programme's data and evidence activities. Examples of wider data and evidence utilisation include; historic data held by Biological Record Centre, British Trust for Ornithology and Centre for Ecology & Hydrology's Countryside Survey. The utilization of wider evidence and data will enhance the power of evaluation and also provide a long term historic backdrop. More workshops will be held with a range of specialist monitoring organisations and Natural Resources Wales in year 2 to ensure full use of data and evidence captured through wider past and current monitoring programmes.



To our knowledge, this will constitute the largest and most in-depth ecosystem monitoring and evaluation programme of any Member State and Managing Authority within the European Union. Many novel elements included are: an ecosystem approach to enable robust analysis of trade-offs and co-benefits; a rolling monitoring programme running parallel to the scheme to provide fast feedback; a major contribution from modelling; incorporation of social and economic analysis; application of new methods such as molecular technique for soil biodiversity, satellite data for peatland condition monitoring and mobile flux towers for measuring greenhouse gases. These will all help to increase efficiency, improve data quality and help ensure the breadth of Glastir impacts on the Welsh landscape, farmers and wider society are reported.

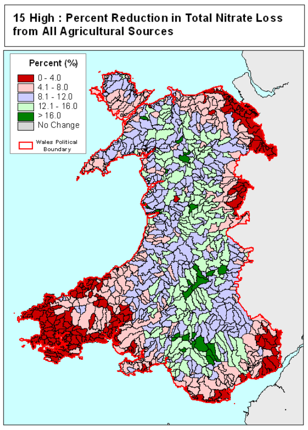
Major achievements by the GMEP team in its inception year Sept 2012 – August 2013 are presented in this report with key 1st year results outlined below. An expanded introduction to GMEP is presented in Chapter 1.

3. Year 1 results and observations

3.1 Modelling work to explore future outcomes from Glastir

1st year results:

- Parameterisation of four models to cover the impacts of scheme intervention measures on diffuse pollution, habitat connectivity, carbon stocks and sequestration, plant diversity and erosion and their trade-offs and synergies.
  - Six contrasting intervention measures have been investigated which cover both ‘broad and shallow’ and ‘narrow and deep’ type interventions. These were; no-input permanent pasture (AWE15), streamside corridor planting (AWE9b), grazing management open country (AWE41a), woodland edge expansion (AWE 24), bracken control (AWE 44) and retain winter stubble (AWE 28).
  - Three scenarios of low, medium and high uptake were explored and assumed maximum implementation of the relevant options of participating farms i.e. across all relevant land on a farm, which it should be noted is likely to significantly overestimate outcomes. No data was available at the time regarding amount of land included in agreements. Also, no assessment of potential emission displacement to other countries has been accounted for.
- Results include:
  - Individual Glastir prescriptions that result in a reduction in farm inputs and overall stock numbers on farm habitat areas (i.e. AWE 9b, AWE 28, AWE 41a, AWE 24) generally delivered small (<1%) national reductions in both eutrophying and climate forcing pollutant emissions.
  - This contrasts with site level results of up to 80% that can be achieved. Anticipated Glastir participation levels and suitable land available for interventions combine to limit national-scale outcomes. For example, local pollutant reductions were several times greater within Priority Catchments that have large areas of relevant land and are targeted for scheme enrolment. As these catchments are not higher than national average the overall effect on national results is small.
  - Reductions in national nitrate leaching, nitrous oxide and methane emissions of 5 to 10% were also achieved by with-holding nitrogen fertiliser and reducing stocking rate on the larger improved grassland area (AW15).
  - The water quality result from the two models which modelled diffuse pollution were similar in their findings adding to our confidence in the results.
  - Change in the overall carbon footprint (which includes embedded greenhouse gas emissions) for specific farms could be as high as 24%.



ADAS WDP-EMF modelled percent reduction in nitrate emissions under the ‘High’ scheme participation scenario for Impact of ‘Permanent Pasture No Inputs’

– The two woodland options (woodland edge expansion and streamside corridor planting) each increased accessible land for 'generic' broadleaf focal species by 3 to 12%, reduced the potential reduction in flood generating land by 1 to 9%, increased national carbon storage by ca. 0.4%, reduced eroded soil and phosphorus delivery by up to 15% due to reduced connectivity of erodible land to rivers and lakes.
– Positive changes in habitat suitability was projected for 75% of the 21 plant species modelled with significant progress towards target habitat suitability scores within 10-23 years of uptake of options.

This use of models is a highly novel component of GMEP. Their value is in exploring what changes we may expect from Glastir interventions according to our current knowledge, and in what timescale as the lag time on the ground can be significant. Models are also being used to assess hard-to measure changes such as greenhouse gas emissions and upscale or interpretation of field survey findings such as water quality within the wider landscape/catchment. Critically, to ensure a scientifically rigorous approach models also provide a hypothesis framework based on our best available scientific understanding against which to test data as it emerges from the field survey. In summary, the initial model scenario work identified:

- The relative modest benefits of some interventions when viewed at a national scale which contrasts which large benefits at a site scale.
- The critical importance of where interventions where placed in the landscape.
- The potential co-benefits of interventions such as tree planting if suitably placed for biodiversity, water quality and carbon are also clear from these model outputs.
- The long term nature of the outcomes particularly for biodiversity should be noted. This suggests there may be a requirement for long term commitment to interventions if the outcomes are to be fully realised.
- The potential value of models to inform a wide range of reporting and policy development needs from the greenhouse gas inventory to spatial planning in addition to Glastir.

Finally, it should be noted the model outcomes depend on a range of assumptions of uptake and implementation. It is expected that the results presented are a large over-estimate of impact where there are barriers to implementation of an option, such as a loss of productivity resulting from with-holding fertiliser applications or conversion of pasture to woodland. The development and construction of these highly complex models will allow further simulations exploring the potential of new interventions for future programmes including the data from our Farm Practice Survey which will better inform how farmers actually deliver interventions on the ground and more detailed information on agreements from Welsh Government. Results are presented in chapter 2 and 5.

3.2 The field survey
1st year results:

- Statistically robust and flexible nationwide survey designed, based on rolling programme and sampling unit chosen to include a the Wider Wales Component (WWC) used for baseline estimation, national trends and national reporting of Glastir, and a Targeted Component (TC), which specifically links to the priority areas and aims of the Glastir scheme.

- The first year of survey was completed successfully. 60 1km squares were surveyed for a wide range of ecosystem properties including birds and pollinators, soils and headwater streams, historic features and footpath condition, hedgerows and woodlands. Examples of the scale of the survey include:
  - 1726 botanical plots surveyed.
  - 1500 soil samples taken from 300 plots coincident with permanent botanical survey using methods appropriate for physical, microbial, chemical, carbon and invertebrate analysis.
  - 2043 point features identified and assessed.
  - 4 separate surveys of birds (April – July).
  - 2 separate surveys walking a 120km of transect to count butterfly species, bee and hover groups plus timed searches within 9000m^2.
  - 790 km of linear features (hedgerows, stream banks etc).
  - First survey of its kind to simultaneously monitor freshwater invertebrates, diatoms (streams only), macrophytes, physical habitat, water chemistry, in both ponds and streams.
  - 47 historic features assessed for their condition.
  - 960 landscape photos taken.
- Landowners granted access to 82% (scheme and none scheme holdings) of the total land area within the 60 1km squares. In years 2-4 the number of squares will be scaled up to 90 squares per year to create a total sample are of 330km^2. By year 4 the relative split between scheme and none scheme holdings within this sample area will be approximately 50 / 50 with the expected uptake of Glastir of *ca.* 4500 individual farms which, this will ensure a robust counterfactual against which to evaluate scheme impact.
- 13 field surveyors were successfully recruited and trained and bespoke field survey software was developed.
- Quality control was carried out by independent surveyors who cross-checked 12% of all survey squares.
- Surveyors collected data using a ruggedized tablet which automated the import, transfer, backup, and completion of survey data.
- Full bio-security measures were put in place to cover both plant and animal diseases. Farmers were also asked if there were any known plant or tree diseases and surveyors avoided these infected areas.

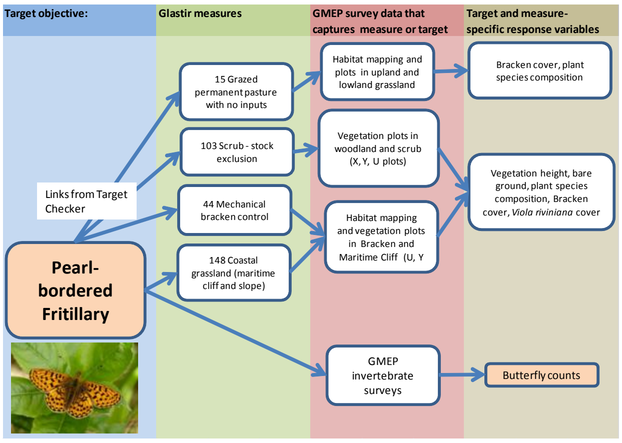
The field survey sits at the heart of the GMEP programme. The aim is to provide the main evidence base for ongoing change in the countryside (a Wider Wales Component) against which the impact of Glastir interventions can be evaluated using a Targeted Component (TC). The Targeted Component sample areas were selected according to the points structure for the Advanced element of Glastir and therefore reflect the priorities for Glastir outcomes. This approach combined with an integrated ecosystem approach to data collection means the survey is flexible over time as the Welsh Government's priorities change over the first 4 years of the programme. A common sampling unit of 1km x 1km square was selected for both components to ensure a practical sampling unit which would allow outcomes from species to landscape to be evaluated. We have not taken a

paired farm-unit approach due to the limitations, including redundancy and biases that can result. The 1km squares are surveyed on a rolling programme with squares re-visited every 4 years. This has several advantages including; (i) maximising efficient use of resources, (ii) capturing year-to-year variation, (iii) providing early data to test and parameterise models such that early feedback to the Welsh Government can be provided, and (iv) ensuring trade-offs and co-benefits are captured which would be missed if e.g. separate bird, plant and soil surveys were not co-located. (Results chapter 3)

3.3 Ongoing trends in biodiversity, development of a High Nature Value Farmland indicator and capture of non-GMEP data

First year results:

- Analysis of opportunistic biological recording species data held by the Biological Records Centre identified 10 out of 18 taxonomic groups were declining from 1970 onwards with the remaining 8 taxonomic groups increasing. Common species are out-performing rare species in terms of the change in the probability of observing a species between 1990 and 2000. This type of analysis provides data for reporting against a range of national and international biodiversity targets but data are limited to those where volunteer recording provides sufficient in-depth coverage. The assessment was carried out on a select subset of priority species where data was sufficient, listed under the Natural Environment & Rural Communities Act 2006; included species that were considered to be of international importance to conservation, *i.e.* Listed as threatened on the IUCN Global Red List (IUCN 2013), on greater than 50% of the regional EU Red Lists or listed as threatened in other reliable sources. Species were included if Wales contained greater than 25% of its EU or Global population and that the population has declined by 25% or more in the last 25 years. In addition, species that have shown greater than 50% declines in Wales in the last 25 years were included. Finally, species were included if they had exceptional threat circumstances, such as a very restricted range size, as verified by taxonomic experts.
- Completion of a first version of a Watch List Indicator for species trends in Wales.
- There have been a number of meetings with stakeholders to discuss the concept of HNV and how we might develop an indicator in the Glastir Monitoring and Evaluation Programme resulting in some decisions in scope and terminology and proposals for future work. A small working group involving CEH, BTO, RSPB and NRW was convened and agreed next steps to develop a way forward including collation of datasets and testing at well known sites, to be followed by analysis to explore coincidence of other ecosystem services and natural capital.



Different methods to be used by GMEP to quantify the impact of interventions on the pearl-bordered fritillary

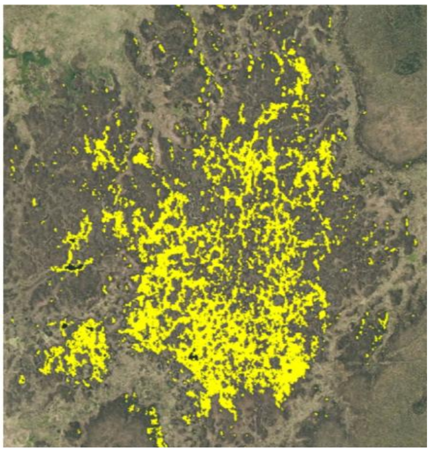
- Initiation of work to extrapolate outside of 1km squares using both BRC data and remote sensing approaches.
- CEH have worked with the Welsh Government to license and obtain a range of > 50 existing primary datasets from various organisations and government bodies such as NRW, CCW, EA, Ordnance Survey, NSRI, Cadw, Defra, Intermap and more. This data can broadly be described under the following 8 headings: Contextual ; Habitats; Soils; Designated Areas; Hydrology; Historic; Farm Holdings; Glastir and Past Schemes and provides both added context to future

analysis and when added to data contained within the GMEP team (e.g. Countryside Survey and the BTO Breeding Bird Survey) provide additional evidence of ongoing change. A major element of Year 2's work will be to meet with specialist conservation groups to identify further species level data which can help identify impacts of Glastir measures.

- All GMEP datasets are held on secure network within confidential folders, with access only permitted for a limited number of staff from the informatics team. Any other staff that require access to datasets must submit requests to data managers and sign a data license agreement. Spatial data access can then be granted through the GMEP spatial database (SDE), with each user permitted read-only access to the specific datasets requested. (Chapter 4)

3.4 New baseline data for greenhouse gas emissions from Wales' grasslands and peatland condition

First year results:



Example of bare peat mapping by BGS using aerial photography

- Two mobile greenhouse gas flux towers have been purchased to undertake real-time carbon dioxide, nitrous oxide and methane measurements. There are few such real-time landscape sensors in the UK (note only one other N_2O sensor exists in the UK) and none to our knowledge which combine all three sensors in a mobile system.
- In addition we are deploying the sensors with innovative new landscape soil moisture sensors as soil moisture is such an important driver of soil greenhouse gas flux. All kit has been purchased (note the long lead times for these specialised piece of kit) plus start of the commissioning and integration of the kit within the mobile trailer systems for deployment in the field April 2014.
- New metrics for monitoring peat are under development including remote sensing approaches for peat erosion and isotopic approaches. We have processed radar images covering an area of 4460km^2 of north Wales which encompassed large areas of upland blanket peat for the period between 1993 and 2000. We showed that it is possible to detect and map small ground movements in areas of upland peat soil which can be analysed to detect short and long-term trends. A second approach classified aerial photographs identifying 0.63km^2 as bare peat from a total organic soil areal extent of 473km^2; this is equivalent to 0.13% of the total area of peat assessed. Together with a new isotopic and vegetation proxy approach, the aim is to identify an improved and objective approach to assess Glastir interventions on peat condition.

Due to insufficient data and the absence of a scientific consensus on current levels of greenhouse gas emissions from Welsh grasslands, there remains uncertainty surrounding which grasslands are currently storing or releasing carbon. The mobile flux towers will be deployed on both Glastir and non-Glastir land in order to establish a robust new evidence base for this important land use type in Wales. It is expected that the monitoring data captured through the GMEP will greatly improve our understanding of scheme intervention and effective policy design to mitigate climate change and will also help in the development of improved methods and data for the Land Use, Land Use Change and Forestry Greenhouse Gas Inventory. A similar situation is present for peatlands where there is no objective empirical methodology for assessing the current trend in peatland condition (and thus the security of the carbon it stores). Quantifying the impact of Glastir interventions is therefore problematic without this exploitation of new technologies. (Chapter 3)

3.5 Woodlands

First year results:

- Field protocols have been agreed and implemented for recording of woodland habitats and species in GMEP survey squares which includes mapping of woodland habitat, dominant species, management information, land use, vegetation plots in small and large woodland patches and along woody linear features and bird and pollinator recording.
- Assembly of explanatory data to analyse changes in woodland extent and condition and impacts on other environmental and biodiversity response variables.
- Mapping of Glastir interventions to GMEP measurements and Woodland Plan for Wales.
- Application of the 3 models to explore forecasting of the effects of 2 woodland Glastir prescriptions (described under 3(i) above).
- Explored habitat connectivity metrics to develop methods for assessing impacts of Glastir measures on connectivity of woodland habitats.

The Welsh Government strategy 'Woodlands for Wales' was published in 2001 and revised in 2012. It promotes the design and management of woodlands to provide a wide and balanced range of ecosystem services. A set of 23 indicators have been developed to measure progress towards achieving the 20 high level outcomes outlined in the Woodlands for Wales's strategy. These include measures on extent, area of woodland of different types (urban, farm *etc*.) and how that is changing, habitat diversity and species, sustainability of woodland management, carbon balance, tree health, local benefits of woodland, accessibility, value of wood and water management; spanning the range of social, economic and environmental benefits. Many of these aspects will be captured in the GMEP survey in addition to quantifying impact of Glastir interventions thus contributing to the wider assessment of the strategy. Joint working with National Resources Wales is planned for Year 2 to align data from GMEP with other sources of forestry and woodland data. (Chapter 7)

3.6 Impacts on the Welsh landscape and historic environment

First year results:

- The construction of detailed 3D datasets for all 60 $1km^2$ squares which take into account both landscape topography and small-scale landscape features which constrain the visibility of the landscape (e.g. significant trees, boundaries such as hedgerows, buildings, woodlands).
- The construction of 3D datasets at 5m resolution for a 3 x 3km area surrounding each of the 60 1 km squares.
- The extraction of a complete Public Rights of Way (PROW) network for different classes of user (walker, cyclist, horse-rider, small vehicle, large vehicle) for all 60 squares.
- The collation of a visual record of all 60 squares from both fixed point photography completed during the field survey (16 per square).
- The construction of detailed 3D viewsheds based on the PROW for all 60 $1km^2$ study sites. In addition, we have also coded the methods to calculate the viewsheds from each 1km study site looking out to the surrounding 3 x 3km, as well as the contribution that the 1km study site makes to the landscape view looking in from the surrounding 3 x 3km area. This is a quantifiable measure of how "visually accessible" this landscape is to the general public.
- The extraction of all historic environment features for the 60 squares.

- An assessment of historic feature condition has been successfully incorporated into the field survey, building on field notes provided by the archaeological trusts. This will yield a timely and significant new set of survey data about historic sites' condition.
- The development of a unique Visual Quality Index (VQI) to quantify the landscape value of each 1km square. This includes five key components: topography (how rugged / varied the landform is); "blue-space" (water features in the landscape); "green-space" (habitat diversity, vegetation complexity); anthropogenic (built components); historic / cultural (including presence of Scheduled Ancient Monuments *etc*).
- All of above will be used to explore the impact of Glastir interventions on landscape quality and accessibility.

Many of the measures embedded in both the Glastir Entry and Glastir Advanced scheme have impacts on both the visual quality of the rural landscape and the historic features it contains and its accessibility by the public. We will be exploring the impact including assessing the link between ecological quality and landscape perception in Year 2. Additional activities to quantify the wider social and economic benefits Glastir Social are planned primarily for Year 2. Activities will include; farmer perception of the Commons element, the wider social and economic values of the Glastir Efficiency Grant and Glastir Woodland. (Chapter 6)

4. Outreach and first year report

A wide range of outreach has been undertaken to ca. 20 organisations in Wales, plus many UK and international organisations. This has included:

- 2 stakeholder meetings and a steering group meeting with representatives from WG, NRW, NFU, CADW, CLA, Confor and RSPB.
- Attendance and briefings at meetings organised by other organisations; RSPB to discuss potential metrics and value of the High Nature Value approach; Dŵr Cymru to introduce organisations including: Canal & River Trust, Afonydd Cymru, Wales Environment Link, Marine Conservation Society, Natural England, National Parks Wales, Wales Environmental Research Hub, Wildlife Trusts Wales, Keep Wales Tidy and Consumer Council for Water Wales to the GMEP project.
- An Association of Applied Biologists conference to present the project to a wide range of science and policy practitioners in the field of agri-environment research.
- Articles have been written for NFU's Farming Wales magazine; and a paper published on the overall methodology in Aspects of Applied Biology 118, 2013.

This first year report is structured to report against the five outcomes of Glastir, with a particular focus on the projected modelled outcomes of selected Glastir interventions.

5. Plans for Year 2

Plans for Year 2 are already in hand with 90 1km squares due to be surveyed from April to September 2014, deployment of the greenhouse gas flux towers, testing of the visual landscape quality approach, further modelling activity, and greater engagement with NGOs and other organisations to make best use of all available species and woodland data. A series of surveys are also planned to identify the wider socio-economic benefits and uptake constraints of the Glastir scheme. Specific questions being asked are:

- What are the wider socio-economic benefits of the Glastir Efficiency Grants?
- What are the current constraints which influence the uptake of the Glastir Woodland grants?

Crynodeb o'r Adroddiad

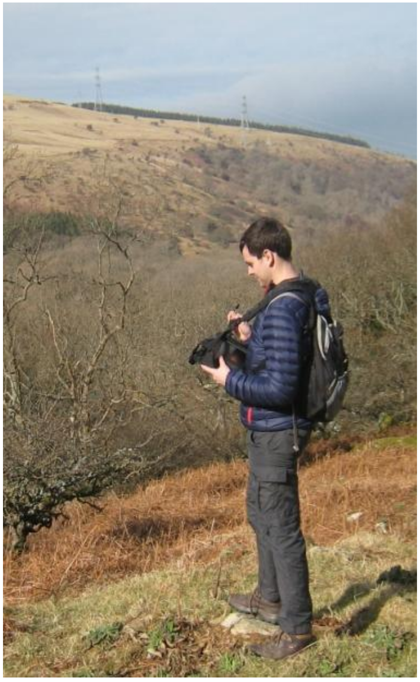
Cyflwyno Rhaglen Monitro a Gwerthuso Glastir a'i thîm

Mae Llywodraeth Cymru wedi comisiynu Rhaglen Monitro a Gwerthuso Glastir (GMEP) newydd gynhwysfawr i fonitro effeithiau cynllun Glastir, ei chynllun rheoli tir newydd, ac i gyfrannu, os bydd modd, at fonitro cynnydd tuag at gyrraedd nifer o dargedau cenedlaethol a rhyngwladol ar fioamrywiaeth a'r amgylchedd. Mae hyn yn cyflawni ymrwymiad Llywodraeth Cymru i sefydlu rhaglen fonitro i gyd-redeg â lansio cynllun Glastir. Mae'n gam mawr ymlaen o raglenni monitro blaenorol sydd wedi cyflwyno eu hadroddiadau wedi i'r cynlluniau ddod i ben. Bydd y prosiect yn sicrhau cydymffurfiaeth hefyd â'r gofynion ymestynnol yn Fframwaith Monitro a Gwerthuso Cyffredin (CMEF) y Comisiwn Ewropeaidd ar gyfer y Cynllun Datblygu Gwledig (CDG) i Gymru yn un o'r pedwar maes allweddol (a elwir yn Echelau) sef "Ein Hamgylchedd a Chefn Gwlad". Bydd y canfyddiadau cynnar o GMEP yn darparu adborth buan ar gyfer negodiadau ynghylch cam nesaf y CDG. Bydd y data, y modelau a'r offer a gaiff eu casglu a'u datblygu gan GMEP yn cyfrannu hefyd at gynllunio adnoddau naturiol Cymru mewn ffordd gydgysylltiedig yn y dyfodol er mwyn datblygu economi werdd a gwireddu dyheadau Bil yr Amgylchedd. Bydd y rhaglen ddwy flynedd bresennol yn cael ei hymestyn am ddwy flynedd ychwanegol os cwblheir tasgau'r ddwy flynedd gyntaf yn llwyddiannus.

Mae tîm GMEP yn cynnwys amrywiaeth o sefydliadau sydd ag arbenigaethau gwahanol ar gyfer gweithgareddau, amcanion a chanlyniadau amrywiol y cynllun. Mae'r rhaglen yn cael ei harwain gan Ganolfan Ecoleg a Hydroleg Bangor sy'n cael ei noddi gan Gyngor Ymchwil yr Amgylchedd Naturiol, corff ymchwil cyhoeddus annibynnol. Aelodau consortiwm y prosiect yw ADAS, APEM, Prifysgol Bangor, Biomathematics and Statistics Scotland, Bowburn Consultants, Arolwg Daearegol Prydain, Ymddiriedolaeth Adareg Prydain, Butterfly Conservation, ECORYS, Edwards Consultants, Ymddiriedolaeth Cynefinoedd Dŵr Croyw, Prifysgol St Andrews, Prifysgol Swydd Stafford, Prifysgol Aberdeen, Prifysgol Southampton, a Phrifysgol Victoria yn Wellington, Seland Newydd.

2. Dull gweithredu GMEP

Prif elfen y rhaglen yw arolwg blynyddol treigl a gynhelir ledled Cymru gan ddefnyddio dull ar lefel yr ecosystem. Ymysg pethau eraill, mae'n mesur nifer o agweddau ar ansawdd pridd a dŵr, nodweddion tirwedd, amrywiaeth planhigion a dŵr croyw, a chyflwr nodweddion hanesyddol, ac yn cynnal dau arolwg o bryfed peillio a phedwar o adar, y cwbl wedi'i fapio ar sail mesurau ymyrryd Glastir a'r pum canlyniad lefel uchel sydd wedi'u rhagnodi gan Lywodraeth Cymru. Rhan ganolog o weithgareddau'r rhaglen ar ddadansoddi data a thystiolaeth yw ystyried data o'r gorffennol sy'n dangos effeithiau cynlluniau amaeth-amgylchedd a thueddiadau parhaus. Rhai enghreifftiau o ddata a thystiolaeth o gylch ehangach sydd wedi'u defnyddio yw: data hanesyddol sy'n cael eu dal gan y Ganolfan Cofnodion Biolegol, Ymddiriedolaeth Adareg Prydain ac Arolwg Cefn Gwlad y Ganolfan Ecoleg a Hydroleg. Bydd y defnydd o dystiolaeth a data o gylch ehangach yn hyrwyddo'r gallu i werthuso a hefyd yn darparu cyd-destun hanesyddol hirdymor. Cynhelir rhagor o weithdai gydag amrywiaeth o sefydliadau monitro arbenigol a Cyfoeth Naturiol Cymru ym mlwyddyn 2 i sicrhau bod yr holl dystiolaeth a data a gasglwyd drwy raglenni monitro cyfredol a blaenorol mewn cylchoedd ehangach yn cael eu defnyddio.



Hyd y gwyddom, hon fydd y rhaglen fwyaf a manylaf ar gyfer monitro a gwerthuso ecosystemau yn holl Aelod-wladwriaethau ac Awdurdodau Rheoli'r Undeb Ewropeaidd. Ymhlith y nifer mawr o elfennau newydd y mae: dull monitro ar lefel yr ecosystem fel y gellir dadansoddi effeithiau gwrthbwyso a chyd-fuddion; rhaglen monitro dreigl sy'n rhedeg ochr yn ochr â'r cynllun i roi adborth buan; cyfraniad o bwys drwy fodelu; cynnwys dadansoddiadau cymdeithasol ac economaidd; cymhwyso dulliau newydd, e.e. techneg foleciwlaidd i fesur bioamrywiaeth mewn pridd, data lloeren i fonitro cyflwr mawndiroedd a thyrau fflwcs symudol i fesur nwyon tŷ gwydr. Bydd pob un o'r rhain yn helpu i hybu effeithlonrwydd a gwella ansawdd data, a sicrhau bod pob math o effeithiau o gynllun Glastir ar dirwedd Cymru, ffermwyr a chymdeithas ehangach yn cael eu cofnodi.

Mae'r adroddiad hwn yn disgrifio prif gyflawniadau tîm GMEP ym mlwyddyn ei sefydlu rhwng Medi 2012 ac Awst 2013, ac mae prif ganlyniadau'r flwyddyn gyntaf ar gyfer pob un o'r pum canlyniad wedi'u dangos isod, gan ddechrau â'r canlyniadau o ymarfer modelu sylweddol i amcangyfrif effeithiau dichonol o rai o ymyriadau Glastir ar lefel y fferm a'r lefel genedlaethol.

Senarios ar gyfer Effeithiau Dichonol o ymyriadau Glastir yn y dyfodol

Y disgwyl yw y bydd yr opsiynau rheoli tir o dan gynllun Glastir yn datblygu i gyd-fynd â newid mewn blaenoriaethau polisi a thystiolaeth newydd am effeithiolrwydd yr opsiynau. Bydd dulliau modelu cyfrifiadurol o ganlyniadau'r cynllun yn offeryn penderfynu allweddol yn y broses hon, ac fe'u defnyddiwyd mewn asesiad meintiol o effeithiau cynlluniau amaeth-amgylchedd blaenorol a oedd wedi dangos bod cysylltiad rhwng y pwysau gan lygryddion a fodelwyd a'r statws cemegol ac ecolegol a fesurwyd mewn dyfroedd croyw yng Nghymru (Anthony *et al*., 2012). Mae modelau cyfrifiadurol yn cyfosod y dystiolaeth sydd ar gael a'r ddealltwriaeth orau sydd gennym o gyflwr a sensitifrwydd yr amgylchedd naturiol. Maent yn rhoi'r cyfle i ryngosod ac rhagamcanu canlyniadau hirdymor ar lefel y dirwedd, fel y gall dadansoddwyr polisi werthuso a threfnu canlyniadau'r cynllun mewn perthynas â'r targedau. Yn benodol, ar gyfer y rhaglen waith hon, maent yn rhoi amcangyfrifon o newidiadau mewn allyriadau o lygryddion y mae'n anodd eu mesur yn uniongyrchol, am resymau sy'n ymwneud â graddfa neu gost, e.e. allyriadau nwyon tŷ gwydr. Lle y mae mesuriadau ar gael, gellir eu cymharu â rhagfynegiadau'r model er mwyn gwirio pa mor gynrychiadol yw'r fframwaith monitro.

Yn bwysicaf oll, mae modelau cyfrifiadurol yn rhoi cyfle i fesur nifer o ganlyniadau a dyrannu effeithiau rhwng y nifer mawr o newidiadau mewn dulliau rheoli tir sy'n gysylltiedig â chynllun penodol. Mae nifer o'r opsiynau rheoli tir o dan gynllun Glastir yn cael effeithiau lluosog, er enghraifft, ar ansawdd dŵr, y gallu i liniaru effeithiau'r newid yn yr hinsawdd, cytrefi planhigion, a darparu cynefinoedd ar gyfer adar ac anifeiliaid. Drwy goladu allbynnau o *ensemble* o fodelau o'r gwahanol wyddorau, gellir rhoi asesiad mwy cyflawn o fuddion cynllun Glastir a phennu'r elfennau mwyaf effeithiol, fel y gall llunwyr polisi ymchwilio i effeithiau gwrthbwyso ac ailddylunio'r cynllun yn gyflymach.

Felly un o brif amcanion rhaglen monitro a gwerthuso Glastir yn ei blwyddyn gyntaf oedd dangos y defnydd o *ensemble* o offer modelu i gwmpasu'r canlyniadau dichonol o opsiynau cynrychiadol ar gyfer rheoli tir o dan gynllun Glastir. Yn y bennod ar 'Senarios y Dyfodol' disgrifir y defnydd o fframweithiau modelu cyfrifiadurol, a'r posibiliadau ar gyfer eu defnyddio yn y dyfodol, i fesur effaith opsiynau cynrychiadol ar gyfer rheoli tir o dan gynllun ar bob un o ganlyniadau arfaethedig Glastir: bioamrywiaeth; lliniaru effeithiau'r newid yn yr hinsawdd; priddoedd a llif ac ansawdd dŵr; ac ehangu a rheoli coetiroedd. Amcan y gwaith hwn oedd dangos y posibilrwydd o ddefnyddio *ensemble* o fodelau i ragamcanu'r canlyniadau lluosog o opsiynau rheoli, er mwyn a) darparu amcangyfrifon o newidiadau mewn allyriadau o lygryddion ac mewn gwasanaethau ecosystemau y mae'n anodd eu mesur yn uniongyrchol; b) gwerthuso'r buddion cymharol o opsiynau rheoli penodol a mireinio dyluniad cynllun Glastir cyn y bydd mesuriadau uniongyrchol o effeithiau ar gael; ac c) mesur y buddion lluosog sy'n codi o ddull o weithredu sy'n ofodol benodol ac wedi'i seilio ar wasanaethau ecosystemau ar gyfer targedu opsiynau. Yn fyr, y cyflawniadau yn y flwyddyn gyntaf yw:

- Sefydlu tri model (WDP-EMP, LUCI a MultiMOVE) sy'n gallu darparu amcanestyniadau lleol a chenedlaethol, a'u helaethu yn ôl yr angen, i gyfrifo effeithiau dichonol 6 o'r opsiynau ar gyfer rheoli tir o dan gynllun Glastir gan ddefnyddio amodau llinell sylfaen cyson a senarios ar gyfer cyfranogi yn y cynllun y cytunwyd arnynt â Llywodraeth Cymru. Y rhain oedd:
    - Cadw Sofl dros y Gaeaf
    - Gadael i Goetir Ymestyn dros ei Ffiniau i Gae Cyfagos
    - Rheoli Pori ar Dir Agored
    - Tir Pori Parhaol heb Fewnbynnau
    - Creu Coridor ar Un Lan Nant a Phlannu Coed
    - Rheoli Rhedyn â Pheiriannau
- Defnyddiwyd y modelau i gyfrifo'r effeithiau dichonol o weithredu pob opsiwn i'r graddau mwyaf posibl ar y rhannau perthnasol o ffermydd sy'n rhan o gynllun Glastir ar strwythur cytrefi planhigion; cysylltedd cynefinoedd coetir; creu llifogydd; colli maethynnau a gwaddodion i afonydd a llynnoedd; allyriadau nwyon tŷ gwydr; a storio carbon. Nid oedd pob un o'r modelau'n gymwys i bob un o'r ymyriadau na'r holl ganlyniadau. Ymchwiliwyd i dri senario lle'r oedd derbyniad isel, canolig ac uchel i'r cynllun a chymerwyd y byddai'r opsiynau perthnasol yn cael eu gweithredu i'r graddau mwyaf posibl gan y ffermydd sy'n cymryd rhan. Dylid nodi bod hyn yn debygol o roi goramcangyfrif arwyddocaol o'r canlyniadau. Nid oedd gwybodaeth ar gael am union arwynebedd y tir yn y cytundebau.
- Roedd rhagnodiadau penodol o dan gynllun Glastir yn arwain at y newidiadau disgwyliedig yn addasrwydd cynefinoedd ar gyfer 75% o'r 21 o rywogaethau planhigion a fodelwyd, o ganlyniad i reoli llystyfiant yn llai dwys a newidiadau ym mhriodweddau pridd. Cafwyd y byddai cynnydd sylweddol tuag at dargedau ar gyfer addasrwydd cynefinoedd o fewn 10 i 23 blynedd ar ôl ymgymryd â'r opsiynau.
- At ei gilydd roedd rhagnodiadau unigol o dan Glastir sy'n arwain at ostyngiad ym mewnbynnau'r fferm a niferoedd cyffredinol y da byw mewn cynefinoedd ar ffermydd yn sicrhau gostyngiadau bach (<1%) ar lefel genedlaethol mewn allyriadau o lygryddion o ewtroffeiddio a llygryddion gorfodi hinsawdd. Roedd maint y gostyngiad lleol mewn llygryddion sawl gwaith yn fwy mewn Dalgylchoedd â Blaenoriaeth lle y mae arwynebedd eang o dir perthnasol sydd wedi'u targedu ar gyfer ymaelodi â'r cynllun. Gallai'r newid yn yr ôl troed carbon cyffredinol (gan gynnwys allyriadau nwyon tŷ gwydr corfforedig) ar gyfer ffermydd penodol fod yn gymaint â 26% (gweler Adran 5.4).
- Cafwyd gostyngiadau mawr ar lefel genedlaethol o 5 i 10% o ran trwytholchi nitradau ac allyriadau o ocsid nitrus a methan drwy atal gwrteithiau nitrogen a lleihau'r gyfradd stocio ar yr arwynebedd mwy o laswelltir wedi'i wella.
- Roedd rhagnodiadau o dan gynllun Glastir ar gyfer cyflwyno coridorau ar lan nant a phlannu coed ac ymestyn y parseli coetir presennol yn cynyddu'r arwynebedd o goetiroedd o tua 10,000ha a'r gyfradd genedlaethol ar gyfer storio carbon o lai na 1%. Enillwyd rhwng 3 a 12% yn fwy o dir hygyrch ar gyfer rhywogaethau ffocol llydanddail 'generig' (math o ddangosydd biolegol) drwy gynyddu cysylltedd rhwng coetiroedd ac roedd gostyngiad dichonol o 1 i 9%

yn arwynebedd tir sy'n achosi llifogydd o ganlyniad i'r ddau opsiwn hyn ar gyfer coetir. Mae potensial sylweddol yn y rhagnodiadau hefyd i leihau cysylltedd rhwng tir sy'n agored i erydu ac afonydd a llynnoedd, a rhagamcanwyd eu bod yn lleihau'r cyflenwad o bridd wedi'i erydu a ffosfforws o hyd at 15%. Dangoswyd yn aml fod tiroedd sy'n cynhyrchu llwyth mawr sy'n symud drwy briddoedd neu lystyfiant sydd â nodweddion rhyng-gipio ar ei ffordd i'r afon neu lyn yn llai arwyddocaol yng nghyswllt maint cyffredinol y maethynnau mewn dŵr na thiroedd sy'n cynhyrchu llwyth llai lle nad oes nodweddion rhyng-gipio rhyngddynt a'r afon. Roedd allyriadau corfforedig o nwyon tŷ gwydr o ganlyniad i leihau niferoedd da byw a'r gostyngiad cysylltiedig mewn gwrteithiau o dan yr ymyriadau coetir hyn yn arwain at ostyngiad o 1 i 4% yn yr allyriadau ar lefel y fferm (gweler Adran 5.4).

- Mae graddfa'r canlyniadau o'r modelau yn awgrymu y gellir cael effaith gronnol sylweddol o dderbyn nifer o ragnodiadau o dan Glastir. Fodd bynnag, mae'r allbynnau wedi'u seilio ar y rhagdybiaeth y bydd yr opsiynau'n cael eu gweithredu i'r graddau mwyaf posibl ar yr holl dir perthnasol ar y fferm, ac ar nifer o ragdybiaethau gwyddonol sy'n rhan o'r modelau. Y disgwyl yw bod y canlyniadau a gyflwynwyd yn oramcangyfrif mawr o'r effaith lle y mae rhwystrau rhag gweithredu'r opsiwn, fel colledion mewn cynhyrchiant o ganlyniad i beidio â thaenu gwrtaith neu droi tir pori yn goetir. Mae'n hanfodol bod dadansoddiad manwl yn cael ei gynnal o'r patrwm ar gyfer derbyn opsiynau, ac arolwg o'r newidiadau gwirioneddol sy'n digwydd wrth reoli ffermydd, er mwyn mesur y cyfyngiadau ar dderbyn opsiynau a phennu gwir lefel yr ychwanegedd. Bydd yr Arolwg o Arferion Ffermwyr y mae GMEP yn bwriadu ei gynnal yn 2016 a gwybodaeth fwy manwl am gytundebau oddi wrth Lywodraeth Cymru yn cyfrannu at fodelu yn y dyfodol.
- Dylid nodi hefyd nad yw newidiadau posibl mewn nwyddau a gwasanaethau amgylcheddol y tu allan i Gymru i gydbwyso unrhyw ostyngiad mewn cynhyrchiant yng Nghymru wedi'u hystyried.

Rhoddir blaenoriaeth mewn gwaith modelu yn y dyfodol i ddefnyddio'r model LUCI i gyfrifo'r buddion o leoli opsiynau rheoli mewn mannau penodol ar ffermydd, er mwyn amlhau'r canlyniadau lluosog wrth ymgymryd ag opsiynau ar arwynebedd cymharol fach; i gymhwyso'r model MultiMOVE at Gymru gyfan; ac i gwmpasu'r effeithiau o opsiynau rheoli sydd heb eu cynnwys yn y cynllun presennol drwy ddefnyddio'r model WDP-EMP er mwyn i Lywodraeth Cymru ystyried y canlyniadau.

Yr arolwg maes

Mae'r arolwg maes yn rhan ganolog o raglen GMEP. Y nod yw darparu'r brif sylfaen dystiolaeth ar gyfer newid sy'n digwydd yng nghefn gwlad (Elfen Cymru Ehangach) y gellir ei defnyddio i werthuso effaith ymyriadau o dan gynllun Glastir drwy Elfen wedi'i Thargedu (TC). Dewisir ardaloedd samplu'r Elfen wedi'i Thargedu ar sail y strwythur pwyntiau ar gyfer Glastir Uwch, felly maent yn adlewyrchu'r blaenoriaethau presennol ar gyfer canlyniadau Glastir. Drwy ddefnyddio'r dull hwn, ynghyd â dull integredig o gasglu data wedi'i seilio ar yr ecosystem, gall yr arolwg newid dros amser yn ôl y newid ym mlaenoriaethau Llywodraeth Cymru yn ystod 4 blynedd cyntaf y rhaglen. Dewiswyd uned samplu gyffredin o 1km x 1km ar gyfer y ddwy elfen er mwyn cael uned samplu ymarferol a fyddai'n rhoi'r gallu i werthuso canlyniadau rhwng lefel y rhywogaeth a lefel y dirwedd. Nid ydym wedi defnyddio dull sy'n paru ffermydd ag unedau oherwydd y cyfyngiadau a fyddai'n codi, gan gynnwys tra-dyblygu a bias. Archwilir y sgwariau 1km ar sail rhaglen dreigl ac ailymwelir â nhw bob 4 blynedd. Mae nifer o fanteision ynglŷn â hyn: (i) defnyddio adnoddau yn y ffordd fwyaf effeithlon, (ii) canfod amrywiadau o flwyddyn i flwyddyn, (iii) darparu data yn gynnar er mwyn profi a phennu paramedrau modelau fel bod modd darparu adborth buan i Lywodraeth Cymru, a (iv) sicrhau bod effeithiau gwrthbwyso a chyd-fuddion yn cael eu cofnodi gan na fyddai hynny'n digwydd pe na byddai arolygon ar wahân, e.e. o adar, planhigion a phridd, yn cael eu cynnal yn yr un lle.

Mae'r bennod ar yr Arolwg Maes yn disgrifio'r holl ddulliau archwilio yn fanwl ac mae rhestr lawn o'r holl fesuriadau a data mewn Atodiad. Yn fyr, y cyflawniadau ym Mlwyddyn 1 yw:

- Dylunio arolwg cenedlaethol hyblyg ar sail ystadegol gadarn, wedi'i seilio ar raglen dreigl ac uned samplu a ddewiswyd fel ei bod yn cynnwys yr Elfen Cymru Ehangach (WWC) a ddefnyddir i amcangyfrif llinellau sylfaen, tueddiadau cenedlaethol ac ar gyfer adroddiadau cenedlaethol ar gynllun Glastir, ac Elfen wedi'i Thargedu (TC), sydd â chysylltiad penodol â'r meysydd a nodau â blaenoriaeth yng nghynllun Glastir.
- Cwblhawyd yr arolwg yn llwyddiannus yn y flwyddyn gyntaf. Archwiliwyd 60 sgwâr 1km ar gyfer amrywiaeth eang o briodweddau ecosystem gan gynnwys adar a phryfed peillio, priddoedd a rhagnentydd, nodweddion hanesyddol a chyflwr llwybrau troed, gwrychoedd a choetiroedd. Rhai enghreifftiau o raddfa'r arolwg yw:
  - 1726 o leiniau botanegol wedi'u harchwilio.
  - 1500 o samplau pridd wedi'u codi o 300 o leiniau i gyd-fynd ag arolwg botanegol parhaol sy'n defnyddio dulliau addas ar gyfer dadansoddi ffisegol, microbaidd, cemegol, carbon ac infertebrata.
  - 2043 o nodweddion pwynt wedi'u pennu a'u hasesu.
  - 4 arolwg ar wahân o adar (Ebrill – Gorffennaf).
  - 2 arolwg ar wahân drwy gerdded trawsdoriad 120km o hyd i gyfrif rhywogaethau o loynnod byw, grwpiau o wenyn a phryfed hofran ynghyd ag archwiliadau wedi'u hamseru o fewn 9000m^2.
  - 790 km o nodweddion llinol (gwrychoedd, glannau nentydd etc).
  - Yr arolwg cyntaf o'i fath i fonitro'r canlynol yr un pryd: infertebrata dŵr croyw, diatomau (mewn nentydd yn unig), macroffytau, cynefinoedd ffisegol, cyfansoddiad cemegol dŵr, mewn pyllau a nentydd.
  - 47 o nodweddion hanesyddol i asesu eu cyflwr.
  - 960 o luniau tirwedd wedi'u tynnu.
- Roedd perchnogion tir wedi rhoi caniatâd i fynd ar 82% o'r arwynebedd tir cyfan (daliadau sydd o fewn y cynllun a daliadau eraill) o fewn y 60 sgwâr 1km. Ym mlynyddoedd 2-4 bydd 90 o sgwariau'n cael eu harchwilio bob blwyddyn er mwyn cael arwynebedd samplu cyfan o 330km^2. Erbyn blwyddyn 4, y rhaniad rhwng daliadau sydd o fewn y cynllun a daliadau eraill o fewn yr arwynebedd samplu hwn fydd tua 50 / 50 a disgwylir y bydd tua 4500 o ffermydd wedi ymaelodi â chynllun Glastir. Bydd hyn yn sicrhau bod sail wrthffeithiol gadarn i werthuso effaith y cynllun.
- Cafodd 13 o syrfewyr maes eu recriwtio a'u hyfforddi a datblygwyd meddalwedd bwrpasol ar gyfer arolygon maes.

- Darparwyd rheolaeth ar ansawdd gan syrfewyr annibynnol a groeswiriodd 12% o holl sgwariau'r arolwg.
- Roedd syrfewyr wedi casglu data drwy ddefnyddio llechen ddurol a oedd yn mewnforio, yn trosglwyddo, ac yn cwblhau data'r arolwg yn awtomatig gan greu copïau wrth gefn.
- Rhoddwyd mesurau bioddiogelwch trwyadl ar waith i ddiogelu rhag clefydau planhigion ac anifeiliaid. Holwyd ffermwyr hefyd i weld a oeddent yn gwybod am unrhyw glefydau mewn planhigion neu goed ac nid oedd y syrfewyr yn mynd ar dir a oedd wedi'i heintio.

Bioamrywiaeth

Y nod ar gyfer datblygu gwledig cynaliadwy yn Rhaglen Datblygu Gwledig yr UE yw sicrhau bod tir a dŵr yn cael eu defnyddio'n gynaliadwy o safbwynt economaidd ac ecolegol. Mae hyn yn dangos cydnabyddiaeth o'r angen i wrth-droi'r dirywiad mewn ecosystemau a'r colledion o ran bioamrywiaeth sydd wrth wraidd hynny. Yng Nghymru, mae cynllun Glastir yn elfen bwysig yn y Rhaglen Datblygu Gwledig ac yn cyfrannu felly at gyflawni nifer o rwymedigaethau statudol a thargedau sy'n berthnasol i fioamrywiaeth. Mae'r rhain yn deillio o gytundebau rhyngwladol (targedau Aichi), Ewropeaidd (Strategaeth Bioamrywiaeth yr Undeb Ewropeaidd (EUBS) ynghyd â'r Cyfarwyddebau Cynefinoedd ac Adar) a deddfwriaeth y DU (Deddf Bywyd Gwyllt a Chefn Gwlad a Deddf yr Amgylchedd Naturiol a Chymunedau Gwledig). Un ystyriaeth neilltuol o bwysig yw targed 3 yn EUBS sydd â'r nod o gynyddu'r cyfraniad gan amaethyddiaeth a choedwigaeth at fioamrywiaeth. Gan fod 81% o dir Cymru'n cael ei ffermio, credir mai cynllun amaeth-amgylchedd yw un o'r ffyrdd pwysicaf o sicrhau newid sylweddol yn y cydbwysedd rhwng cynhyrchu, cyflenwi gwasanaethau ecosystemau a bioamrywiaeth er mwyn cael datblygu gwledig cynaliadwy. Yn y bennod ar Fioamrywiaeth disgrifir y cynnydd a gafwyd a'r cynlluniau ar gyfer asesu'r effaith o ganlyniadau cynllun amaeth-amgylchedd newydd Glastir ar fioamrywiaeth yng Nghymru yn y dyfodol. Rydym yn cyfuno nifer o ddulliau gweithredu gan gynnwys casglu data yn y rhaglen fonitro dreigl 4 blynedd, modelu a dadansoddi'r cynlluniau monitro presennol. Yn fyr, y cyflawniadau ym Mlwyddyn 1 yw:

- Cwblhau arolygon o gynefinoedd, planhigion, adar a phryfed peillio yn holl sgwariau GMEP gan addasu protocolau i fesur effeithiau cynllun Glastir yn y ffordd fwyaf effeithiol.
- Diweddaru'r allweddau mapio ar gyfer cynefinoedd drwy ymgynghori â CNC gan gynnwys newidiadau yn y rhestrau o rywogaethau dangosol a diweddariadau.
- Cynnal asesiad rhagarweiniol o'r graddau y mae dosbarthiad arfaethedig y sgwariau ar gyfer arolwg GMEP yn gorgyffwrdd â'r dosbarthiad o rywogaethau a chynefinoedd â blaenoriaeth sydd o ddiddordeb o ran cadwraeth, ymchwilio i dair astudiaeth achos a mapio ymyriadau gyda mesuriadau i bennu a fydd mesuriadau uniongyrchol neu rai procsi yn cael eu cofnodi.
- Casglu setiau data cyd-destunol fel y gellir amcangyfrif effeithiau ar fioamrywiaeth o ganlyniad i gynllun Glastir yn y dyfodol ar ôl ystyried effeithiau etifeddol o gynlluniau blaenorol ac effeithiau cyfredol a blaenorol o ffactorau sbarduno eraill fel hinsawdd, defnydd tir a llygredd aer.
- Defnyddio *ensemble* y model MultiMOVE arbenigol i ymchwilio i ragolygon o effeithiau o ragnodiadau Glastir ar rywogaethau planhigion. Defnyddiwyd MultiMOVE i roi prawf ar ddau ddalgylch a phedwar mesur. Modelwyd 21 o rywogaethau planhigion, pob un wedi'i chodi o blotiau presennol yr Arolwg Cefn Gwlad ar gyfer y dosbarthiadau tir mewn dalgylchoedd a'r cynefinoedd a oedd wedi'u targedu gan bob rhagnodiad yng Nghymru. O'r cyfanswm o

amcanestyniadau ar gyfer rhywogaethau a mesurau penodol a gwblhawyd ar gyfer rhywogaethau cyffredin, roedd 30 (75%) yn gyson â'r effaith ddisgwyliedig o gynllun Glastir. Fodd bynnag, roedd y newidiadau hyn wedi'u hymestyn dros gyfnodau cymharol hir.

- Creu cronfeydd data newydd 10km ar gyfer rhywogaethau planhigion wedi'u seilio ar ddata am ddosbarthiad ac wedi'u cywiro i ddarparu ar gyfer gorgofnodi a thangofnodi. Defnyddiwyd y cronfeydd hyn wrth ddewis rhywogaethau ar gyfer modelu drwy MultiMOVE.
- Cwblhau dadansoddiad o dueddiadau ar gyfer grwpiau rhywogaethau yng Nghymru a oedd wedi'u casglu drwy gynlluniau gwirfoddoli. O'r rhywogaethau lle'r oedd digon o ddata i'w dadansoddi, gwelwyd bod tuedd negyddol net ar gyfer 10 o blith 18 o grwpiau tacsonomig o 1970 ymlaen a bod tuedd gadarnhaol net ar gyfer yr 8 grŵp tacsonomig a oedd yn weddill. Mae'r ffigurau ar gyfer rhywogaethau cyffredin yn well na'r rheini ar gyfer rhywogaethau prin o ran y newid yn y tebygolrwydd o arsylwi ar rywogaeth rhwng 1990 a 2000.
- Cwblhau'r fersiwn gyntaf o Ddangosydd Rhestr Gwylio ar gyfer tueddiadau mewn rhywogaethau yng Nghymru.
- Gwaith rhagarweiniol i roi prawf ar fetrigau gofodol ar gyfer cysylltedd cynefinoedd.
- Casglu meini prawf a setiau data i roi prawf ar y diffiniad o Dir Ffermio o Werth Mawr i Natur yng Nghymru ac ar gyfer mesur ei arwynebedd presennol a'i arwynebedd yn y dyfodol a'i gyflwr ecolegol.
- Dechrau ar waith i allosod mesuriadau y tu allan i sgwariau 1km arolwg GMEP drwy ddefnyddio data o offer synhwyro o bell er mwyn rhagdybio meintiau a gaiff eu monitro a'u modelu ledled Cymru.

Y Newid yn yr Hinsawdd a Lliniaru Effeithiau Llygredd Gwasgaredig

Mae amaethyddiaeth yn ffynhonnell arwyddocaol i lygredd gwasgaredig mewn dŵr ac allyriadau nwyon tŷ gwydr yng Nghymru. Mae rhai arferion amaethyddol yn gyfrifol hefyd am golli ac ennill carbon mewn pridd. Mae Llywodraeth Cymru wedi gosod targedau cenedlaethol i wella ansawdd dŵr a lleihau allyriadau nwyon tŷ gwydr, a disgwylir i'r sector amaethyddol gyfrannu at gyrraedd y targedau hynny. O ganlyniad i hyn, mae cynllun Glastir wedi'i ddatblygu fel ei fod yn ddigon hyblyg i dargedu themâu â blaenoriaeth (fel carbon mewn pridd) mewn cyd-destun gofodol, ac i gyflwyno mesurau ar ffermydd e.e. i ddal a storio mwy o garbon, ac i leihau allyriadau nwyon tŷ gwydr a llygredd gwasgaredig mewn dŵr o'r sector amaethyddol. Mae Llywodraeth Cymru wedi rhoi blaenoriaeth i ariannu ymyriadau sy'n canolbwyntio ar liniaru effaith y newid yn yr hinsawdd a llygredd gwasgaredig mewn dŵr ym Mlynyddoedd 1 a 2 y cynllun.

Er mwyn dechrau ar y gwaith o bennu'r effeithiau dichonol o gynllun Glastir ar lygredd gwasgaredig mewn dŵr, allyriadau nwyon tŷ gwydr a dal a storio carbon, mae Llywodraeth Cymru wedi ymddiried y gwaith o asesu effeithiau dichonol o ymyriadau Glastir ar y meysydd blaenoriaeth hyn i Raglen Monitro a Gwerthuso Glastir. Bydd yn gwneud hyn drwy fodelu, drwy Arolwg o Arferion Ffermwyr i bennu newidiadau gwirioneddol ar lawr gwlad, a thrwy waith ychwanegol i bennu'r buddion ehangach o Grantiau Effeithiolrwydd Glastir.

Yn fyr, y cyflawniadau yn y flwyddyn gyntaf yw:

- Asesu ffynonellau nwyon tŷ gwydr a dal a storio carbon, y gellir eu hamcangyfrif drwy bob un o'r offer modelu (e.e. methan mewn pridd, methan enterig, allyriadau corfforedig)
- Mapio'r pedwar dull o fodelu ymyriadau Glastir, gan y Panel Arbenigol
- Defnyddio dull Bangor o fesur ôl troed y cylch bywyd ar 16 o ffermydd enghreifftiol ar gyfer pedwar o ymyriadau Glastir er mwyn mesur newidiadau mewn allyriadau nwyon tŷ gwydr o ffynonellau ar y fferm, yn ogystal ag allyriadau corfforedig sy'n gysylltiedig â chynhyrchu porthiant a gwrtaith. Amcangyfrifwyd bod posibilrwydd o gael gostyngiad o 0-24% yn yr ôl troed carbon o ganlyniad i ddefnyddio 4 o'r ymyriadau.
- Cyflenwi data i offeryn modelu ADAS ar raddfa genedlaethol ar gyfer 5 o ymyriadau Glastir i asesu newidiadau dichonol mewn allyriadau nwyon (ocsid nitrus, methan) a llygredd gwasgaredig mewn dŵr (nitrogen, ffosfforws a gwaddodion)
- Caffael setiau data ar gyfer modelu gofodol yn y dyfodol drwy ddefnyddio model ECOSSE
- Datblygu protocol drafft ar gyfer ailgynnal yr Arolwg o Arferion Ffermydd yng Nghymru, gan gynnwys y strategaeth haenu arfaethedig, i'w drafod â chyrff ariannu a thîm prosiect ehangach y rhaglen
- Cynllunio'r dull o asesu effaith Grantiau Effeithiolrwydd Glastir ar i) ôl troed carbon y ffermydd sydd wedi'u defnyddio, a ii) y buddion ehangach (y tu allan i'r fferm) i'r economi wledig

Tirwedd a Nodweddion Hanesyddol

Yng Nghymru y ceir rhai o'r golygfeydd harddaf o fynyddoedd a'r arfordir yn Ewrop, yn ogystal â thirweddau mirain wedi'u ffermio a thirweddau treftadaeth o bwysigrwydd cenedlaethol a rhyngwladol (WLP, 2009). Tirweddau yw'r fframwaith ar gyfer ein cyfalaf naturiol a'r elfennau unigol sy'n creu'r cyfoeth hwn – cynefinoedd, rhywogaethau, diwylliant, daeareg, a'r gweithgarwch economaidd sy'n digwydd ynddynt – mae pob un yn cyfrannu at eu datblygiad. Oherwydd hyn, nid "cipluniau" yn unig yw tirweddau ond tystiolaeth uniongychol a gweladwy o ganrifoedd o weithgarwch dynol. Mae natur gyfoethog a neilltuol yr amgylchedd hanesyddol yng Nghymru yn cael ei hamlygu yng nghymeriad ei thirwedd hanesyddol (caeau, gweunydd, lonydd, aneddiadau etc.) a hefyd yn ei gwaddol unigryw o safleoedd archeolegol, henebion maes ac olion ffisegol eraill. Cafwyd cydnabyddiaeth glir i gyfraniad sylweddol yr amgylchedd hanesyddol i ansawdd bywyd yng Nghymru. Mae Strategaeth Amgylchedd Hanesyddol Cymru (Llywodraeth Cymru, 2013) a gyhoeddwyd yn ddiweddar yn canolbwyntio ar gamau gweithredu sy'n rhoi'r gallu i ddiogelu treftadaeth Cymru gan roi anogaeth hefyd ar gyfer mynediad, mwynhad a chyfranogiad cyhoeddus. Mae'r amgylchedd hanesyddol yn cwmpasu amrywiaeth o asedau sy'n cynnwys safleoedd â dynodiad ffurfiol yn ogystal â thirnodau a nodweddion pwysig lleol. Ledled Cymru ceir 3 Safle Treftadaeth y Byd, 428 o dirweddau hanesyddol, parciau a gerddi cofrestredig, 519 o ardaloedd cadwraeth, 4,000 o henebion rhestredig a 30,000 o adeiladau rhestredig. Cafwyd tystiolaeth bod asedau o'r fath yn rhoi amrywiaeth o fuddion gan gynnwys twristiaeth, creu swyddi, creu naws am le, hunaniaeth, addysg a chyfranogiad cymunedol. Mae gwaith ymchwil i asesu gwerth yr amgylchedd hanesyddol yng Nghymru (ECOTEC, 2010) wedi amcangyfrif bod y sector yn cynnal mwy na 30,000 o swyddi ac yn cyfrannu tua £840 miliwn at werth ychwanegol crynswth. Mae rhai o'r atyniadau mwyaf i ymwelwyr yng Nghymru yn safleoedd treftadaeth, gan gynnwys Castell Conwy a ddenodd fwy na 160,000 o ymwelwyr yn 2012. Gwneir defnydd helaeth o'r amgylchedd hanesyddol i hyrwyddo Cymru fel cyrchfan ac mae'n un o'r rhesymau sy'n cael ei grybwyll amlaf yn ymchwil Croeso Cymru i gymhellion y rhai sy'n dewis ymweld â Chymru. Er hynny, mae'r strategaeth yn nodi bod angen gweithredu er mwyn cynyddu hygyrchedd a dealltwriaeth a chynnwys grwpiau sydd wedi'u tangynrychioli. Mae'r gost o gynnal ac adfer asedau'n her sylweddol hefyd. Mae'r Rhaglen Lywodraethu, a gyflwynwyd yn 2011 ar gyfer tymor y Cynulliad presennol, yn cynnwys dyhead i gyfoethogi bywydau unigolion a chymunedau drwy ddiwylliant a threftadaeth gyda'r nod tymor hwy o gynyddu canran yr asedau yn yr amgylchedd hanesyddol sydd mewn cyflwr sefydlog neu well. Mae'r diweddariad yn 2013 yn cofnodi bod ymgysylltiad y cyhoedd â threftadaeth yn cynyddu, bod rhywfaint o lwyddiant wedi bod o ran cryfhau lle'r Gymraeg mewn bywyd pob dydd, ac mai'r amcangyfrif o ganran yr asedau yn yr amgylchedd hanesyddol sydd mewn cyflwr sefydlog neu well yw ychydig dros 78%.

Mae ansawdd tirwedd yn gysyniad goddrychol o'i hanfod. Mae'r dull o'i fesur yn dibynnu ar amrywiaeth o ffactorau, gan gynnwys lle y mae'r asesiad yn digwydd, a pha bryd (amser/tymor/tywydd) ac, yn hollbwysig, pwy sy'n barnu. Y brif her, felly, mewn astudiaethau tirwedd ac yng ngwaith prosiect GMEP yw pennu dull meintiol o fesur elfennau ansawdd y gellir ei ailadrodd, ac mae hyn yn allbwn allweddol yng ngham cyntaf y gwaith ar dirwedd gan GMEP. Y cyflawniadau mwyaf yn y flwyddyn gyntaf i ymateb i'r her hon yw:

- Adeiladu setiau data 3D manwl ar gyfer pob un o'r 60 safle astudio 1km^2 sy'n cynnwys topograffi tirweddau a nodweddion tirwedd ar raddfa fach sy'n cyfyngu'r gallu i weld y dirwedd (e.e. coed mawr, terfynau fel gwrychoedd, adeiladau, coetiroedd).
- Adeiladu setiau data 3D ar fanylder o 5m ar gyfer arwynebedd 3 x 3km o gwmpas pob un o'r 60 safle astudio.
- Canfod y rhwydwaith Hawliau Tramwy cyfan ar gyfer gwahanol fathau o ddefnyddwyr (cerddwyr, beicwyr, marchogion, cerbydau bach, cerbydau mawr) ar gyfer pob un o'r 60 safle astudio.
- Coladu cofnod gweledol o bob un o'r 60 safle o luniau a dynnwyd o bwynt penodol yn ystod yr arolwg maes (16 ar bob safle), a thrwy goladu bron 200 o luniau o'r 60 safle hyn a gyfrannwyd gan y cyhoedd i wefan Geograph (http://www.geograph.org.uk/), gan ddarparu 4 o luniau ychwanegol ar gyfer pob safle gan amlaf (Ffigur 6.1.1).
- Adeiladu golygfeydd 3D manwl ar sail yr Hawliau Tramwy ar gyfer pob un o'r 60 safle astudio 1km^2. Rydym hefyd wedi codio'r dulliau o gyfrifo'r golygfeydd o bob safle astudio 1km wrth edrych allan ar yr arwynebedd o 3 x 3km o gwmpas, yn ogystal â chyfraniad y safle astudio 1km i'r olygfa o'r dirwedd wrth edrych i mewn o'r arwynebedd 3 x 3km o gwmpas. Mae hyn yn ffordd o fesur pa mor weladwy yw'r dirwedd hon i'r cyhoedd.
- Canfod yr holl nodweddion amgylchedd hanesyddol ar gyfer y 60 safle.
- Mae dull o asesu cyflwr nodweddion hanesyddol wedi'i gynnwys yn yr arolwg maes, ar sail nodiadau maes a ddarparwyd gan yr ymddiriedolaethau archeolegol. Bydd hyn yn rhoi set newydd, amserol a phwysig o ddata arolwg am gyflwr safleoedd hanesyddol.

- Datblygu Mynegai Ansawdd Gweledol (VQI) unigryw i fesur gwerth tirwedd pob un o'r safleoedd astudio 1km. Mae'n cynnwys pum elfen allweddol: topograffi (pa mor arw / amrywiol yw'r tirffurf); "gofod glas" (nodweddion dŵr yn y dirwedd); "gofod gwyrdd" (amrywiaeth cynefinoedd, cymhlethdod llystyfiant); anthropogenig (elfennau adeiledig); hanesyddol / diwylliannol (gan gynnwys presenoldeb Henebion Rhestredig etc).

Un datblygiad allweddol yn ystod gwanwyn 2014 fydd datblygu delweddau tirwedd i ddangos newidiadau yn y dirwedd yn y dyfodol ar y safleoedd sydd wedi'u targedu a'u noddi drwy gynllun Glastir a defnyddir arolygon mynegi dewis i werthuso ymateb y cyhoedd. Un agwedd ar y gwaith ar dirwedd fydd defnyddio delweddau gemau cyfrifiadurol o'r math diweddaraf i ddarlunio tirweddau ecolegol gywir yn y dyfodol. Bydd y delweddau hyn wedi'u seilio ar y sefyllfa wirioneddol, a bydd yr holl lystyfiant wedi'i seilio ar y wybodaeth a gasglwyd yn yr arolwg maes gan ecolegwyr a bydd newidiadau yn yr adeileddau coediog hyn yn dilyn patrymau ecolegol gywir ar gyfer twf yng Nghymru. Trefnir i'r delweddau fod ar gael ar-lein a bydd y defnyddiwr yn gallu "cerdded drwy" y dirwedd. Bydd hyn yn gyfle i gasglu barn dinasyddion Cymru, yn ogystal â barn ymwelwyr posibl i Gymru o bob rhan o'r byd. Nid gimig yw'r delweddau hyn o gwbl, a chystal yw eu hansawdd bellach fel bod modd eu defnyddio i ddenu sylw pobl ifanc ac aelodau o'r cyhoedd yng Nghymru (rhai mewn ardaloedd mwy trefol efallai, neu ardaloedd o dan anfantais gymdeithasol) at yr asedau tirwedd y maent yn talu am eu diogelu yng Nghymru. Rydym yn credu mai hwn yw'r tro cyntaf y bydd delweddau mor uchel eu hansawdd ac mor ecolegol gywir o dirweddau yn cael eu creu a'u defnyddio i ymgysylltu â'r cyhoedd i'r diben hwn.

Coetiroedd

Mae coetiroedd yn bwysig ar gyfer darparu Gwasanaethau Ecosystemau lluosog, nwyddau a buddion gan gynnwys pren, diogelu pridd, atal llifogydd, hamdden, rheoleiddio'r hinsawdd ac amrywiaeth rhywogaethau gwyllt (rhywogaethau cyffredinol a rhai arbenigol mewn coetiroedd). Mae nifer o'r gwasanaethau hyn yn ategu ei gilydd a cheir synergeddau rhwng gwasanaethau yn hytrach na gwrthbwyso: mae coetiroedd yn gynefinoedd aml-swyddogaethol. Pennwyd mai gwerth y buddion i'r amgylchedd o goetiroedd yng Nghymru yw £34 miliwn (Read *et al*. 2009). Mewn arolwg diweddar, dangoswyd bod bron 65% o'r bobl yng Nghymru'n ymweld yn rheolaidd â choetiroedd yng Nghymru a bod 94% yn credu eu bod yn darparu budd pendant i'r gymuned leol. Yn ôl amcangyfrif y Rhestr Goedwigaeth Genedlaethol, cyfanswm yr arwynebedd o goetiroedd yng Nghymru yn 2010 oedd 303.5 000 ha, sef 14% o arwynebedd Cymru. Cafwyd amcangyfrif hefyd yn y Rhestr fod arwynebedd y coetiroedd llydanddail wedi cynyddu 16000ha rhwng 2001 a 2010 a bod arwynebedd y coetiroedd conwydd wedi lleihau 13000ha. Yng Nghymru, coetir o goed llydanddail yn bennaf yw'r unig goetir brodorol, a'r math hwn o goetir sydd o'r diddordeb mwyaf o safbwynt gwarchod natur. Mae'n cynnwys saith math o Gynefin â Blaenoriaeth sydd wedi'u cydnabod yng Nghynllun Gweithredu Bioamrywiaeth y DU. Roedd yr adroddiad ar ddangosyddion Coetiroedd i Gymru (2012) yn dangos bod y tueddiadau ym mhoblogaeth y rhan fwyaf o rywogaethau sy'n destun pryder o ran cadwraeth yn anhysbys o hyd. Fodd bynnag, roedd y dirywiadau ym mhoblogaeth gwiwerod coch a llyriad-y-dŵr arnofiol wedi sefydlogi, y dirywiadau ym mhoblogaethau'r fritheg berlog, y fadfall ddŵr gribog a'r ferywen wedi arafu a’r cynnydd ym mhoblogaeth y rugiar ddu wedi sefydlogi. Nid oedd tuedd arwyddocaol ym mynegai adar y coetiroedd rhwng 1994 a 2009.

Cyhoeddwyd strategaeth Llywodraeth Cymru ‘Coetiroedd i Gymru’ yn 2001 a’i diwygio yn 2012. Mae’n hyrwyddo dulliau o ddylunio a rheoli coetiroedd sy’n darparu amrediad eang a chytbwys o wasanaethau ecosystemau. Datblygwyd set o 23 o ddangosyddion i fesur cynnydd tuag at gyrraedd yr 20 canlyniad lefel uchel sydd wedi’u disgrifio yn y strategaeth ‘Coetiroedd i Gymru’. Mae’r rhain yn cynnwys mesurau sy’n ymwneud â chyrhaeddiad, arwynebedd coetiroedd o wahanol fath (trefol, fferm etc.) a’r newid ynddynt, amrywiaeth cynefinoedd a’u rhywogaethau, dulliau cynaliadwy o reoli coetir, cydbwysedd carbon, iechyd coed, buddion lleol o goetiroedd, hygyrchedd, gwerth pren a rheoli dŵr. Mae’r rhain yn cwmpasu amrywiaeth o fuddion cymdeithasol, economaidd ac amgylcheddol. Roedd yr adroddiad ar Ddefnydd Tir a Newid Hinsawdd yn argymell ehangu coetiroedd dros 20 mlynedd o tua 100 000ha (rhai collddail yn bennaf ond rhywfaint o goed conwydd) gan addasu tarddiad y coed yn ôl y rhagamcan o’r hinsawdd. Byddai’r fenter hon yn creu dalfa nwyon tŷ gwydr a photensial ar gyfer defnyddio tanwydd coed. Roedd hefyd yn argymell dulliau o reoli sy’n sicrhau na fydd coetiroedd Cymru yn dod yn ffynhonnell flynyddol o nwyon tŷ gwydr ac y byddant yn atal nwyon tŷ gwydr i’r graddau mwyaf posibl yn y tymor hir. Mae clefydau coed ac iechyd coed wedi cael lle mwy amlwg o lawer ar yr agenda wleidyddol yn ddiweddar yn sgîl ymlediad clefydau e.e. *Chalara fraxinea*, *Phytophthora ramorum*, marwolaeth sydyn y deri, malltod nodwyddau Dothistroma a’r nifer mawr o fygythiadau posibl i nifer o rywogaethau.

Mae elfen coetir yng nghynllun Glastir sydd â’r amcan o helpu rheolwyr tir i greu coetiroedd newydd a rheoli coetiroedd presennol er mwyn hybu gwasanaethau ecosystemau ac ymdrin â bioamrywiaeth, dŵr, carbon, tirweddau, nodweddion hanesyddol a mynediad. Mae’r elfen coetir yn darparu grantiau cyfalaf a grantiau ar sail arwynebedd ar gyfer:

- Teneuo – caniatáu i fwy o olau ddod drwy frig y coed i wella llystyfiant y llawr a hybu adfywio naturiol.
- Ailstocio – gwella amrywiaeth y rhywogaethau.
- Seilwaith – rheoli coetiroedd a oedd yn anhygyrch gynt.
- Gwaith ar derfynau – i gadw da byw allan o goetiroedd neu reoli da byw yn well.
- Rhywogaethau a warchodir a rhywogaethau â blaenoriaeth – grantiau i warchod rhywogaethau pwysig.
- Rheoli llystyfiant – i reoli planhigion goresgynnol ac egsotig.
- Rheoli plâu – gan gynnwys gwiwerod llwyd a cheirw.
- Mynediad cyhoeddus – i wella mynediad i goetiroedd a darparu gwybodaeth i ymwelwyr.

Mae Rhaglen Monitro a Gwerthuso Glastir yn defnyddio arolygon a dulliau modelu ar y cyd i bennu’r buddion o ymyriadau Glastir ar raddfa genedlaethol. Y cynnydd a gafwyd ym Mlwyddyn 1 yw:

- Cytuno ar brotocolau maes, a’u rhoi ar waith, ar gyfer cofnodi cynefinoedd a rhywogaethau coetiroedd yn sgwariau arolwg GMEP. Mae hyn yn cynnwys mapio cynefinoedd coetir, y prif rywogaethau, gwybodaeth reoli, defnydd tir, plotiau llystyfiant mewn llecynnau bach a mawr yn y coetir ac ar hyd nodweddion llinol coediog, a chofnodi adar a phryfed peillio.

- Casglu data esboniadol i ddadansoddi newidiadau ym maint a chyflwr coetiroedd ac effeithiau ar newidynnau eraill sy'n dangos ymateb o ran yr amgylchedd a bioamrywiaeth.
- Mapio ymyriadau Glastir ar sail mesuriadau GMEP a Chynllun Coetiroedd Cymru
- Defnyddio *ensemble* y model MultiMOVE arbenigol ar gyfer rhywogaethau planhigion i ymchwilio i ragolygon o effeithiau 2 o ragnodiadau Glastir ar gyfer coetiroedd: (AWE 9b) Creu coridor ar un lan nant a phlannu coed, (AWE 24) Gadael i goetir ymestyn dros ei ffiniau i dir wedi'i wella (gweler Pennod 2).
- Defnyddio model ecosystemau tirweddau LUCI i ymchwilio i ragolygon o effeithiau 2 o ragnodiadau Glastir ar gyfer coetiroedd a'r synergeddau neu'r gwrthbwyso rhyngddynt a gwasanaethau eraill (gweler Pennod 2).
- Defnyddio'r model WDP-EMF i ymchwilio i ragolygon o effeithiau 2 o ragnodiadau Glastir ar gyfer coetiroedd (gweler Pennod 2).
- Ymchwilio i fetrigau ar gyfer cysylltedd cynefinoedd er mwyn datblygu dulliau o asesu effeithiau mesurau o dan gynllun Glastir ar gysylltedd cynefinoedd mewn coetiroedd (gweler Pennod 4).

Rhai o'r cynlluniau ar gyfer Blwyddyn 2 yw:

Dadansoddi'r effeithiau o fesurau coetir Glastir ar wasanaethau ecosystemau a bioamrywiaeth gan ddefnyddio gwahanol dechnegau dadansoddol ac ystadegol a modelu sydd wedi'u disgrifio'n fanwl mewn penodau eraill a sefydlu grŵp pwnc Coetiroedd i gynghori a rhoi sylwadau am yr amcanion, y dadansoddiadau a'r allbynnau o waith GMEP ar goetiroedd.

Cyfalaf Naturiol Pridd a llif ac ansawdd dŵr

Yn ogystal â darparu bwyd a maeth i gynnal dynoliaeth, mae ffermwyr yn stiwardiaid ar eu tir. Mae stiwardiaeth dda yn gallu rhyddhau maethynnau o bridd a rheoli dŵr yn effeithiol i greu a chynnal cynefinoedd bioamrywiol. Ar y llaw arall, mae dealltwriaeth wael o'r arferion rheoli gorau, neu stiwardiaeth wael, yn gallu arwain at ddirywiad mewn cynefinoedd a disbyddu cyfalaf naturiol y pridd. Yn aml bydd cymdeithas yn gofyn i ffermwyr droedio llwybr cul, drwy gynhyrchu bwyd heb achosi dirywiad yn y dirwedd. Gall rheoli ac aflonyddu amaethyddol fod yn bwysig ar gyfer rhyddhau maethynnau a gwella dŵr, priddoedd a bioamrywiaeth, ond mae gormod o fewnbynnau, cyfraddau stocio rhy uchel, neu bwyslais ar amaethu ungnwd yn gallu arwain at ddifrod amgylcheddol. Ar wahân i gynhyrchu bwyd, mae dŵr a phriddoedd yn cyflenwi gwasanaethau ecosystemau sy'n bwysig o safbwynt rheoleiddiol a diwylliannol. Os bydd y dŵr mewn cronfeydd yn lân, ni fydd angen ei drin i raddau helaeth cyn ei yfed gan bobl; gall priddoedd fod yn glustog rhag llifogydd a sychder sy'n gallu achosi difrod cymdeithasol ac economaidd mawr. Mae cysylltiad hanfodol rhwng rheoleiddio ansawdd a llif dŵr a phriddoedd a'r defnydd ohonynt. Yn ogystal â hyn, mae priddoedd yn rheoli ac yn rheoleiddio'r ailgylchu ar wastraff a maethynnau, ond mae gormod o fewnbynnau maeth yn gallu arwain at ddŵr ffo a llygru crynofeydd dŵr. Mae priddoedd yn storio llawer o garbon a gallant un ai helpu i leihau'r newid yn yr hinsawdd drwy ddal a storio CO_2 o'r atmosffer neu, mewn rhai achosion, ychwanegu at y newid yn yr hinsawdd drwy allyrru methan ac ocsid nitrus. Mae priddoedd a chrynofeydd dŵr yn gynefinoedd ac yn gronfeydd genynnau pwysig hefyd: o briddoedd y cafwyd y gwrthfiotigau cyntaf ac mae'r rhain yn hollbwysig bellach ym meddygaeth pobl ac anifeiliaid. Mae priddoedd a dŵr wyneb yn agored i effeithiau dirywiol ac yn cael eu bygwth gan ddefnydd rhy ddwys o dir, llygredd a newid yn yr hinsawdd, a rhaid eu rheoli'n ofalus.

Nodwyd yn yr Asesiad Ecosystemau Cenedlaethol fod afonydd ym mynyddoedd Cymru'n neilltuol o agored i effaith asideiddio, a bod y rheini sy'n draenio tir sy'n cael ei amaethu'n fwy dwys yn agored i'r perygl o ewtroffeiddio drwy'r llwyth maethynnau. Mae asesiadau diweddar wedi dangos bod ansawdd dŵr afonydd wedi gwella rhwng 1990 a 2008. Mae'r llwyth maethynnau yn fygythiad mawr ac mae 8% o afonydd Cymru yn cael eu hystyried yn uchel o ran ffosffadau. Mae gwaith monitro wedi dangos bod gordyfiant o algae mewn afonydd yn fwy cyffredin yn ystod y 1990au a bod hynny'n gysylltiedig â chrynodiadau uchel o nitradau, ond mae'n ymddangos bod y rhain wedi gostwng er 2000. Gwelwyd gostyngiad mewn asideiddio hefyd mewn dyfroedd mynyddig, tra cafwyd cynnydd mewn carbon organig tawdd.

Yr Arolwg Cefn Gwlad sydd wedi cynhyrchu'r canlyniadau diweddaraf ar gyfer cyflwr a thueddiadau newidiol mewn uwchbriddoedd ledled Cymru yn y 25 mlynedd diwethaf. Mae canlyniadau wedi dangos na fu newid cyffredinol yn y carbon organig mewn priddoedd yng Nghymru. Roedd pH cymedrig y priddoedd wedi cynyddu'n sylweddol rhwng 1978 a 1998 a hyn oedd yn gyfrifol am ran helaeth o'r cynnydd sylweddol yn pH cymedrig y priddoedd rhwng 1978 a 2007: mae hyn yn dangos bod llawer o'r budd o leihau mewnbynnau asidig wedi'i weld yn barod. Fodd bynnag, yn achos Coetir Conwydd, Glaswelltir Asidig a Gweunydd Corlwyni ni chafwyd newidiadau arwyddocaol yn y pH cymedrig rhwng Arolygon nac yn ystod yr holl gyfnod rhwng 1978 a 2007: mae hyn yn adlewyrchu eu gallu clustogi a'u cyfraddau hindreulio isel ac felly eu cyfnodau ymadfer hir. Roedd canlyniadau a gofnodwyd yn adroddiad diweddar Asiantaeth yr Amgylchedd ar gynllun Glastir yn dangos bod 80% o'r holl gaeau a brofwyd yn rhy asidig ar gyfer y twf planhigion gorau. Mae hyn yn golygu bod perygl hefyd o ran trwytholchi i gyrsiau dŵr. Roedd dadansoddiad o ffermydd o dan Raglen Cefn Conwy yn dangos bod y pH is-optimaidd hwn yn ganlyniad i daenu llai o galch, am resymau economaidd yn bennaf. Mae data a gafwyd yn ddiweddar gan Asiantaeth yr Amgylchedd yn dangos bod lefelau P mewn 31% o'r caeau a brofwyd ar ffermydd yn is na'r lefel optimwm. Fodd bynnag, nodwyd mai priddoedd mynyddig oedd y rhain mewn llawer achos, sydd heb fod yn naturiol gynhyrchiol nac yn addas i gadw P. Serch hynny, roedd y ffigurau ar gyfer 32% o'r caeau ar fynegrif 3 neu'n uwch ac nid oedd angen mewnbynnau ychwanegol. Dim ond mewn 1% o'r caeau a brofwyd yr oedd lefelau uchel o P a oedd yn achosi perygl drwy drwytholchi. Yn ôl yr Arolwg Cefn Gwlad, roedd cyfanswm y dwysedd N mewn glaswelltir wedi'i wella yng Nghymru yn 2007 yn uchel o'i gymharu â gwledydd eraill a Phrydain Fawr gyfan. Glaswelltir Anffrwythlon a Glaswelltir Ffrwythlon oedd yr unig fathau o lystyfiant yng Nghymru lle'r oedd digon o bwyntiau samplu i roi ystadegau dilys ar gyfer da byw a newid: roedd y rhain yn dangos nad oedd cyfanswm y crynodiadau cymedrig o N wedi newid i raddau arwyddocaol rhwng 1998 a 2007 yn y naill fath o lystyfiant na'r llall. Roedd gwaith monitro o dan gynllun Tir Gofal yn dangos bod gaeafu gwartheg a defaid yn yr awyr agored yn achosi dirywiad yn ansawdd pridd ac yn dwysáu'r perygl o erydu pridd yn sylweddol. Mae hyn yn amlygu'r gwrthbwyso rhwng buddion dichonol (e.e. adar) a chanlyniadau negyddol (e.e. ansawdd pridd) mewn ymyriadau amaethyddol penodol.

Y nod wrth fonitro ansawdd pridd a dŵr o dan gynllun Glastir yw casglu tystiolaeth o effeithiolrwydd y cyfuniadau o ymyriadau rheoli o ran helpu i wella ansawdd pridd a dŵr mewn ffordd a fydd yn hybu'r canlyniadau sy'n gysylltiedig â'r newid yn yr hinsawdd, bioamrywiaeth, ansawdd pridd a dŵr ac ehangu coetiroedd. Am fod y dull monitro presennol yn gyfaddas i'r Arolwg Cefn Gwlad, gall wneud defnydd o’r cofnodion data hyn i ddeall a dehongli newidiadau mewn tueddiadau cenedlaethol o ganlyniad i effaith benodol y cyfuniadau o ymyriadau. Yn ogystal â hyn, mae angen monitro er mwyn casglu tystiolaeth i fesur statws a thueddiadau o ran ansawdd pridd a dŵr yn gyffredinol ar gyfer anghenion cofnodi eraill a bydd y gwaith hwn yn darparu sylfaen dystiolaeth wrthffeithiol bwysig. Drwy gyfosod a dadansoddi’r data hyn, ceisir dangos sut y mae’r ffactorau sy’n sbarduno newid, e.e. defnydd tir, yr hinsawdd a llygredd, yn effeithio ar yr amgylchedd yng Nghymru, yn ogystal â’r ymyriadau o dan gynllun Glastir. Bydd llawer o’r data o’r gwaith ar briddoedd yn darparu tystiolaeth ar gyfer y dadansoddiad integredig, a bydd hefyd yn cyfrannu at y gwaith modelu sydd wedi’i ddisgrifio yn yr adroddiad hwn ar gyfer cyfuniadau penodol o ymyriadau.

Gyda golwg ar fonitro dŵr a phriddoedd, nod GMEP yw egluro’r cysylltiadau gofodol ac amserol rhwng ymyriadau rheoli tir ac ansawdd dyfroedd croyw, yn enwedig mewn pyllau a rhagnentydd. Mae’r crynofeydd dŵr bach hyn yn adlewyrchu’r ardal o’u cwmpas, yn wahanol i’r afonydd a llynnoedd mwy sy’n adlewyrchu dalgylchoedd cyfan. Felly mae ansawdd cemegol ac ecolegol nentydd a phyllau’n ddangosydd da ar gyfer ymyriadau Glastir ac unrhyw effeithiau dichonol. Am y tro cyntaf mewn arolwg ar y raddfa hon, ac iddo’r cwmpas hwn, bydd y rhaglen yn archwilio macroinfertebrata, diatomau (mewn nentydd yn unig) a macroffytau er mwyn cynyddu ein gallu i adnabod patrymau a thueddiadau ecolegol, a’u cysylltu ag ansawdd pridd a dŵr. Bydd arolygon o gynefinoedd yn mesur dirywiad/ymaddasu mewn cynefinoedd, sy’n gallu dylanwadu’n fawr ar ecoleg a gwneud crynofeydd dŵr croyw yn fwy agored i effaith ffactorau pwyso eraill fel maethynnau, llifau isel neu waddodion mân. Bydd y dull cyfannol a ddefnyddir gan GMEP 1) yn rhoi mwy o allu i ganfod gwyriadau oddi wrth amodau llinell sylfaen/cyfeirio, 2) yn rhoi mwy o allu i wahaniaethu rhwng effeithiau ffactorau pwyso lluosog ac ymyriadau Glastir, a 3) yn ein helpu i briodoli rhesymau dros newidiadau i ansawdd ecolegol.

Ymgymerwyd â gwaith i sefydlu rhaglen monitro effeithiol ac effeithlon ar gyfer priddoedd a dŵr ym Mlwyddyn 1. Y prif gyflawniadau yw:

Dŵr croyw

- Hyfforddi 13 o syrfewyr i gyflawni’r protocolau safonol cydnabyddedig ar gyfer biomonitro mewn nentydd yn y 60 sgwâr astudio 1km. Roedd y dulliau’n gyfaddas i ddata EA/WFD a hefyd i raglenni monitro hirsefydlog eraill fel yr Arolwg Cefn Gwlad a’r Rhwydwaith Newid Amgylcheddol.
- Defnyddio technegau sefydledig a phrofedig ar gyfer pyllau (nid oes protocol safonol ar eu cyfer yn y DU/UE yn yr un modd â nentydd) sy’n gyfaddas i ddata’r Arolwg Cefn Gwlad, a data o arolygon pyllau a ddarparwyd gan yr Ymddiriedolaeth Cynefinoedd Dŵr Croyw.
- Cydymffurfio â safonau bioreolaeth cadarn a pholisi iechyd a diogelwch.
- Cyflawni’r arolwg cyntaf o’i fath sy’n monitro, ar yr un pryd, infertebrata dŵr croyw + diatomau (mewn nentydd yn unig) + macroffytau + cynefinoedd ffisegol + cyfansoddiad cemegol dŵr, mewn pyllau a nentydd.
- Sicrhau gwerth ychwanegol o waith mewn pyllau drwy waith olrhain moleciwlaidd ar fadfallod dŵr cribog

- Trosglwyddo'r holl ffurflenni cae ar gyfer y technegau biomonitro hyn i becyn meddalwedd cyfannol.
- Gweler hefyd y gwaith modelu ar lygredd gwasgaredig yn y bennod ar senarios.

Pridd

- Paratoi a threialu'r prif arolwg:
  - Hyfforddi 13 o syrfewyr i ddefnyddio dulliau samplu pridd.
  - Cynhyrchu ffilm hyfforddi 25 munud o hyd ar samplu priddoedd.
  - Datblygu protocolau labordy newydd a phrofi / prynu cyfarpar i wella effeithlonrwydd gan roi prawf ar ddulliau unigryw ar gyfer mesur bioamrywiaeth mewn pridd yn yr holl briddoedd yng Nghymru.
- Samplu uwchbriddoedd: casglu 1500 o samplau o 300 o leiniau ar yr un pryd ag arolwg botanegol parhaol gan ddefnyddio dulliau sy'n addas ar gyfer dadansoddi ffisegol, microbaidd, cemegol, carbon ac infertebrata.
- Newid yn yr hinsawdd:
  - Cwblhau gwaith profi cysyniad ar gyfer mesur newid yn uchder mawn drwy ddulliau synhwyro o bell.
  - Cwblhau gwaith profi cysyniad ar gyfer adnabod mawn noeth, sy'n agored i effaith erydu, mewn lluniau a dynnwyd o'r awyr.
- Erydu: mae BGS wedi darparu rhediadau model o erydu pridd gan ddŵr a gwynt gan ddefnyddio'r model PESERA ar gyfer Cymru. Gweler hefyd y gwaith modelu ar erydu yn y bennod ar senarios.
- Ffynonellau data allanol: casglu data am briddoedd o ffynonellau eraill gan gynnwys setiau data CNC er mwyn gwella a chymharu data a gasglwyd gan GMEP.

Ym Mlwyddyn 2 bydd nifer y sgwariau 1km yn yr arolwg yn codi o 60 i 90, felly bydd priddoedd yn cael eu samplu mewn 450 o leoliadau. Bydd creiddiau pridd yn cael eu samplu ar gyfer dadansoddi ffisegol, cemegol, biolegol ac infertebrata. Bydd y gwaith ar gronni mawn yn parhau, a bwriedir llunio methodoleg i'w chynnwys yn rhaglen monitro GMEP yn y dyfodol erbyn diwedd yr ail flwyddyn. Byddwn yn parhau i goladu setiau data perthnasol a geir oddi wrth sefydliadau eraill ac yn ymchwilio i'r posibilrwydd o'u hintegreiddio â data GMEP er mwyn adrodd ar dueddiadau cenedlaethol. Byddwn hefyd yn datblygu sgriptiau cyfrifiadur awtomatig i ganfod effeithiau o ymyriadau a throsglwyddo'r data i'r porth data drwy gydweithredu ag aelodau eraill y tîm. Bydd mwy o nentydd a phyllau'n cael eu harchwilio hefyd a chyflawnir yr un mesuriadau â'r rhai ar gyfer y sgwariau ym Mlwyddyn 1. Byddwn yn cydweithio â modelwyr dalgylchoedd LUCI er mwyn canfod yr effaith o leoliadau gofodol yr ymyriadau, nodweddion ar dir uwch a gweithgarwch o dan Glastir ar ansawdd dŵr croyw yn y sgwâr samplu.

Report Summary

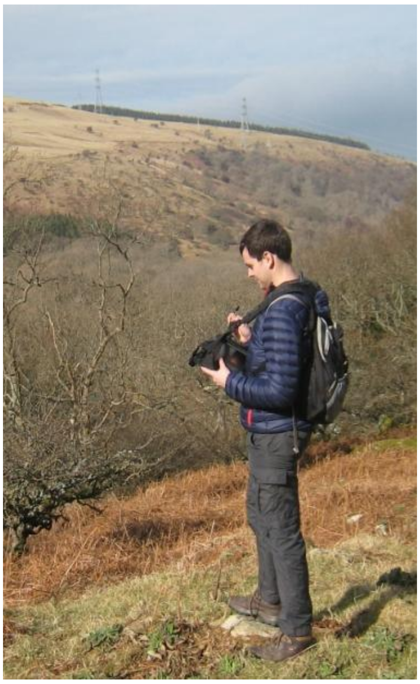
Introduction to the Glastir Monitoring and Evaluation Programme and team

The Welsh Government has commissioned a comprehensive new Glastir Monitoring and Evaluation Programme (GMEP) to monitor the effects of Glastir, its new land management scheme, and potentially contribute to the monitoring of progress towards a range of national and international biodiversity and environmental targets. This fulfils a commitment by the Welsh Government to establish a monitoring programme concurrently with the launch of the Glastir scheme. It is a major development from past monitoring programmes which have only reported after schemes have been closed. The project will also ensure compliance with the rigorous requirements of the European Commission's Common Monitoring and Evaluation Framework (CMEF) through the Rural Development Plan (RDP) for Wales within one of its four key areas (known as Axes) called "Our Environment and Countryside". The early findings from GMEP will provide fast feedback to inform negotiations for the next phase of the RDP. The data, models and tools collected and developed within GMEP will also help inform future planning of Wales' natural resources in a joined-up way to ensure the development of a green economy and the aspirations of the Environment Bill. The current two year programme will be extended by a further two years subject to successful completion of the first two year deliverables.

The GMEP team compromises a mix of organisations with different specialisations covering the different schemes activities, objectives and outcomes. The programme is led by the Natural Environment Research Councils' Centre for Ecology & Hydrology Bangor, an independent public research body. The project consortium includes ADAS, APEM, Bangor University, Biomathematics and Statistics Scotland, Bowburn Consultants, British Geological Survey, British Trust for Ornithology, Butterfly Conservation, ECORYS, Edwards Consultants, Freshwater Habitats Trust, St Andrews University, Staffordshire University, University of Aberdeen, University of Southampton, and Victoria University of Wellington, New Zealand.

The GMEP approach

A major part of the programme involves a rolling annual survey across Wales using an ecosystem approach. Measurements include a range of soil and water quality metrics, landscape features, plant and freshwater diversity, condition assessment of historic features, two pollinator and four bird surveys; all mapped to Glastir intervention measures and the five high level outcomes as prescribed by the Welsh Government. Work to look at past data on impacts of agri-environment schemes and on-going trends is central to the programme's data and evidence activities. Examples of wider data and evidence utilisation include; historic data held by the Biological Record Centre, British Trust for Ornithology and Centre for Ecology & Hydrology's Countryside Survey. The utilization of wider evidence and data will enhance the power of evaluation and also provide a long term historic backdrop. More workshops will be held with a range of specialist monitoring organisations and Natural Resources Wales in Year 2 to ensure full use of data and evidence captured through wider past and current monitoring programmes.



To our knowledge, this will constitute the largest and most in-depth ecosystem monitoring and evaluation programme of any Member State and Managing Authority within the European Union. Many novel elements included are: an ecosystem approach to enable robust analysis of trade-offs and co-benefits; a rolling monitoring programme running parallel to the scheme to provide fast feedback; a major contribution from modelling; incorporation of social and economic analysis; application of new methods such as molecular technique for soil biodiversity, satellite data for peatland condition monitoring and mobile flux towers for measuring greenhouse gases. These will all help to increase efficiency, improve data quality and help ensure the breadth of Glastir impacts on the Welsh landscape, farmers and wider society are reported.

Major achievements by the GMEP team in its inception year Sept 2012 – August 2013 are presented in this report with key 1st year results for each of the five outcomes outlined below starting with results from a major modelling exercise to estimate potential effects of some Glastir interventions at the farm and national scale.

Future scenarios of Potential Glastir Impacts

Glastir land management options are expected to evolve with changing policy priorities and emerging evidence on the effectiveness of options. Computer modelling of scheme outcomes will be a key decision making tool in this process, and was used in a quantitative assessment of the impacts of the fore-runner agri-environment schemes that was able to link modelled pollutant pressures with the measured chemical and ecological status of freshwaters in Wales (Anthony *et al*., 2012). Computer models synthesise the available evidence and our best understanding of the state and sensitivity of the natural environment. They provide an opportunity to interpolate and project long-term outcomes at landscape scale, allowing policy analysts to evaluate and rank scheme outcomes relative to targets. Specifically for this programme of work, they provide estimates of changes in pollutant emissions that are difficult to measure directly, for reasons of scale or cost, such as greenhouse gas emissions. Where measurements are available, they can be compared against model predictions to verify the representativeness of the monitoring framework.

Most importantly, computer models provide an opportunity to quantify multiple outcomes and apportion impacts between the many changes in land management associated with a scheme. Many of the land management options under Glastir have multiple impacts on, for example, water quality, mitigation of climate change, plant communities, and provision of habitat for birds and animals. By collating outputs from an ensemble of models from the different sciences it is possible to provide a more complete assessment of the benefits of the Glastir scheme and to identify the most effective elements, enabling policy makers to explore trade-offs and iterate the scheme design faster.

A key objective in the first year of the Glastir monitoring and evaluation programme was therefore to demonstrate the use of an ensemble of modelling tools to scope the potential outcomes of representative Glastir land management options. The 'Future Scenarios' chapter reports on the application and future potential of computer modelling frameworks to quantify the impact of representative Glastir management options on each of the intended Glastir outcomes: biodiversity; climate change mitigation; soil and water flow and quality; and woodland expansion and management. The intent of this work was to demonstrate the potential for an ensemble of models to project the multiple outcomes of management options, for a) provision of estimates of changes in pollutant emissions and eco-system services that are difficult to measure directly; b) evaluation of the relative benefits of individual management options and refinement of the Glastir scheme design in advance of direct measurements of impacts becoming available; and c) quantification of the multiple benefits that arise from a spatially explicit and eco-systems services approach to the targeting of options. In summary, achievements in the first year are:

- Three models (WDP-EMP, LUCI and MultiMOVE) with the capability to provide both local and national projections were set up and augmented as appropriate to calculate the potential impacts of 6 Glastir land management options using consistent baseline conditions and scenarios of scheme participation as agreed with the Welsh Government. These were:
    - Retain Winter Stubbles
    - Allow Woodland Edge to Develop Out into Adjoining Field
    - Grazing Management of Open Country
    - Grazed Permanent Pasture with No Inputs
    - Create Streamside Corridor with Tree Planting
    - Mechanical Bracken Control
- The models calculated the potential impacts of the maximum implementation of each option on the relevant areas of participating farms on plant community structure; connectivity of woodland habitats; flood generation; nutrient and sediment losses to rivers and lakes; greenhouse gas emissions; and carbon storage. Not all models were applicable to all interventions or all outcomes. Three scenarios of low, medium and high uptake were explored and assumed maximum implementation of the relevant options of participating farms which it should be noted is likely to significantly overestimate outcomes. Information on actual area of land in agreements was not available.
- Individual Glastir prescriptions resulted in the expected changes in habitat suitability for 75% of the 21 plant species modelled, resulting from de-intensification of vegetation management and changes in soil properties. Significant progress towards target habitat suitability scores was made within 10 to 23 years of uptake of options.
- Individual Glastir prescriptions that result in a reduction in farm inputs and overall stock numbers on farm habitat areas generally delivered small (<1%) national reductions in both eutrophying and climate forcing pollutant emissions. Local pollutant reductions were several times greater within Priority Catchments that have large areas of relevant land and are targeted for scheme enrolment. Change in the overall carbon footprint (which includes embedded greenhouse gas emissions) for specific farms could be as high as 26% (see Section 5.4).
- Large reductions in national nitrate leaching, nitrous oxide and methane emissions of 5 to 10% were achieved by with-holding nitrogen fertiliser and reducing stocking rate on the larger improved grassland area.

- Glastir prescriptions to introduce streamside corridors with trees and extend existing woodland parcels increased the area of woodland by *ca.* 10,000ha and national carbon storage by less than 1%. The gain in accessible land for 'generic' broadleaf focal species (a type of bio-indicator) through increased woodland connectivity was 3 to 12% with a potential reduction in flood generating land of 1 to 9% due to these two woodland options. The prescriptions also have a significant potential to reduce the connectivity of erodible land to rivers and lakes, and were projected to reduce eroded soil and phosphorus delivery by up to 15%. Areas generating high load that move through soils or vegetation with intercepting qualities en route were often shown to be of less significance to the overall water nutrient budget than more moderate-generation areas with no interception en route to the river. Embedded greenhouse gas emissions resulting from reduced stock numbers and associated fertilisers with these woodland interventions resulted in a 1 to 4% reduction in emissions at a farm scale (see Section 5.4).

- The scale of the model results suggests that the cumulative impact of uptake of a number of Glastir prescriptions can be significant. However, the outputs are based on the assumption of maximum implementation of options across all the relevant land area on a farm and a range of scientific assumptions embedded within the models. It is expected that the results presented are a large over-estimate of impact where there are barriers to implementation of an option, such as a loss of productivity resulting from the with-holding fertiliser applications or conversion of pasture to woodland. There is a critical need for a detailed analysis of the pattern of option uptake and a survey of the actual changes in farm management to quantify the limits to uptake and establish the true level of additionality. The planned GMEP Farmer Practice Survey for 2016 and more detailed information on agreements from Welsh Government will inform future model applications.
- It should also be noted that possible changes in environmental goods and services outside of Wales to compensate for any reduction in production within Wales is not accounted for.

Future modelling work will prioritise use of the LUCI model to calculate the benefits of targeted placement of management options on farm, to maximise the multiple outcomes of relatively small areas of option uptake; application of the MultiMOVE model to the whole of Wales; and scoping of the impacts of management options not included in the current scheme design using the WDP-EMP model for consideration by the Welsh Government.

The field survey

The field survey sits at the heart of the GMEP programme. The aim is to provide the main evidence base for ongoing change in the countryside (a Wider Wales Component) against which the impact of Glastir interventions can be evaluated using a Targeted Component (TC). The Targeted Component sample areas are selected according to the points structure for the Advanced element of Glastir and therefore reflect the current priorities for Glastir outcomes. This approach combined with an integrated ecosystem approach to data collection means the survey is flexible over time as the Welsh Government's priorities change over the first 4 years of the programme. A common sampling unit of 1km x 1km square was selected for both components to ensure a practical sampling unit which would allow outcomes from species to landscape to be evaluated. We have not taken a paired farm-unit approach due to the limitations, including redundancy and biases that can result. The 1km squares are surveyed on a rolling programme with squares re-visited every 4 years. This has several advantages including; (i) maximising efficient use of resources, (ii) capturing year-to-year variation, (iii) providing early data to test and parameterise models such that early feedback to the Welsh Government can be provided, and (iv) ensuring trade-offs and co-benefits are captured which would be missed if e.g. separate bird, plant and soil surveys were not co-located.

The Field Survey chapter describes all the field methods in detail with a full list of all measurements and data contained within an Appendix. In summary, achievements in Year 1 are:

- Statistically robust and flexible nationwide survey designed, based on rolling programme and sampling unit chosen to include a the Wider Wales Component (WWC) used for baseline estimation, national trends and national reporting of Glastir, and a Targeted Component (TC), which specifically links to the priority areas and aims of the Glastir scheme.
- The first year of survey was completed successfully. 60 1km squares were surveyed for a wide range of ecosystem properties including birds and pollinators, soils and headwater streams, historic features and footpath condition, hedgerows and woodlands. Examples of the scale of the survey include:
  - 1726 botanical plots surveyed.
  - 1500 soil samples taken from 300 plots coincident with permanent botanical survey using methods appropriate for physical, microbial, chemical, carbon and invertebrate analysis.
  - 2043 point features identified and assessed.
  - 4 separate surveys of birds (April – July).
  - 2 separate surveys walking a 120km of transect to count butterfly species, bee and hover groups plus timed searches within 9000m^2.
  - 790 km of linear features (hedgerows, stream banks etc).
  - First survey of its kind to simultaneously monitor freshwater invertebrates, diatoms (streams only), macrophytes, physical habitat, water chemistry, in both ponds and streams.
  - 47 historic features assessed for their condition.
  - 960 landscape photos taken.
- Landowners granted access to 82% (scheme and none scheme holdings) of the total land area within the 60 1km squares. In years 2-4 the number of squares will be scaled up to 90 squares per year to create a total sample are of 330km^2 (33,000 ha.). By year 4 the relative split between scheme and none scheme holdings within this sample area will be approximately 50 / 50 with the expected Glastir uptake of *ca.* 4500 individual farms which will ensure a robust counterfactual against which to evaluate scheme impact.
- 13 field surveyors were successfully recruited and trained and bespoke field survey software was developed.
- Quality control was carried out by independent surveyors who cross-checked 12% of all survey squares.
- Surveyors collected data using a ruggedized tablet which automated the import, transfer, backup, and completion of survey data.

- Full bio-security measures were put in place to cover both plant and animal diseases. Farmers were also asked if there were any known plant or tree diseases and surveyors avoided these infected areas.

Biodiversity

The goal of sustainable rural development within the EU Rural Development Programme seeks to achieve economically and ecologically sustainable use of land and water. This recognises a requirement for reversing ecosystem degradation and the loss of underpinning biodiversity. In Wales, the Glastir scheme is a significant component of the Rural Development Programme and so contributes to fulfilling a number of statutory obligations and targets relevant to biodiversity. These are derived from agreements as global (Aichi targets), European (European Union Biodiversity Strategy (EUBS) plus Habitats and Birds Directives) and UK levels (Wildlife and Countryside Act and Natural Environment and Rural Communities Act). Of particular significance is target 3 of the EUBS that aims to 'increase the contribution of agriculture and forestry to biodiversity'. Since 81% of Wales is farmed, agri-environment scheme funding is seen as one of the most important mechanisms for delivering a large-scale re-balancing of production, ecosystem service supply and biodiversity to achieve sustainable rural development. The Biodiversity chapter describes progress and future plans for assessment of the outcomes of the new Glastir agri-environment scheme on Welsh biodiversity. We apply a combination of approaches including data collection within the 4 year rolling monitoring programme, modelling and analysis of existing monitoring schemes. In summary achievements in Year 1 are:

- Habitat, plant, bird and pollinator surveys completed in all GMEP squares with protocols modified specifically to optimise detection of Glastir impacts.
- Habitat keys updated in consultation with NRW including changes to indicator species lists and updates.
- Preliminary assessment of the extent to which the distribution of the planned GMEP survey squares overlaps with those of priority species and habitats of conservation interest, exploration of three case studies and mapping of interventions with measurements to identify if direct or proxy measures will be reported.
- Assembly of contextual datasets to enable estimation of future Glastir impacts on biodiversity in light of the legacy effects of past schemes and the past and ongoing impacts of other drivers such as climate, land-use and air pollution.
- Application of the MultiMOVE niche model ensemble to explore forecasting of the effects of Glastir prescriptions on plant species. MultiMOVE was applied to two test catchments and four measures. 21 plant species were modelled where each was drawn from existing Countryside Survey plots representing the catchment land classes and habitats targeted by each prescription in Wales. Of the total number of species and measure-specific projections run for common species, 30 (75%) were consistent with the expected impact of Glastir however these changes were projected over relatively long periods.
- Production of new 10km plant species pools based on distribution data holdings and corrected for over and under-recording. These species pools were subsequently used to aid species selection for MultiMOVE modelling.
- Completion of trends analysis for Welsh species groups collected by volunteer schemes. Of the species with sufficient data for analysis, 10 out of 18 taxonomic groups had a net

negative trend from 1970 onwards with the remaining 8 taxonomic groups showing a positive net change trend. Common species are out-performing rare species in terms of the change in the probability of observing a species between 1990 and 2000.

- Completion of a first version of a Watchlist Indicator for species trends in Wales
- Preliminary work testing spatial metrics of habitat connectivity.
- Compilation of criteria and datasets for testing the definition of High Nature Value Farmland in Wales and measuring its present and future extent and ecological condition.
- Initiation of work to extrapolate outside of 1km GMEP squares using remote sensing data so as to enable inference of monitored and modelled quantities across Wales.

Climate Change and Diffuse Pollution Mitigation

Agriculture is a significant source of diffuse water pollution and greenhouse gas emissions in Wales; whilst some agricultural practices are also responsible for losses and gains of soil carbon. The Welsh Government has set national targets to improve water quality and reduce greenhouse gas emissions, and the agricultural sector is expected to contribute to the meeting of these targets. In consequence, the Glastir scheme has been developed with sufficient flexibility to target priority themes (such as soil carbon) in a spatial context, and introduce measures on farms to e.g. enhance carbon sequestration, reduce greenhouse gas emissions and diffuse water pollution from the agricultural sector. The Welsh Government has prioritised funding for interventions focussed on climate change mitigation and diffuse water pollution for Years 1 and 2 of the scheme.

As a first step to determine the potential impacts of Glastir on diffuse water pollution, greenhouse gas emissions and carbon sequestration, The Welsh Government has tasked the Glastir Monitoring and Evaluation Programme to assess the potential impact of Glastir interventions on these priority areas through modelling, a Farmer Practice Survey to identify actual changes on the ground, and additional work to identify the wider benefits of the Glastir Efficiency Grants.

In summary, achievements in first year are:

- Assessment of the greenhouse gas sources and carbon sequestration, which each of the modelling tools has the capacity to estimate (e.g. soil methane, enteric methane, embedded emissions)
- Mapping of four modelling approaches to Glastir intervention measures, by the Expert Panel
- Application of the Bangor footprinting life cycle approach on 16 model farms for four Glastir intervention measures to quantify changes in greenhouse gas emissions from on-farm sources, as well as embedded emissions associated with feed and fertiliser production. Estimates of the potential outcome of 4 intervention measures were a 0-24% decrease in carbon footprint.
- Population of the ADAS modelling tool at the national scale for five Glastir interventions to assess potential changes in gaseous emissions (nitrous oxide, methane) and diffuse water pollution (nitrogen, phosphorus and sediment)

- Acquisition of datasets for future spatial modelling using the ECOSSE model
- Developed a draft protocol for the repeat Wales Farm Practice Survey, including the proposed stratification strategy, for discussion with funders and the wider programme project team
- Planned the approach for assessing the impact of Glastir Efficiency grants on i) the carbon footprint of farms which have made use of them, and ii) the wider (off-farm) benefits to the rural economy

Landscape and Historic

Wales is typified by some of the finest mountain and coastal scenery in Europe, as well as small-grained farmed landscapes and heritage landscapes of national and international significance (WLP, 2009). Landscapes provide the framework for our natural capital and the individual components which create this wealth –habitats, species, culture, geology, and the human economic activity which takes place within them, all contribute to their development. As such, landscapes are not just "snap-shots" rather they provide direct and visible evidence of centuries of human activity. The rich and distinctive nature of Wales's historic environment is revealed through its historic landscape character (fields, moors, lanes, settlements *etc*.) and is further manifested in its unique endowment of archaeological sites, field monuments and other material remains. There is clear recognition of the significant contribution of the historic environment to quality of life in Wales. The recent Historic Environment Strategy for Wales (Welsh Government, 2013) is focused on actions to enable the protection of Wales's heritage while also encouraging public access, enjoyment and participation. The historic environment comprises a diverse set of assets ranging from formally designated sites to locally important landmarks and features. Across Wales there are 3 World Heritage Sites, 428 registered historic landscapes, parks and gardens, 519 conservation areas, 4,000 scheduled ancient monuments and 30,000 listed buildings. There is evidence that such assets contribute to a range of benefits spanning job creation, tourism, place-making, identity, education and community involvement. Research to assess the value of the historic environment in Wales (ECOTEC, 2010) estimated that the sector supports over 30,000 jobs and contributes around £840 million to national gross value added (GVA). Some of the most popular visitor attractions in Wales are heritage sites, including Conwy Castle which attracted over 160,000 visitors in 2012. The historic environment is widely used in the promotion of Wales as a destination and is one of most popular reasons cited by visitors in Visit Wales research of visitor motivations. However, the strategy identifies a need for action to increase accessibility, understanding and engage under-represented groups. The cost of maintaining and restoring assets is also a significant challenge. The Programme for Government, set out in 2011 for the current Assembly term, includes an aspiration to enrich the lives of individuals and communities through culture and heritage with a longer-term goal to increase the percentage of historic environment assets in a stable or improved condition. The 2013 update reports that public engagement with heritage is growing and there has been some success in strengthening the place of the Welsh language in everyday life and the percentage of historic environment assets in a stable or improved condition is estimated at just over 78%.

Landscape quality is an inherently subjective concept, the measurement of which is dependent on a variety of factors, including where the assessment is made, when it is made (time/season/weather) and, critically, on who is making the judgment. The key challenge in landscape studies and for the GMEP project is therefore to define a method which can measure components of quality in quantifiable and repeatable ways and this is a key output of the first phase of the landscape component of the GMEP work. Major achievements in the first year to address this challenge are:

- The construction of detailed 3D datasets for all 60 1km^2 study sites which take into account both landscape topography and small-scale landscape features which constrain the visibility of the landscape (e.g. significant trees, boundaries such as hedgerows, buildings, woodlands).
- The construction of 3D datasets at 5m resolution for a 3 x 3km area surrounding each of the 60 study sites.

- The extraction of a complete Public Rights of Way (PROW) network for different classes of user (walker, cyclist, horse-rider, small vehicle, large vehicle) for all 60 sites.
- The collation of a visual record of all 60 sites from both fixed point photography completed during the field survey (16 per site), and from the collation of nearly 200 publically contributed photographs of these 60 sites to the geograph website (http://www.geograph.org.uk/), with typically 4 additional photographs provided per site (Figure 6.1.1).
- The construction of detailed 3D viewsheds based on the PROW for all 60 1km^2 study sites. In addition, we have also coded the methods to calculate the viewsheds from each 1km study site looking out to the surrounding 3 x 3km, as well as the contribution that the 1km study site makes to the landscape view looking in from the surrounding 3 x 3km area. This is a quantifiable measure of how "visually accessible" this landscape is to the general public.
- The extraction of all historic environment features for the 60 sites.
- An assessment of historic feature condition has been successfully incorporated into the field survey, building on field notes provided by the archaeological trusts. This will yield a timely and significant new set of survey data about historic sites' condition.
- The development of a unique Visual Quality Index (VQI) to quantify the landscape value of each 1km study site. This includes five key components: topography (how rugged / varied the landform is); "blue-space" (water features in the landscape); "green-space" (habitat diversity, vegetation complexity); anthropogenic (built components); historic / cultural (including presence of Scheduled Ancient Monuments *etc*).

A key development during spring 2014 will be the development of landscape visualisations to illustrate future landscape changes on the target sites instigated and paid for through Glastir and preference surveys will be used to evaluate the public response. As part of the landscape component, we will be making use of cutting-edge, computer-gaming visualisations to produce ecologically correct future landscapes. These visualisations will be grounded in reality, with all of the vegetation based on the survey information collected in the field by the ecologists and changes in these wooded structures will follow ecologically realistic growth patterns for Wales. The user will be able to "walk through" the landscape which will be made available online and will not only gather the views of Welsh citizens, but also of potential visitors to Wales from across the globe. Far from being a gimmick, these visualisations are now of such a quality that they can be used to engage the view of young people and those members of the Welsh public (perhaps in more urban locales / potentially socially disadvantaged areas) with regards to the shared landscape assets of Wales which they are all paying to help protect. We believe that this will be the first time, such high quality and ecologically correct landscape visualisations will be created and used for such public engagement purposes.

Woodlands

Woodlands are important for the provision of multiple Ecosystem Services, goods and benefits including timber, soil protection, flood prevention, recreation, climate regulation and wild species diversity (for both generalists and woodland specialists). Many of these services are additive and there are synergies between services rather than trade-offs, woodlands are multi-functional habitats. The environmental benefits of woodlands in Wales have been valued at £34 million (Read *et al*. 2009). A recent survey demonstrated that nearly 65% of people in Wales visit Welsh woodlands regularly and 94% believe they provide a definite benefit to the local community. The National Forestry Inventory estimate the total area of all woodland in Wales in 2010 to be 303.5 000 ha, 14% of Wales. The Inventory also estimated that between 2001-2010 the area of broadleaved woodland increased by 16000ha and the area of conifers decreased by a 13000ha. In Wales, only broadleaf-dominated woodland is native, and this type is the main focus of nature conservation interest. It includes seven Priority Habitat types recognised in the UK Biodiversity Action Plan. The Woodlands for Wales indicators report (2012) showed that the population trends of the majority of species of conservation concern are still unknown, however, the population declines of red squirrels and floating water plantain had been stabilised, declines of the pearl bordered fritillary, the great crested newt and Juniper were slowing and the population increase of black grouse had stabilised. There was no significant trend in the woodland bird index between 1994 and 2009.

The Welsh Government strategy 'Woodlands for Wales' was published in 2001 and revised in 2012. It promotes the design and management of woodlands to provide a wide and balanced range of ecosystem services. A set of 23 indicators have been developed to measure progress towards achieving the 20 high level outcomes outlined in the Woodlands for Wales's strategy. These include measures on extent, area of woodland of different types (urban, farm *etc*.) and how that is changing, habitat diversity and species, sustainability of woodland management, carbon balance, tree health, local benefits of woodland, accessibility, value of wood and water management; spanning the range of social, economic and environmental benefits. The Land Use Climate Change report recommended an expansion of woodland over 20 years by about 100 000ha (mainly deciduous but with a proportion of conifer) with tree provenance adapted to the projected climate. This initiative would create a GHG sink and a fuel wood potential. They also recommended management to ensure that woodlands do not become an annual GHG source and that Welsh woods are managed to optimize long term GHG abatement. Tree disease and tree health has risen sharply up the political agenda recently with the spread of diseases e.g. *Chalara fraxinea*, *Phytophthora ramorum*, sudden oak death, Dothistroma needle blight and the high number of potential threats that could adversely affect a number of species.

Glastir has a woodlands element which has been designed to support land managers to create new woodlands and manage existing woodland to promote ecosystem services; Biodiversity, Water, carbon, landscape, historic features and access. The woodland element provides area and capital grants for

- Thinning-allowing more light to enter the woodland top improve ground flora and natural regeneration.
- Restocking- improving species diversity.
- Infrastructure- managing previously inaccessible woodlands.
- Boundary work- to stock proof woodlands or improve stock management.
- Protected and priority species- grants to conserve important species.
- Vegetation management- to control invasive and exotic plants.
- Pest control- including grey squirrels and deer.
- Public access- to improve woodland access and provide visitor information.

The Glastir Monitoring and Evaluation Programme is using a combined survey and modelling approach to identify the benefits of Glastir interventions at the national scale. Progress to date in Year 1 includes:

- Field protocols agreed and implemented for recording of woodland habitats and species in GMEP survey squares which includes mapping of woodland habitat, dominant species, management information, land use, vegetation plots in small and large woodland patches and along woody linear features and bird and pollinator recording.
- Assembly of explanatory data to analyse changes in woodland extent and condition and impacts on other environmental and biodiversity response variables.
- Mapping of Glastir interventions to GMEP measurements and Woodland Plan for Wales
- Application of the MultiMOVE niche plant species model ensemble to explore forecasting of the effects of 2 woodland Glastir prescriptions (AWE 9b) Create streamside corridor on improved land with tree planting, (AWE 24) Allow woodland edge to develop out into adjoining fields (see Chapter 2).
- Application of the LUCI landscape ecosystem model to explore forecasting of the effects of 2 woodland Glastir prescriptions and their synergies or trade-offs with other services (see Chapter 2).
- Application of the WDP-EMF model to explore forecasting of the effects of 2 woodland Glastir prescriptions (see Chapter 2).
- Explored habitat connectivity metrics to develop methods for assessing impacts of Glastir measures on connectivity of woodland habitats (see Chapter 4).

Plans for Year 2 include:

Analysis of the impacts of Glastir woodland measures on ecosystem services and biodiversity using different analytical and statistical techniques and modelling described in detail in other chapters and creation of a Woodlands topic group will be formed to advise and comment on the objectives, analysis, and outputs of GMEP woodland work

Soil Natural Capital and water flow and quality

Farmers not only provide the food and nutrition supporting human existence, but they act as stewards of the land. Good stewardship can unlock nutrients from soils and manage water effectively to create and sustain biodiverse habitats. Conversely, poor understanding of best management practice, or poor stewardship, can lead to habitat degradation and a depletion of soil natural capital stocks. Farmers are often asked by society to tread a narrow path, producing food without degrading the landscape. Agricultural management and disturbance can be important for unlocking nutrition and enhancing water, soils and biodiversity, but too many inputs, over stocking, or emphasis on monocultures can lead to environmental damage. Aside from food production, water and soils fulfil important regulating and cultural ecosystem services. Clean water from reservoirs minimizes treatment for human consumption; soils can buffer floods and droughts which can cause major social and economic damage. Regulation of water quality and flows is inextricably linked with soils and their functionality. Moreover, soils control and regulate the recycling of waste and nutrients, but excessive nutrient inputs can lead to runoff and pollution of water bodies. Soils are a major carbon store and can either help to reduce climate change by sequestering CO_2 from the atmosphere, or in some circumstances add to climate change through methane and nitrous oxide emissions. Soil and water bodies also provide important habitat and gene pools; antibiotics were first extracted from soils and now fulfil vital roles in human and animal medicine. Soils and surface waters are vulnerable to degradation and threatened by over-intensive landuse, pollution and climate change, and must be managed with care.

The National Ecosystem Assessment reported that Welsh upland rivers are particularly vulnerable to acidification, while those draining more intensive agricultural land are at risk of eutrophication through nutrient loading. Recent assessments indicate that from 1990 to 2008 river water quality has improved. Nutrient loading is a major threat with 8% of Welsh rivers being regarded as high in phosphates, and monitoring indicating an increase in algal blooms during the 1990’s associated which high nitrate concentrations, which since 2000 appears to be declining. Acidification has also been observed to be declining in upland freshwaters, whereas Dissolved Organic Carbon (DOC) has been increasing.

Countryside Survey produced the most recent results for state and change trends of topsoil across Wales over the last 25 years. Results indicated no overall change in soil organic carbon in Wales. The mean pH of soils increased significantly between 1978 and 1998 accounting for much of the significant increase in mean soil pH between 1978 and 2007 indicating much of the benefit of reduced acidic inputs has already been gained. For Coniferous Woodland, Acid Grassland and Dwarf Shrub Heath however, there were no significant changes in mean soil pH between any of the Surveys or across the entire period between 1978 and 2007 reflecting their low buffering capacity and weathering rates and thus slow recovery times. Results reported in the recent EA report on Glastir found that 80% of all fields tested were too acidic for optimal plant growth, which also poses a leaching risk to water courses. Analysis of farms under the Cefn Conwy Programme revealed that this sub optimal pH is due to a reduction in lime application, primarily for economic reasons. Recent data from EA showed that 31% of farmers fields tested were below optimum levels for P, however, they note that in many situations this was on upland soils, which are not naturally productive, nor suited to retaining P. Conversely, 32% of fields were at index 3 or above requiring no extra inputs. Whilst only 1% of fields tested had very high P levels posing a leaching risk. According to Countryside Survey, total N density in Improved Grassland in Wales in 2007 was relatively high compared with other countries and with GB as a whole. Infertile Grassland and Fertile Grassland were the only vegetation types in Wales to have sufficient sample points to provide valid statistics for stock and change showing mean concentrations of total N did not change significantly between 1998 and 2007 in either vegetation types. Monitoring under Tir Gofal showed that outwintering both cattle and sheep caused a decline in soil quality and greatly exacerbated the risk of soil erosion. This highlights the trade-offs between the potentially positive benefits (e.g. birds) and negative consequences (e.g. soil quality) of individual agri-intervention measures.

The aim of the Glastir monitoring of soil and water quality is to collect evidence for the effectiveness of bundles of management interventions in helping deliver improved soil and water quality that will address the outcomes of interest related to climate change, biodiversity, soil and water quality and woodland expansion. The compatibility of the current monitoring with Countryside Survey means it can draw on this data record to understand and disentangle changes in national trends from the specific impact of intervention bundles. The monitoring is also required to collect evidence to quantify the status and trend of water and soil quality in general for other reporting requirements and this work will provide an important counterfactual evidence base. Synthesis and analysis of this data will seek to identify how the Welsh environment is being impacted by drivers of change, such as landuse, climate and pollution over and above Glastir interventions. Much of the data from the soils work package will not only provide evidence in the integrated analysis, but will also help support he modelling previously described in this report for specific bundles of interventions.

With regard to water and soils GMEP aims to elucidate the spatial and temporal links between land management interventions and the quality of freshwaters, in particular ponds and head water streams. These small water bodies reflect their surrounding area, unlike larger rivers and lakes that reflect whole catchments areas. Thus the chemical and ecological quality of streams and ponds are a good indicator of Glastir interventions and any potential effects. For the first time in a survey of this scale and scope, the programme will simultaneously survey macroinvertebrates, diatoms (streams only) and macrophytes to maximise the potential to detect ecological patterns and trends, and our ability to link them to soil and water quality. Habitat surveying will provide a measure of habitat degradation/modification, which can strongly influence the ecology and may make freshwater bodies more susceptible to other stressors such as nutrients, low flows or fine sediment. The holistic approach delivered by GMEP will 1) provide us with greater power to detect deviations from baseline/reference conditions, 2) enhance our ability to disentangle the effects of multiple stressors and of Glastir interventions, and 3) help us attribute reasons for changes to ecological quality.

Work to establish an effective and efficient monitoring programme for soils and water has been undertaken in Year 1. Major achievements include:

Freshwater

- Successfully trained 13 surveyors to deliver the recognised biomonitoring standard protocols for streams where they occurred in the 60 1km survey squares. Methods compatible with EA/WFD data and also other long running monitoring programmes such as Countryside Survey CS, Environmental Change Network.
- Delivered established and proven techniques for ponds (there is no standard UK/EU protocol as for streams) compatible with Countryside Survey data, and pond survey data provided by the Fresh Water Habitats Trust.
- Strict biocontrol and H&S policy were followed.
- Successfully delivered first survey of its kind to simultaneously monitor freshwater invertebrates + diatoms (streams only) + macrophytes + physical habitat + water chemistry, in both ponds and streams.
- Obtained added value on ponds through molecular tracer work on great crested newts
- Transferred all the field forms for all these biomonitoring techniques into a holistic software package.
- See also diffuse pollution modelling work described in the scenarios chapter.

Soil

- Main survey pilot and preparation:
  - Trained 13 surveyors in soil sampling methods.
  - Made a 25 minute training film of how to sample the soils.
  - Developed new lab protocols and tested / bought equipment to improve efficiency including methods tested for quantifying soil biodiversity uniquely for all Welsh soils.
- Topsoil sampling: 1500 samples collected from 300 plots coincident with permanent botanical survey using methods appropriate for physical, microbial, chemical, carbon and invertebrate analysis.
- Climate change:
  - Proof of concept work completed for measuring change in peat height using remote sensing.
  - Proof of concept work completed for identifying bare peat, susceptible to erosion, from air photos.
- Erosion: BGS has provided model runs of soil erosion by water and wind using the PESERA model for Wales. See also modelling work for erosion in the scenario chapter.
- External data sources: Gathered other sources of soils data including NRW data sets to enhance and compare data collected within GMEP.

In Year 2 the survey of squares will be expanded from 60, 1km squares to 90 meaning 450 locations will be sampled for soils. Soil cores for physical, chemical, biological and invertebrate analysis will be sampled. Work on peat accumulation will be on going, with the expectation of producing a methodology that could be incorporated into a future GMEP monitoring program by the end of the second year. We will continue to collate relevant datasets from other organisations and explore their potential for the integration with GMEP data to report on national trends. We will also develop automated scripts to detect impacts of interventions to deliver to the data portal in collaboration with the other team members. The number of streams and ponds surveyed will also increase with measurements repeated as for Year 1 squares. We will work with the LUCI catchment modellers to identify the impact of the impact of spatial location of interventions, upstream characteristics and Glastir activity on freshwater quality within our sample square.

1. Introduction

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The Welsh Government has commissioned a comprehensive new Glastir Monitoring and Evaluation Programme (GMEP) to monitor the effects of Glastir, its new land management scheme, and which potentially contribute to the monitoring of progress towards a range of international biodiversity and environmental targets. This fulfils a commitment by the Welsh government to establish a monitoring programme concurrently with the launch of the Glastir scheme. This is a major development from past monitoring programmes which have only reported after schemes have been closed. The programme will also ensure compliance with the rigorous requirements of 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”. The early findings from GMEP will provide fast feedback to inform negotiations for the next phase of the RDP. The data, models and tools collected and developed within GMEP will also help inform future planning of Wales’ natural resources in a joined-up way to ensure the development of a green economy and the aspirations of the Environment Bill.

A particular emphasis of the RDP and thus Glastir is to encourage actions that increase environmental sustainability. Specified outcomes required by the EU and the Welsh Government are 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. The GMEP programme will assess the cost-benefit of the impact of specific measures within an ecosystem framework and the wider benefits to society. The aim is to provide a scientifically-rigorous approach to the scheme replacing a fragmented array of existing monitoring projects with a programme which recognises the essential processes, functions and interactions among organisms and their environment. The adoption of this ecosystem approach recognises the potential co-benefits and trade-offs between individual intervention measures to be quantified and supports the ‘Living Wales’ agenda.

The first step in this approach is to improve the empirical evidence base for the current state and integrity / condition of Wales’s natural assets (termed natural capital)[1] and how these are changing in response to drivers such as climate change, land management practices and air pollution onto which Glastir interventions are superimposed. The second step is to isolate the changes connected to Glastir interventions itself. Changes in the extent and integrity of the natural capital in turn impacts on how well they can deliver the ecosystem functions and services we need and value. This link is currently not well quantified. The distinction between natural capital and services is important as capital is a longer term asset which we want to protect for the future and is hard to value it itself, whereas the services which flow from this capital are what economists and social scientists are able to value. This valuation step is an essential one if we are to provide a grounded framework for understanding the choices government and society face and considering the relative costs and benefits of Glastir policies including specific interventions - a requirement of the GMEP programme.

[1]The stock of our physical natural assets (such as soil, forests, water and biodiversity) which provide flows of services that benefit people (such as pollinating crops, natural hazard protection, climate regulation or the mental health benefits of a walk in the park http://www.official-documents.gov.uk/document/cm80/8082/8082.pdf

Natural capital covers a wide range of individual natural resources which come together as capital to deliver services. Biodiversity is assumed to be a critical component of this natural capital and thus essential to the provision of ecosystem services (Millennium Ecosystem Assessment, 2005). It is thought to be particularly important to increase resilience through functional diversity and redundancy of species and traits within the ecosystem and can be considered both a component of natural capital and a services or good in itself (Mace *et al.* 2012). However, different elements of biodiversity do not converge on the landscape with all ecosystem services and there are complex inter-relationships which are not fully understood. Thus attempts to maximise one service may in the loss of other services (*i.e.* Trade-offs). There is a need to better quantify these relationships preferably using a common scale of measurement to avoid false or incomplete conclusions concerning e.g. the contribution of 'within habitat' versus 'among habitat' diversity to ecosystem provision (Eigenbrod *et al*. 2010). Relationships between services are also unlikely to be linear but have optima or even tipping points. These issues can best be illustrated in an analysis of past monitoring work at Great Britain (GB) level where the coincidence of different components of natural capital and ecosystem service provision were explored using Countryside Survey data collected in 2007 from 591 1km squares (Figure1.1) (Maskell *et al*. 2013).

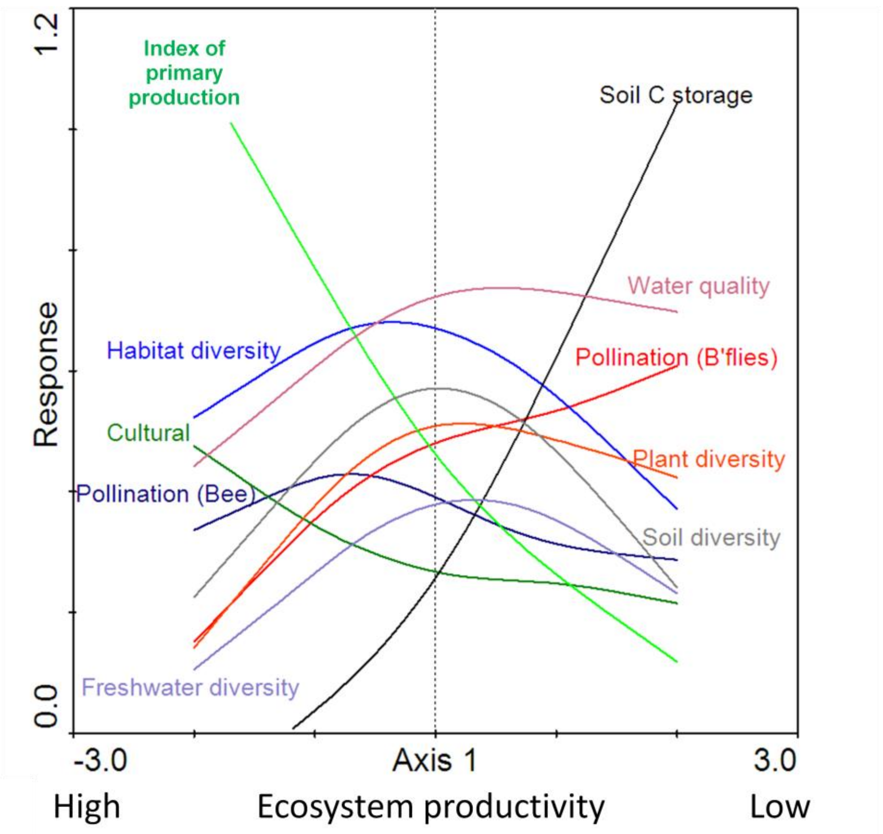


Figure 1.1 Ecosystem service indicator response curves at a GB scale derived from Countryside Survey (CS) 1km square data collected in 2007. Response curves of ecosystem service indicators are projected along the first ordination axis (fitted using Generalised Additive Models). A new analysis for Wales only data is presented in Section 4.11.2.

It is clear that biodiversity tends to be highest at intermediate levels of productivity as shown for GB analysis by Maskell *et al*. (2013). Soil carbon storage is greatest in low productivity systems e.g. peatland systems. Cultural services are aligned to semi-natural habitats. The results clearly show the non-convergence of different ecosystem properties and functions within the landscape as a whole and that primary production is the main explanatory variable for this. Decisions to promote one function will impact on another and this will differ along the production gradient. Future GMEP data will allow us to carry out similar analyses for different habitat types for both stock and, critically, for change. Differential lag times in the responsiveness to drivers of change such as Glastir interventions are to be expected and this approach can track that lag time concurrently for a suite of indicators Spatial trade-offs from local to national scale will also be explored for our 1km squares, test catchments and for Wales as a whole using the LUCI ecosystem model (Jackson *et al*. 2013) in Year 2.

Overall, the aim is to provide a robust evidence base as an on-going part of the scheme, to allow for fast iterative assessment of multiple outcomes and their inter-dependence and thus timely adaptation of scheme payments to maximise benefits. To our knowledge, this will constitute the largest and most in-depth ecosystem monitoring and evaluation programme of any member state and managing authority of the European Union with many novel elements including; an ecosystem approach, a rolling monitoring programme run parallel to the scheme to provide fast feedback, a major contribution from modelling; incorporation of social and economic analysis, and application of new methods where current baseline data or approaches are known to be poor. The approach has been published here (Emmett *et al*. 2013).

In summary there are six elements to the GMEP programme:

- A rolling survey programme which takes an ecosystem approach and includes a Targeted Component specifically for Glastir priority areas and a Wider Wales Component which aims to capture the national trends, counterfactuals and key baseline comparisons throughout the course of the survey (Chapters 3, 4, 7, 8). The approach is robust to possible future modifications to the Glastir scheme likely following CAP reform.
- Integration of data from existing and ongoing monitoring programmes into the GMEP analysis (3, 4, 7, 8).
- Testing of new methods to; i) more effectively quantify changes in peatland condition and carbon storage (Section 8.2.5.5), ii) establish baseline data for the greenhouse gas mitigation work focussed on the role of grassland management (Section 3.7.1), and iii) quantify changes in landscape quality (Chapter 6).
- A modelling component to; i) assess hard-to measure changes such as greenhouse gas emissions (Chapters 2 and 5), ii) upscale to include the wider landscape/catchment contextual information (Chapter 2), iii) quantify trade-offs, iv) explore scenarios for fast feedback to The Welsh Government (Chapters 2 and 5), and v) provide a hypothesis framework based on best available scientific understanding against which to test data as it emerges from the field survey (Chapter 2).
- A Farm Practice Survey to be conducted in 2016 will identify actual changes made by farmers in response to Glastir payments which will help inform analysis of the survey and modelling assumptions (Section 5.5.4), and an economics analysis to provide a cost-benefit analysis of the societal costs and benefits of Glastir.
- A data portal to make data publicly available in a user-friendly web interface maintaining farmer confidentiality and provide access to model outputs. In time, two of the models used by the team will be web-enabled for more general use together with tools to enable submission of data by the public to the GMEP data portal (Chapter 3).

The programme team involves 17 organisations led by the Natural Environment Research Council's Centre for Ecology & Hydrology, a public research organisation. The team reflects the ambitious aims of the Glastir scheme which requires monitoring from species to historic features, soils to economics, greenhouse gas emissions to access. All organisations have experience in large-scale monitoring programmes and many bring a wealth of existing monitoring data on which the team can build e.g. the Biological Records Centre, Breeding Bird Survey, National River Flow Archive and Countryside Survey. Combining data with long term trends from these sources will provide an important evidence base for a range of other national and international reporting requirements over and above that of EU RDP e.g. UK Greenhouse Gas Emission Inventories, biodiversity reporting from the global to UK scale (Aichi targets; European Union Biodiversity Strategy (EUBS) plus Habitats and Birds Directives; Wildlife and Countryside Act and Natural Environment and Rural Communities Act habitat reporting, Water Framework Directive *etc.* as well as informing policy development e.g. Payment for Ecosystem Services.

In our first year, the team have:

- Recruited and trained 13 field surveyors.
- Developed protocols and novel robust field data capture systems.
- Surveyed 60 squares once for vegetation, soils, water, historic features, habitat and linear features, landscape, 4 times for birds and 2 times for pollinators.
- Developed new databases to enable the validation, safe storage and dissemination of GMEP data, including the protection of site locations and personal information plus internal web sites with secure logins to share documents and transfer data to and from remote teams in the field.
- Purchased kit which is now being commissioned to build 2 new novel mobile greenhouse gas flux towers to remove the uncertainty concerning which types, and under what conditions, are Welsh Grasslands sources or sinks for greenhouse gas emissions to robustly test modelling forecasts.
- Commissioned work to test three new approaches to monitoring of change in peatland carbon accumulation rates for which there is no nationally accepted protocol
- Populated 2 models at national scale and 2 at local scales and run three scenarios for 6 diverse Glastir interventions.
- Engaged with *ca.* 20 organisations from NGOs, to government agencies, farmer representatives and industry with many more in-depth meetings planned particularly with the large number of conservation/species organisations for Year 2 now the drive to develop the field programme has been completed. (See Appendix 1.1 for a full listing and our Communication Plan Appendix 1.2).
- Organised 2 stakeholder meetings to explain the programme and identify possible co-working and established a Steering Group of 13 public and private organisations to help inform the programme and identify links and potential co-working with other organisations.
- Articles have been written for Farming Wales (Appendix 1.3); and a paper published on the overall methodology in Aspects of Applied Biology 118, 2013 (Appendix 1.4).

This first year report is structured around the work ongoing to report against each of the 5 outcomes starting initially with a report from our modelling teams who have explored potential national and/or catchment based outcomes for six Glastir interventions selected by The Welsh Government in the long term. The Welsh Government asked for this work to enable early review of expected outcomes.

Plans for Year 2 include:

- Survey of 90 1km squares.
- Interaction with various conservation / species organisations to identify additional data sources which can contribute to Glastir impact monitoring.
- Development of methods for the integration of long running monitoring scheme data with GMEP data and thus reporting of ongoing national trends and legacy of historic agri-environment schemes. Contribution to reporting requirements of a range of national and international reporting requirements where appropriate.
- Deployment of mobile greenhouse gas flux towers across grassland types in Wales.

- Further modelling applications to evaluate potential outcomes of additional Glastir interventions and the potential for interventions not currently included in the scheme.
- Exploitation of 3D gaming technology to assess landscape quality and perceptions.
- Explore trade-offs and win-wins for all 1km squares, test catchments (Conwy and Plynlimon) and for Wales as a whole using the LUCI model.
- Assess wider benefits of the Glastir Efficiency Grants and perceptions of the Commons element.
- Development and launch of GMEP website April 2014. Development of automated scripts to enable reporting direct from field capture scripts to a web data portal to be launched in April 2015.
- Stakeholder and Steering Group meetings and other outreach activities as opportunities arise.

A full list of milestones and outputs is presented in Appendix 1.5.

2. Future Scenarios of Potential Glastir Impacts

Anthony, S.[1], Smart, S.[2], Jackson, B.[3], Cooper, D.M[4], Emmett, B.A[4] and Jarvis, S[2].
[1]ADAS, [2]CEH Lancaster, [3]Victoria University of Wellington, [4]CEH Bangor

The Glastir agri-environment scheme provides financial support under Axis 2 of the Rural Development Pillar (RDP) to farmers in Wales to manage their land in a way that contributes to 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. The Glastir scheme is comprised of an All Wales Entry level element which is accessible to all farmers, an Advanced level element which targets issues of concern in pre-defined priority areas, a Common Land element, the Glastir Efficiency Grant Scheme aimed at improved resource and business efficiency and reduced carbon emissions, and a stand-alone Woodland Creation element (National Assembly for Wales, 2011). The All Wales and Advanced elements require farmers to choose from a list of land management options that have the potential to benefit biodiversity, reduce diffuse pollution from agricultural land and enhance a wide range of ecosystem services. Each management option is worth a number of points and farms have to meet or exceed a threshold to gain entry to the scheme. Entry to the Advanced element is competitive, with farmers receiving additional payments providing that management options are selected that address local requirements for environmental improvement and match the Welsh Government policy priorities. In the first two years of the Glastir scheme the scoring process for the Advanced element is weighted towards improved carbon storage and water management.

The scheme land management options and Advanced level selection process are expected to evolve with changing policy priorities and emerging evidence on the effectiveness of options. Computer modelling of scheme outcomes will be a key decision making tool in this process, and was used in a quantitative assessment of the impacts of the fore-runner agri-environment schemes that was able to link modelled pollutant pressures with the measured chemical and ecological status of freshwaters in Wales (Anthony *et al*., 2012). Computer models synthesise the available evidence and our best understanding of the state and sensitivity of the natural environment. They provide an opportunity to interpolate and project long-term outcomes at landscape scale, allowing policy analysts to evaluate and rank scheme outcomes relative to targets. Specifically for this programme of work, they provide estimates of changes in pollutant emissions that are difficult to measure directly, for reasons of scale or cost, such as greenhouse gas emissions. Where measurements are available, they can be compared against model predictions to verify the representativeness of the monitoring framework.

Most importantly, computer models provide an opportunity to quantify multiple outcomes and apportion impacts between the many changes in land management associated with a scheme. Many of the land management options under Glastir have multiple impacts on, for example, water quality, mitigation of climate change, plant communities, and provision of habitat for birds and animals. By collating outputs from an ensemble of models from the different sciences it is possible to provide a more complete assessment of the benefits of the Glastir scheme and to identify the most effective elements, enabling policy makers to explore trade-offs and iterate the scheme design faster.

A key objective in the first year of the Glastir monitoring and evaluation programme was therefore to demonstrate the use of an ensemble of modelling tools to scope the outcomes of representative Glastir land management options.

This chapter reports on the application and future potential of computer modelling frameworks to quantify the potential impact of representative Glastir management options on each of the intended Glastir outcomes: biodiversity; climate change mitigation; soil and water flow and quality; and woodland expansion and management.

The intent of this work was to demonstrate the potential for an ensemble of models to project the potential multiple outcomes of management options, for a) provision of estimates of changes in pollutant emissions and eco-system services that are difficult to measure directly; b) evaluation of the relative benefits of individual management options and refinement of the Glastir scheme design in advance of direct measurements of impacts becoming available; and c) quantification of the multiple benefits that arise from a spatially explicit and eco-systems services approach to the targeting of options.

2.1 Achievements in Year 1

- Three models (WDP-EMP, LUCI and MultiMOVE) with the capability to provide both local and national projections were set up and augmented as appropriate to calculate the potential impacts of 6 Glastir land management options using consistent baseline conditions and scenarios of scheme participation as agreed with the Welsh Government:
    - Retain Winter Stubbles
    - Allow Woodland Edge to Develop Out into Adjoining Field
    - Grazing Management of Open Country
    - Grazed Permanent Pasture with No Inputs
    - Create Streamside Corridor with Tree Planting
    - Mechanical Bracken Control
- The models calculated the impacts of the maximum implementation of each option on the relevant areas of participating farms on plant community structure; connectivity of woodland habitats; flood generation; nutrient and sediment losses to rivers and lakes; greenhouse gas emissions; and carbon storage. Not all models were applicable to all interventions or all outcomes. Three scenarios of low, medium and high uptake were explored and assumed maximum implementation of the relevant options of participating farms which it should be noted is likely to significantly overestimate outcomes.
- Individual Glastir prescriptions resulted in the expected changes in habitat suitability for 75% of the 21 plant species modelled, resulting from de-intensification of vegetation management and changes in soil properties. Significant progress towards target habitat suitability scores was made within 10 to 23 years of uptake of options.
- Individual Glastir prescriptions that result in a reduction in farm inputs and overall stock numbers on farm habitat areas generally delivered small (<1%) national reductions in both eutrophying and climate forcing pollutant emissions. Local pollutant reductions were several times greater within Priority Catchments that have large areas of relevant land and are targeted for scheme enrolment. Change in the overall carbon footprint (which includes embedded greenhouse gas emissions) for specific farms could be as high as 26% (see Section 5.4).
- Large reductions in national nitrate leaching, nitrous oxide and methane emissions of 5 to 10% were achieved by with-holding nitrogen fertiliser and reducing stocking rate on the larger improved grassland area.
- Glastir prescriptions to introduce streamside corridors with trees and extend existing woodland parcels increased the area of woodland by *ca.* 10,000ha and national carbon storage by less than 1%. The gain in accessible land for 'generic' broadleaf focal species through increased woodland connectivity was 3 to 12% with a potential reduction in flood generating land of 1 to 9% due to these two woodland options. The prescriptions also have a significant potential to reduce the connectivity of erodible land to rivers and lakes, and were

projected to reduce eroded soil and phosphorus delivery by up to 15%. Areas generating high load that move through soils or vegetation with intercepting qualities en route were often shown to be of less significance to the overall water nutrient budget than more moderate-generation areas with no interception en route to the river. Embedded greenhouse gas emissions resulting from reduced stock numbers and associated fertilisers with these woodland interventions resulted in a 1 to 4% reduction in emissions at a farm scale (see Section 5.4).

- The scale of the model results suggests that the cumulative impact of uptake of a number of Glastir prescriptions can be significant. However, the outputs are based on the assumption of maximum implementation of options across all the relevant land area on a farm and a range of scientific assumptions embedded within the models. It is expected that the results presented are a large over-estimate of impact where there are barriers to implementation of an option, such as a loss of productivity resulting from the with-holding fertiliser applications or conversion of pasture to woodland. There is a critical need for a detailed analysis of the pattern of option uptake and a survey of the actual changes in farm management to quantify the limits to uptake and establish the true level of additionality. The planned GMEP Farmer Practice Survey for 2016 will inform future model applications.
- It should also be noted that possible changes in environmental goods and services outside of Wales to compensate for any reduction in production within Wales is not accounted for.
- Future modelling work will prioritise use of the LUCI model to calculate the benefits of targeted placement of management options on farm, to maximise the multiple outcomes of relatively small areas of option uptake; application of the MultiMOVE model to the whole of Wales; and scoping of the impacts of management options not included in the current scheme design using the WDP-EMP model for consideration by the Welsh Government.

2.2 Modelling Frameworks

Three existing modelling frameworks were selected for demonstration purposes (see also Box 2.2.1):

- Wales Diffuse Pollutant Emission Modelling Framework – WDP-EMF (ADAS).
- MultiMOVE (Centre for Ecology & Hydrology (CEH)).
- Land Utilisation and Capability Indicator – LUCI (Victoria University Wellington (VUW), CEH)).

The modelling frameworks were selected as they are each capable of quantifying multiple land management outcomes for Biodiversity (MultiMOVE), Climate Change Mitigation (WDP-EMF and LUCI), and Soil Quality, Water Flow and Quality (WDP-EMF and LUCI) (Table 2.2.1). They are each sensitive to local soil and climate conditions, and have previously been applied in Wales.

Model Name	Biodiversity	Climate Change Mitigation	Soil and Water Flow and Quality	Landscape and Historic Features	Woodland Expansion and Management
WDP-EMF (ADAS)	-	Methane Emissions, Nitrous Oxide Emissions, Carbon Dioxide Emissions	Water Balance; Soil Erosion; Nutrient Leaching;	-	-
LUCI (VUW/CEH)	Habitat Augmentation Suitability	Carbon Sequestration	Flood Mitigation, Soil Erosion, Nutrient Leaching	[Landscape Valuation – *Under Development*]	Woodland Habitat Connectivity, Carbon Sequestration
MultiMOVE (CEH)	Habitat Suitability and Plant Abundance	-	-	-	Habitat Suitability and Plant Abundance

Table 2.2.1 Model functionality and the link to intended Glastir outcomes.

Box 2.2.1 Modelling Frameworks

MultiMOVE – CEH (Smart *et al.,* 2010b) The modelling framework is an ensemble of three statistical modelling techniques (Generalised Linear Models, Multiple Adaptive Regression Splines and Generalised Additive Models) that are used to predict species occurrence from climate variables, soil pH, soil moisture, carbon to nitrogen ratio and canopy height (Smart *et al*., 2010b). These variables define the essential features of the realised niche of each plant species. The ensemble is used to project changes in plant communities based on measurements or projections of the impact of changes in agricultural inputs to soils and the intensity of vegetation removal. The model has also been used to project changes in response to climate change and air pollution through their impact on these biophysical properties. The model is a significant expansion of the climate envelope approaches which fail to capture other abiotic constraints on plant distributions. The MultiMOVE ensemble first produces probability of occurrence values for each species. Interpreting these directly is problematic because rare species will have a lower maximum probability at their niche optimum than common species simply because of differences in prevalence across the sampled region used in training the models. It is more informative and sensible to use the models to estimate the suitability of conditions for each species on an equal basis for all species. This places the emphasis on the potential of the habitat to support the species *if it were in the local species pool* and reduces emphasis on outputs as a prediction of presence. Modelled change in habitat suitability is therefore reported as percent progressed from a baseline towards the habitat suitability scores for a target habitat (Van den Berg *et al*., 2011). (See Appendix 2.3)
Wales Diffuse Pollutant Emissions Modelling Framework – ADAS (Anthony *et al.,* 2012) The modelling framework is an integration of existing policy models for the catchment and national scale simulation of nutrient, sediment and greenhouse gas emissions from agriculture. The framework was developed for and applied to calculating the impact of the Tir Cynnal, Tir Gofal and Organic Farming schemes under previous project 'EcoSystems Lot 3' for the Welsh Government. Climate average quantities of pollutants lost are calculated by application of a range of empirical and process based models including PSYCHIC (Davison *et al*., 2008) for phosphorus and sediment, and N-CYCLE, NITCAT and MANNER (Scholefield *et al*., 1991; Lord, 1992; Chambers *et al*., 1999) for nitrate, and IPCC tier one and two methods for methane and nitrous oxide (Baggott *et al*., 2006). Carbon dioxide emissions from energy use on farm are also calculated using the methods and source data reported by Metcalfe (1996) and Cormack (2000). The models require detailed data on crop areas and livestock numbers, and fertiliser and manure practices that are sourced from national surveys of farm management. The contributing models have been enhanced and integrated to provide an explicit source apportionment of emissions by pollutant source, farm area and delivery pathway for farm system types across Wales. Scheme land management options result in a percentage reduction again emissions from targeted coordinates. The reductions may be trivially calculated if the management option maps directly to a modelled pollutant source (*e.g*. a reduction in fertiliser nitrogen) or are based on a synthesis of experimental literature and further computer modelling for representative scenarios. The framework links to a library of *ca.* 100 changes in land management (Newell-Price*, et al*., 2011).
Land Utilisation and Capability Indicator – VUW/CEH (Jackson *et al.,* 2013) The modelling framework is a second-generation extension and software implementation of the Polyscape framework described in Jackson *et al*. (2013). LUCI is designed to investigate the impact of sub-field scale interventions, tracking impacts of cumulative interventions from farm scale to catchment to regional/national scale. It considers both current and potential impacts of land management change on a range of single service criteria, and also evaluates where trade-offs or "win-win" opportunities for existing or potential ecosystem service delivery exist. The LUCI services considered in this chapter are 1) broadleaved habitat network connectivity; 2) capacity of the landscape to reduce flood water entering streams/rivers; 3) sediment delivery to streams/rivers; 4) nutrient delivery to streams/rivers (nitrogen and phosphorous); and 5) carbon sequestration. The algorithms require as inputs high-resolution topographical data, soil and land cover information, climate information, all available at the national scale and (for the purposes of applications such as this) spatially explicit intervention data. Climate data and drainage network data further refine predictions. A large number of parameters derived from literature and supplemented by expert knowledge where literature studies do not cover all possible combinations are accessed through look-up tables relating individual land cover, land management and soil types to quantities such as infiltration threshold, erodibility, capacity to store soil carbon, nutrient export, *etc*. LUCI's uniqueness lies in the ability to exploit; (i) national data for local applications, (ii) test impacts of sub-field interventions and the impacts beyond the area directly modified, and (iii) to spatially explore trade-offs between services.

2.3 General Modelling Approach

The selected modelling frameworks take very different approaches to calculating the baseline state of the environment and the impacts of land management options. The MultiMOVE framework is based on statistical relationships between observed abiotic conditions and plant communities. The WDP-EMF framework is based on process based models that generally describe environmental processes at field scale, whereas the LUCI framework is based on explicit spatial modelling on a sub-field scale raster model and explicitly tracks the movement of pollutants from field to farm and catchment scales. However LUCI does not consider detail of farm management such as specific crop or stocking type, slurry treatment, *etc.,* as the WDP-EMF modelling framework does. The frameworks are driven using existing national stratified survey and spatial datasets on, for example, land cover, soil properties and farm practices that allows scaling of outputs to provide catchment and national scale results.

Details of each framework are provided in Box 2.2.1. Only an overview of the modelling approach is given here.

2.3.1 Wales Diffuse Pollutant Emissions Modelling Framework

The ADAS modelling framework relies on an ensemble of empirical and process based models to provide an explicit source apportionment of baseline pollutant losses prior to implementation of any management options. For example, modelled pollutant losses are split between losses attributable to manufactured fertiliser and those resulting from livestock excreta and managed manures. Management options are then characterised in terms of the percent change in fertiliser inputs and livestock numbers on typical farms in Wales, and these values used to directly reduce the relevant baseline emissions from the target pollutant sources, areas and delivery pathways.

Estimates of the magnitude of change in fertiliser and livestock numbers were based on the option prescriptions and results from a Wales Farm Practice Survey (Anthony *et al*., 2012) and the British Survey of Fertiliser Practice (2010). The effects of land use change at field margins following introduction of riparian buffers and woodland planting is modelled by comparison of baseline pollutant emissions under the different land uses. The modelling framework was used to calculate changes in emissions of phosphorus, nitrate, sediment, nitrous oxide, methane and carbon dioxide. Changes were reported as absolute quantities of pollutants entering watercourses or released to the atmosphere, after accounting for any landscape retention. The reductions in pollutant emissions were calculated for individual river catchments and at national scale, accounting for non-agricultural sources of pollutants (Figure 2.3.2.1).

2.3.2 MultiMOVE

The MultiMOVE modelling framework relies on an ensemble of statistical models to predict species occurrence and thence habitat suitability from climate and soil properties. It is in an earlier stage of development relative to the two other models and therefore has only been applied in 2 test catchments in this first year, Conwy and Plynlimon. These catchments were selected as test sites as they are the subject to intensive ecosystem services research activity at present and represent contrasting catchments in both scale and habitat types (Figure 2.3.2.1).

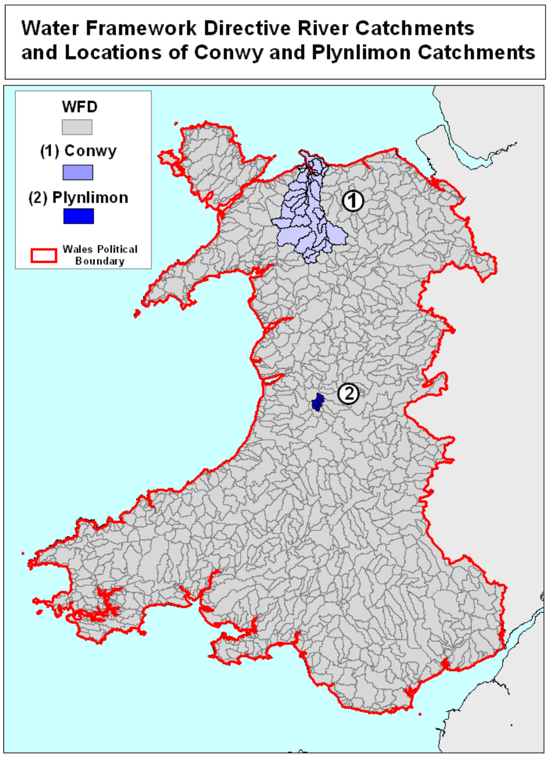


Figure 2.3.2.1 Water Framework Directive river catchments used for reporting outputs from the ADAS Wales Diffuse Pollutant Emissions Modelling Framework, and locations of the Conwy and Plynlimon catchments used to source soils and climate data for input to the MultiMOVE framework.

The framework was applied to scenarios of changing abiotic conditions and vegetation height based on starting values defined to be as ecologically close as possible to conditions found in the two catchments. Modelling was carried out for 21 common and rare plant species over a period of between 10 and 23 years for scenarios of land use change or reduced agricultural inputs. Species selected were either dominant species typical of either the starting or target assemblage, or they were indicator species for the starting or target assemblage.

For each species, habitat suitability in the baseline was modelled as a function of measured soil and climate conditions and vegetation height. For each of the land management options we quantified the magnitude of change expected in soil conditions and vegetation height (see Appendix 2.4). Literature searches were used to source experimental evidence for changes in the model input variables following treatments corresponding to a Glastir management option. Change in habitat suitability for a species was measured as percent progress from the baseline towards or away from the habitat suitability scores for the target habitat (Smart *et al*., 2003; Van den Berg *et al*., 2011). Species, habitats and features expected to benefit from each modelled measure is shown in Table 3 of Appendix 2.5.

2.3.3 Land Utilisation and Capability Indicator (LUCI)

The LUCI modelling framework examines the impact of spatial placement of interventions. It is process-based where established knowledge and computational constraints permit – for example the water routing capabilities honour physical thresholds such as volumetric constraints, field capacity, infiltration rate constraints, *etc*. For other services such as erosion and carbon sequestration where processes are less well understood, estimates are a combination of process-based knowledge and empirical relationships. All LUCI calculations and valuations are produced at the resolution of the input digital elevation model (DEM) - in this case the 5x5m NextMap DEM product for Wales. This fine resolution is considered the most appropriate for the water, sediment and nutrient delivery services to take advantage of LUCI's topographical routing capabilities, and is also of an appropriate order for agricultural productivity estimates (which are influenced by topographical variables such as slope and aspect) and habitat connectivity calculations This resolution is continued for all services to ensure each service valuation is produced at a resolution consistent (identical) with the other service valuations. This is necessary to allow trade-offs and synergies in provision to be meaningfully calculated.

For this study, baseline model calculations used the CEH Land Cover Map 2007 (LCM 2007) as input, with average fertiliser and stocking rates assigned based on farm survey data (see Appendix 2.1). As scenarios have by definition to be spatially explicit for input to LUCI, and only partial take-up of land management options was assumed for most scenarios (see Section 2.4), a random sampling scheme was used to assign areas where interventions were carried out. All eligible areas for interventions were estimated by analysis of digital maps. Due to time and computational constraints, only single realisations for each uptake scenario were generated. For more robust treatment, multiple sample realisations should be generated so the impact of changing placement of interventions can be meaningfully calculated. Results for the scenario interventions are reported as percent change from the baseline LCM2007 scenario.

2.4. Representative Land Management Options and Targeting

Six land management options were selected in consultation with James Skates (the Welsh Government; Scientific Evidence and Assessment Branch) as representative of the range of options that could be selected by farm managers for enhancement of biodiversity, control of diffuse pollution from agricultural land, enhancing soil carbon storage and mitigation of climate change (see Box 2.4.1):

- Retain Winter Stubbles (AWE No. 28).
- Allow Woodland Edge to Develop Out into Adjoining Field (AWE No. 24).
- Grazing Management of Open Country (AWE No. 41A).
- Grazed Permanent Pasture with No Inputs (AWE No. 15).
- Create Streamside Corridor with Tree Planting (AWE 9B).
- Mechanical Bracken Control (AWE 44).

Each of the management options is available under both the All Wales and Advanced elements of Glastir, and they cover 4 of the 5 intended Glastir outcomes. They were selected to cover options that are narrow and deep (*i.e*. few sites expected to receive payments but major outcome expected *e.g*. retain winter stubbles) or broad and shallow (*i.e*. low input grassland with low impact by area but extensive uptake) (Box 2.4.1).

All of the interventions have a scientific or expert judgement evidence base to them, and each has the potential to deliver large benefits at the immediate site of the impacted fields:

Delaying cultivation and retaining over-winter stubbles can reduce nitrate leaching from fields of spring cereals by 30% (Hansen and Djurhuus, 1997). The interception of surface runoff by a streamside corridor can reduce soil and nutrient losses from adjacent fields by up to 80% (White and Arnold, 2009). The extension of woodland edges can double the carbon stock in standing vegetation (Cantarello *et al*., 2011). Achieving sustainable stocking rates will require a 45% reduction in present sheep numbers utilising Open Country land (modelling based on Pakeman and Nolan, 2009), resulting in a proportional reduction in methane emissions. The with-holding all fertiliser inputs from grazed permanent pasture will reduce forage production and grazing cattle numbers by up to 35% (modelling based on Scholefield *et al*., 1991), and subsequently nitrous oxide emissions from fertiliser and manures. Cutting reduces bracken frond abundance, and multiple cuts within a growing season are more effective, and can be as effective as chemical sprays (Stewart *et al.*, 2005).

Not all of the models were able to represent every management option (Table 2.4.1). Further evidence for the effect and the assumptions made for the technical implementation of each option are summarised in Appendix 2.1.

Box 2.4.1 Representative Land Management Options

(AWE 9b) Create Streamside Corridor on Improved Land with Tree Planting

The management option requires the fencing of a corridor of improved land and riparian habitat along both sides of a watercourse that is planted with native broadleaf trees. Livestock are excluded from the corridor that is managed as habitat land. As the corridor matures the tree roots and ground cover of herbaceous plants improve soil structure and can be effective in increasing water infiltration and trapping soil particles, reducing and slowing runoff from the adjacent fields and intercepting nutrients and sediment. The wooded corridor may also contribute to stabilising the riverbank against erosion and prevents the direct access of livestock and defecation into the watercourse

(AWE 28) Retain Winter Stubbles

The management option requires that winter stubbles are retained in advance of spring-sown crops rather than ploughing in autumn. The natural regeneration of grasses and broadleaved plants provides a winter habitat for birds and maintaining some over-winter ground cover can provide protection to the soil from water erosion. Herbicides must not be used, although the option can be rotated around the farm to allow weed control.

(AWE 41a) Grazing Management of Open Country

The management option requires that stocking levels for habitat land designated as Open Country under the Countryside Rights of Way Act (CRoW, 2000) be reduced to levels that allow recovery and sustainable management. The aim is to prevent vegetation change, loss and soil erosion that result from over-grazing and trampling of the soil.

(AWE 24) Allow Woodland Edge to Develop Out into Adjoining Fields

The management option requires that an existing woodland parcel be extended out into an improved field. The aim is to expand the permanent habitat for birds and animals, and contribute to carbon capture.

(AWE 15) Grazed Permanent Pasture with No Inputs

The management option requires that no manufactured fertiliser or organic manures be spread to permanent pasture. The pasture must continue to be grazed to maintain a sward with a range of heights during the growing season. The aim is to increase plant diversity, reduce nutrient leaching and contribute to carbon capture.

(AWE 44) Mechanical Bracken Control

The management option requires that bracken be controlled by cutting and rolling rather than spraying chemicals. Bracken management is undertaken to benefit the flora and fauna that is associated and known to thrive with it, or to recover habitats that are in danger of being lost to dense bracken encroachment.

Management Option	(28) Retain Stubble	(24) Woodland Edge	(41a) Open Country	(15) No Inputs	(9b) Streamside Corridor	(44) Bracken Control
WDP-EMF	Yes	Yes	Yes	Yes	Yes	No
LUCI	No	Yes	Yes	Yes	Yes	No
MultiMOVE	No	Yes	No	Yes	Yes	Yes

Table 2.4.1 Management options analysed with the modelling frameworks.

The effectiveness of the selected land management options at catchment and national scales depends on their relevance to typical cropping and stocking, the opportunity for spatial targeting, and the achieved level of uptake by farms participating in the Glastir scheme.

2.4.1 Relevance of Management Options

The relevance of a management option was defined as the maximum agricultural land area to which the option can be applied. The relevance was calculated using digital maps of the distribution of agricultural land in Wales:

- Retain Winter Stubbles – The option applies to 24,000ha of spring cereals and oilseed rape.
- Allow Woodland Edge to Develop Out into Adjoining Field – The option applies to 29,700ha of arable and 570,400ha of improved grassland that is located immediately adjacent to existing woodland[2].
- Grazing Management of Open Country – The option applies to 146,000ha of rough grazing designed as Open Country.
- Grazed Permanent Pasture with No Inputs – The option applies to 620,900ha of permanent grassland receiving some manufactured nitrogen fertiliser.
- Create Streamside Corridor with Tree Planting – The option applies to 8,300ha of arable land and 409,200ha of improved grassland that is located immediately adjacent to a watercourse and has no existing boundary feature.
- Mechanical Bracken Control – The option applies to the 284,900ha of agricultural land that is located in association with stands of bracken.

Figure 2.4.1.1 maps the proportions of agricultural land adjacent to existing woodland or watercourses and relevant to the 'Woodland Edge' and 'Streamside Corridor' options. Each representative management option is relevant to between 30 and 55% of the total areas of arable (74,200 ha), improved grassland (1,140,800 ha) and sole rights or commons rough grazing (381,800ha) in Wales.

[2] Note that the relevant area is the total field area located adjacent to a woodland parcel or streamside corridor, and not the smaller area of the woodland extension or streamside corridor that is reported in Welsh Government statistics as the option area.

a) Adjacency to Woodland *b) Adjacency to Watercourse*

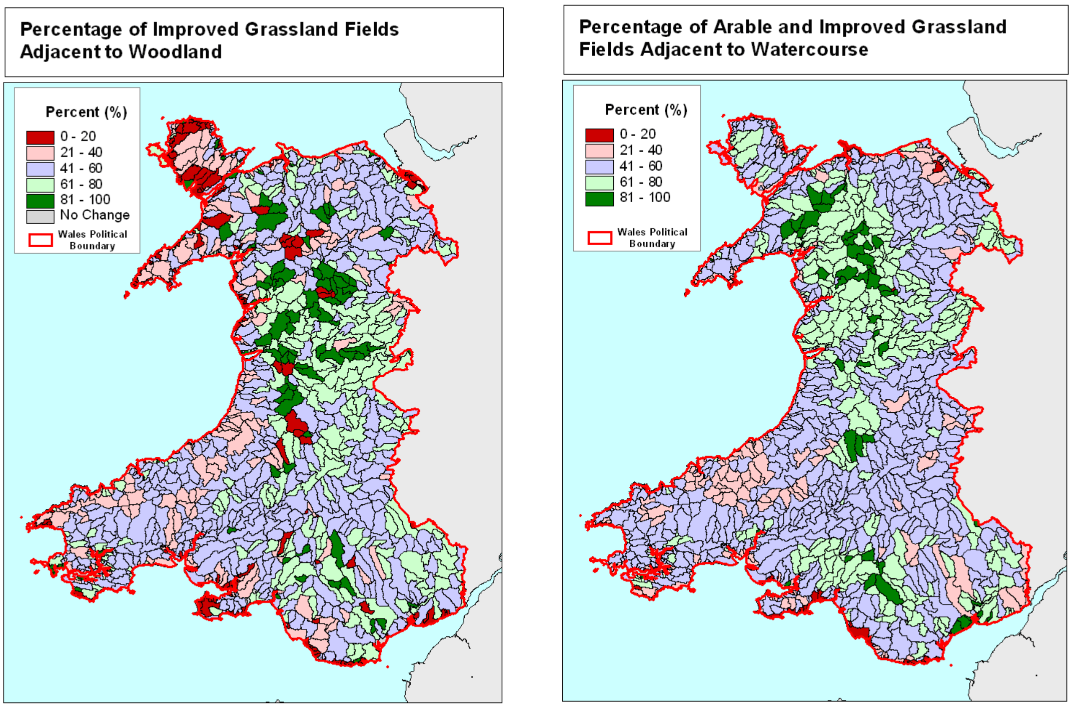


Figure 2.4.1.1 Percent of agricultural land adjacent to a) existing woodland; and b) watercourses within individual Water Framework Directive river catchments.

2.4.2 Level of Scheme Participation and Spatial Targeting

Although relevant to a high percentage of the agricultural land area in Wales, the impact of the representative management options is potentially limited by constraints on the level of scheme participation which in the longer term will be budget constrained. This can in part be over-come by targeting participation to areas affected by environmental degradation.

2.4.2.1 Scheme Participation

Three scenarios of participation in the Glastir scheme were constructed based on guideline forecasts of the number of farms in the All Wales Entry and Advanced level elements provided by Kevin Austin (the Welsh Government; Head of Sustainable Land Management, Agriculture, Fisheries and Rural Strategy). These scenarios defined the number of participating farms in the All Wales and Advanced elements of the scheme (Table 2.4.2.1.1).

Scenario	Entry (No. of farms)	Advanced (No. of farms)	Commons (ha)
Low	3,500	1,500	90,000
Medium	4,500	1,800	100,000
High	5,500	2,000	110,000

Table 2.4.2.1.1 Scenario numbers of farms participating in each element of the Glastir scheme.

There are approximately 25,000 active farm holdings in Wales. The High scenario would therefore result in 30% of all farms entering the scheme. Farms that have entered the All Wales element of the scheme to date have been larger than the average Welsh farm, and so the proportion of the total managed land area in scheme may be higher. The High scenario is comparable to the level of participation achieved at the close of the previous Tir Cynnal, Tir Gofal and Organic Farming schemes. Targeting was also arranged by Robust Farm Types (MAFF, 1993)[3] in order to maximise the relevance and uptake of the options for this scoping study (Table 2.4.2.1.2).

Management Option	Target Farm Types	Target Priority Area			
		Water Quality	Soil Carbon	Open Country	Bracken Stand
(15) No Inputs	CS-LFA + CS-LOW	Yes	Yes	No	No
(41a) Open Country	CS-LFA	No	No	Yes	No
(9b) Streamside Corridor	CS-LFA + CS-LOW + DAIRY	Yes	No	No	No
(28) Retain Winter Stubble	CS-LFA + CS-LOW + DAIRY + MIXED + CEREAL + GENERAL	Yes	No	No	No
(24) Woodland Edge	CS-LFA + CS-LOW	Yes	No	No	No
(44) Bracken Control	CS-LFA + CS-LOW	No	No	No	Yes

Table 2.4.2.1.2 Robust farm types and priority areas used for targeting each of the representative Glastir land management options.

2.4.2.2. Spatial Targeting

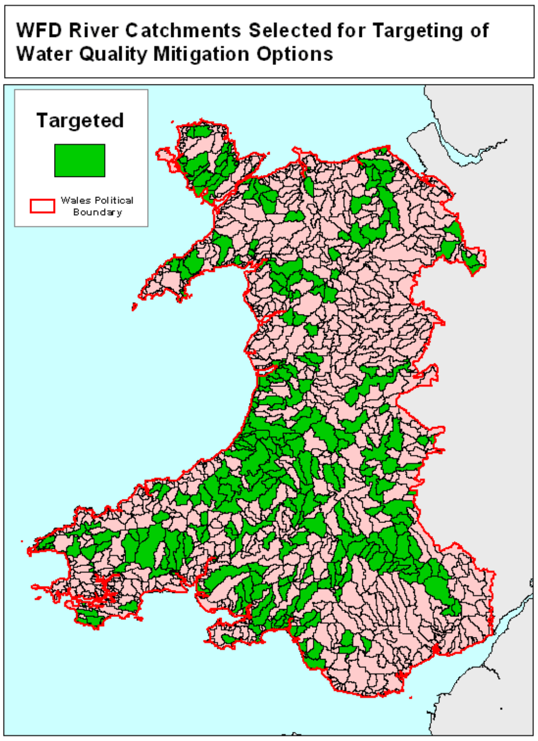
Participation in the Advanced element is subject to spatial targeting according to policy priorities. Excepting the 'Bracken Control' option, the representative land management options were selected as the Welsh Government has identified them as making a contribution to the current priorities for improved carbon storage and water management.

The Welsh Government in collaboration with a range of stakeholders and government agencies has defined priority areas for a number of policy themes, including biodiversity, access and water resources. Of specific relevance to this study, Priority Catchment areas for targeting land management options contributing to an improvement in Water Quality have been defined (Figure 2.4.2.2.1a). These catchment areas are based on Water Framework Directive (WFD) River Catchment boundaries. These WFD River Catchment boundaries were used with the Welsh Government maps of areas prioritised for improvement in Soil Carbon to define equivalent Priority Catchment areas for Soil Carbon. A provisional map of Open Country was also used to define Priority Catchment areas for the 'Grazing Management of Open Country' management option. In each case, WFD River Catchments were designated as Priority Catchments providing that 10% of the catchment area over-lapped with the Soil Carbon or Open Country priority areas provided by the Welsh Government (Figures 2.4.2.2.1b and 2.4.2.2.1c). For 'Bracken Control' we defined also Priority Catchment areas based on the extent of bracken stands mapped by the Phase One Habitat Survey (Figure 2.4.2.2.1d; (Howe et al. 2005)).

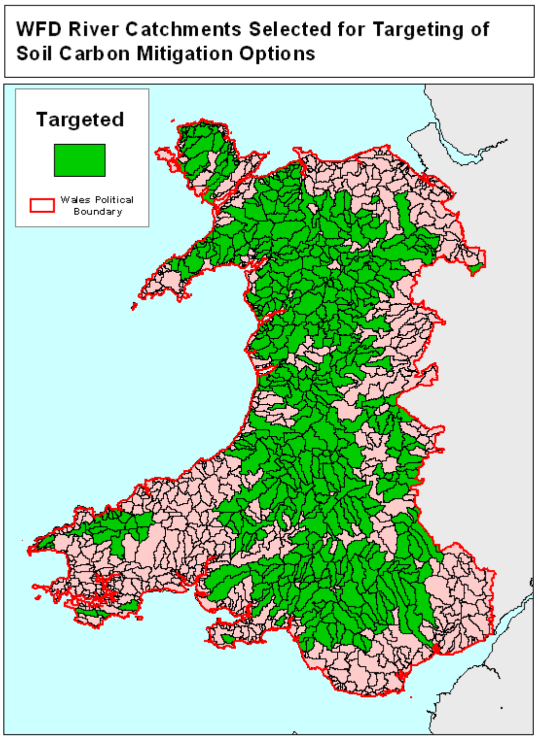
For each of the participation scenarios, the All Wales element cohort of farms was distributed between the WFD River Catchments in Wales in proportion to the number of farms of the targeted type. The Advanced cohort was similarly distributed across the Priority Catchment areas only. Table 2.4.2.2.1 summarises the achieved levels of participation inside and outside of the Priority Catchment areas for each management option. The scenario of High participation results in at least 55% of all farms within a Priority Catchment area participating in the Glastir scheme.

[3] Robust Farm Types: General Cropping (GENERAL); Specialist Cereal (CEREAL); Specialist Dairy (DAIRY); Mixed Farming (MIXED); Lowland Cattle and Sheep (CS-LOW); and Less-Favoured-Area Cattle and Sheep (CS-LFA).

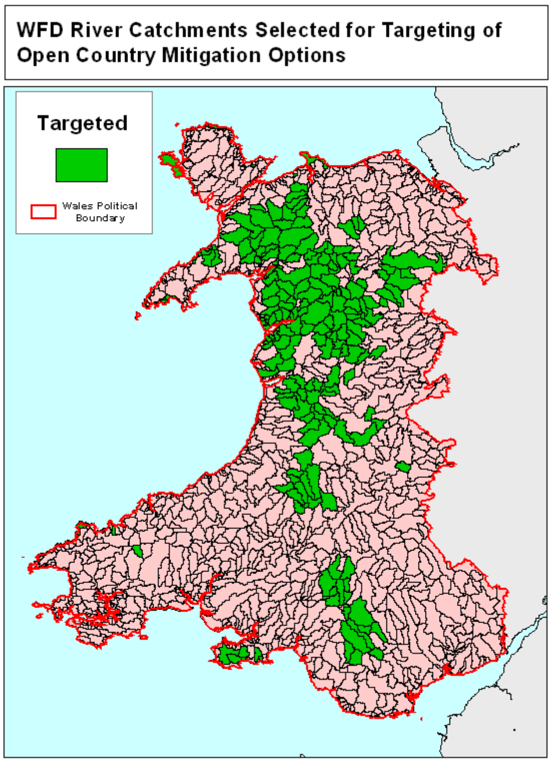
a) Water Quality



b) Soil Carbon



c) Open Country



d) Bracken Control

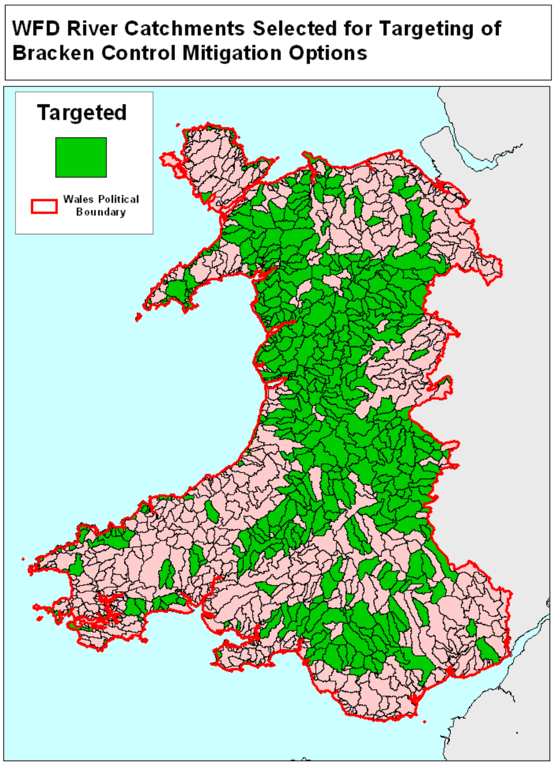


Figure 2.4.2.2.1. Water Framework Directive river catchments selected to define Priority Catchment areas for targeting of land management options under the Advanced element of Glastir that are relevant to the improvement of a) water quality; b) soil carbon storage; c) management of Open Country land, and d) bracken control.

Management Option	(28) Retain Stubble		(24) Woodland Edge		(41a) Open Country	(15) No Inputs		(9b) Streamside Corridor		(44) Bracken Control	
Priority Area	Water Quality		Water Quality		Open Country	Water Quality and Soil Carbon		Water Quality		Bracken Stands	
Scenario	In	Out	In	Out	Open Country	In	Out	In	Out	In	Out
Low	41	18	51	22	98	37	22	43	19	45	22
Medium	50	23	63	29	100	47	29	53	24	55	29
High	58	28	73	35	100	55	35	61	30	65	35

Table 2.4.2.2.1 Percent of farms participating in the Glastir scheme inside and outside of the Priority Catchment areas, defined separately for each management option and scheme participation scenario.

2.4.2.3 Aspects of Scheme Targeting Not Implemented

Protected Zones: The 'Streamside Corridor' option is not permitted in certain Protected Zones of Wales because it would be detrimental to the long-term survival of water vole, red squirrel or club-tailed dragonfly. The Protected Zones have been mapped by the Welsh Government, but were not used to restrict uptake in this study.

Regional Packages: Farmers entering Glastir and choosing from reduced groups of options specific to one of fifteen Welsh regions receive more points per option, thereby making it easier to achieve the points threshold for eligibility. This may increase the uptake of options with certain regions. The 'Open Country' and 'Woodland Edge' options are listed in option groups for 11 and 12 regions respectively. The 'Streamside Corridor' and 'Permanent Pasture No Inputs' options are both listed in option groups for 3 regions. No attempt has been made to restrict the pattern of option uptake based on the Regional Packages in this study.

2.4.3 Level of Option Implementation

For the scenarios modelled, we assumed that a management option was implemented fully across the entire relevant land area on a farm. This may be an unrealistic assumption. For example, a requirement to produce sufficient forage for livestock may prevent withholding of all fertiliser inputs.

The Welsh Government statistics for farms that have entered the All Wales element were used to calculate the average field area affected by an option on the farms taking up each of the representative land management options. Where uptake of an option was recorded as a length (*e.g.* streamside corridor); this was converted into an estimate of the adjacent field area. The affected areas ranged from 4ha for the 'Woodland Edge' to 18ha for the 'Permanent Pasture No Inputs' options (Table 2.4.3.1).

The average area of permanent improved grassland and arable land on farms in Wales varies from *ca.* 30ha for the CS-LOW to *ca.* 60ha for the DAIRY and CS-LFA farm types (Welsh Assembly Government 2007). The majority (64%) of farms entering Glastir to date are of the CS-LFA farm type. Uptake of the 'Permanent Grassland No Inputs' option is therefore only *ca.* 30% of the relevant area on a typical farm.

Further work is therefore necessary to analyse scheme records of option uptake with respect to farm land use and to survey actual changes in land management in order to determine actual levels of uptake on relevant land and to quantify the true level of additionality.

Management Option	Affected Area (ha)	No. of Customers	Area per Customer (ha)
(15) Permanent Grassland No Inputs	22,364	1,274	18
(9b) Streamside Corridor	261	25	10
(28) Retain Winter Stubble	614	53	12
(24) Woodland Edge	145	34	4
(44) Bracken Control	271	35	8

Table 2.4.3.1 Average area of land affected by land management options on farms enrolled into the All Wales element of Glastir (Welsh Government Statistics, 2013).

2.5 Model Results

The outputs from the modelling frameworks are presented by themes relating to the intended Glastir scheme outcomes.

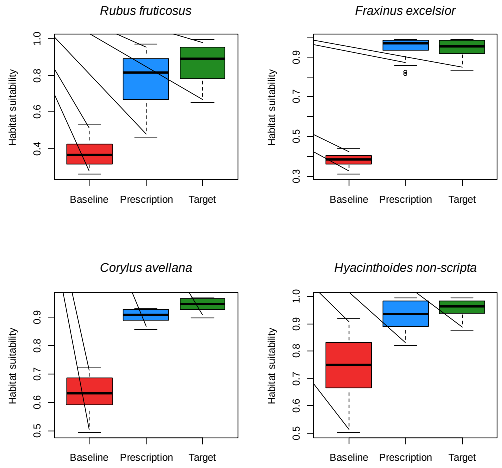
2.5.1 Biodiversity and Woodland Expansion

The potential for improvement was modelled using the MultiMOVE framework to quantify changes in the suitability of habitats for plant species and the LUCI framework to quantify changes in landscape connectivity for woodland focal species.

2.5.1.1 Habitat Suitability for Plant Species

The MultiMOVE modelling framework was used to calculate progression towards levels of habitat suitability associated with a target vegetation type for each land management option and each plant species. Appendix 2.1 provides details of the assumed changes in soil properties and vegetation height for the source and target habitats, summarised in Table 2.5.1.1.1.3. Figure 2.5.1.1.1 illustrates the output from the model, showing how suitability scores for the 'Woodland Edge' and 'Bracken Control' options transitioned between the source and target values. Of the 40 projections run for common species, the majority (75%) were consistent with the expected impact of Glastir. Table 2.5.1.1.1.2 summarises the projected changes in habitat suitability for all of the representative management options. Detailed habitat suitability scores for each species and management option are presented in Appendix 2.3. The model was used to calculate changes in suitability at the affected site, using survey data taken from the Conwy and Plynlimon catchments.

a) Allow Woodland Edge to Develop (AWE 24) – Grass to Wood



b) Mechanical Bracken Control (AWE 44) – Bracken to Acid Grass

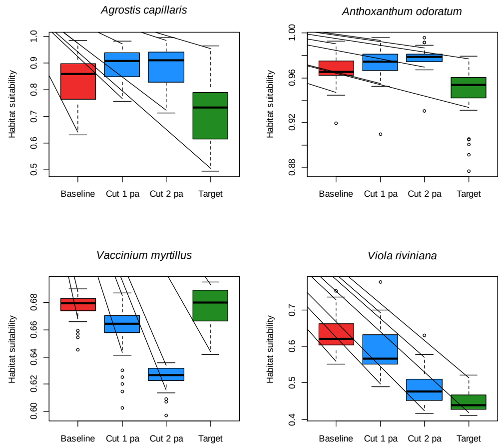


Figure 2.5.1.1.1 *CEH MultiMOVE model outputs showing relative habitat suitability scores for selected plant species following a) conversion of improved grassland to woodland; and b) conversion of bracken to acid grassland. Suitability scores are shown for the source and target habitats, and the prescription for a period between 10 and 23 years after adoption of relevant Glastir land management options.*

2.5.1.1.1 Common Species

The most significant of the options investigated were the 'Woodland Edge' and 'Streamside Corridor' that have the potential to create an additional 12,100ha of woodland under the 'High' scenario of scheme participation (Table 2.5.1.1.1.1).

Scenario	Woodland Expansion (AWE 24)	Streamside Corridor (AWE 9b)
High	8,300	3,800
Medium	7,000	3,100
Low	5,500	2,500

Table 2.5.1.1.1.1 National area (ha) of woodland habitat created by 'Woodland Expansion' and 'Streamside Corridor' management options for scenarios of Glastir participation.

The MultiMOVE projections of community change from an improved grassland starting point resulted in an 83 to 100% (*i.e.* complete) progression towards the target broadleaved woodland for representative plant species following conversion of grassland (Table 2.5.1.1.1.2). Projected changes from an arable starting point suggested less progression, reflecting initial soil conditions that are less like broadleaved woodland. The vast majority of the land area converted will be improved grassland. On this basis, we estimate that 10,000ha of suitable woodland habitat could be created. This represents 10% of the Welsh Government commitment to achieve a 100,000ha increase in woodland cover in Wales from the present 14% of the land area to 20% by 2030. However, creation of a suitable habitat does not guarantee dispersal and colonisation of a newly favourable patch. The MultiMOVE scenarios were run for 23 years and common sense suggests that less change is likely over shorter periods. Future model applications should assess the sensitivity of projected magnitudes of change to the differences in conditions between starting points.

Species modelled	Woodland expansion (AWE 24) on Improved Grassland	Streamside buffer strips (AWE 9B) on Improved Grassland	Streamside buffer strips (AWE 9B) on Arable land	Low input grassland (AWE/ Advanced 15), sward height <10cm on Improved Grassland	Low input grassland (AWE/ Advanced 15), sward height 10-30cm on Improved Grassland	Bracken control (AWE 44/ Commons) on Acid Grassland; 1 cut pa Con/ Plyn	Bracken control (AWE 44/ Commons) on Acid Grassland; 2 cuts pa Con/ Plyn	Bracken control (AWE 44/ Commons) on lowland heath; 1 cut pa Con/ Plyn	Bracken control (AWE 44/ Commons) on lowland heath ; 2 cuts pa Con/ Plyn
Rubus fruticosus	+ 83	+ 83	+ 27						
Fraxinus excelsior	+ >100	+ >100	+ 60						
Corylus avellana	+ 88	+ 88	+ >100						
Hyacinthoides non-scripta	+ 83	+ 83	+ 59						
Lolium perenne				- T	(+) T				
Juncus effusus				(-) T	(-) T				
Lotus corniculatus				+ 50	+ 78				
L. pedunculatus				+ >100	+ >100				
Lathyrus pratensis				(-) T	(-) T				
Trifolium pratense				+ >100	+ >100				
Centaurea nigra				+ 87	+ 92				
Agrostis capillaris						+ T / + T	+ T / + T		
Anthoxanthum odoratum						+ T / + T	+ T / + T		
Vaccinium myrtillus						(-) T / (-) T	(-) T / (-) T		
Viola riviniana						- 24 / - 29	- 80 / -82		
Hylocomium splendens								+ 80 / + 61	(-) 56 / (-)40
Calluna vulgaris								+ 51 / + 57	(-) 8 / (-) 8
Festuca ovina								+ 53 / + 57	+ 41 / + 50
Serratula tinctoria				- T	No cge T				
Stachys officinalis	+ >100	+ >100							

Table 2.5.1.1.1.2 CEH MultiMOVE model results for selected plant species. Habitat suitability was projected to increase '+' or decrease '-'with the change expressed as a percent progression to the habitat suitability associated with a target vegetation. Modelled directions of change are bracketed and the cell dark shaded where not consistent with the expected impact of the measure. In cases where the target vegetation definition needs revisiting no percent progression figure is given but instead a 'T' appears.

Glastir measure	**Scenario derived from published evidence**	**Contributing studies**
Woodland expansion	Decrease in pH (- 1.33 units), increase in C:N ratio (+ 1.01), increase in canopy height (+ 2.32 index points[1])	Poulton *et al.* 2003; Bossuyt *et al*. 1999
Buffer strips	Decrease in pH (- 1.33 units), increase in C:N ratio (+ 1.01), increase in canopy height (+ 3.53 index points)	Poulton *et al.* 2003; Bossuyt *et al*. 1999
Low input grassland	Decrease in pH (- 0.50 units), increase in C:N ratio (+ 0.86), decrease in canopy height (- 1.25 to 2.25 index points)	Olff and Bakker 1991; Pywell *et al.* 2007; MICROSITES report 2013 (unpublished)
Bracken control	Increase in pH (+ 0.15 units), increase in C:N ratio (+ 0.2 to 1.6), decrease in canopy height (- 0.25 to 1.6 index points)	Mitchell *et al.* 1999; Marrs *et al.* 2007; Cox *et al*. 2007

Table 2.5.1.1.1.3. Key modelling assumptions for MultiMOVE; Studies and final change values. Canopy height is weighted by percentage cover and is included as an index between 1 and 8. For further details see Smart et al. (2010). Estimates of change for canopy height were obtained from the Countryside Survey database.

For the 'Permanent Pasture No Inputs' option, because the Glastir prescription requires a sward of mixed vegetation height to be maintained, projections were run for selected species to a target canopy height of either <10cm or between 10 and 30cm. Results were qualitatively similar between the two scenarios but conditions for *Lolium perenne* were expected to decline for the shorter sward but increase under the taller canopy height (Table 2.5.1.1.1.2). The implication is that greater disturbance in combination with reductions in nutrient availability reduce habitat suitability for Lolium but a taller sward allows it to persist. Since other mesotrophic grassland indicators were favoured under a taller canopy height the expected persistence of *Lolium* may not be problematic. Evidently *Lolium perenne* is still a frequent presence even in unimproved hay meadow communities (Rodwell 1991.) These results require closer inspection especially since the target conditions appeared to be more favourable to this dominant of Improved grassland than the Improved grassland starting point. The same inconsistently lower suitability in the target than the baseline was also seen for *Lathyrus pratensis* and *Juncus effusus*. Projections for other indicator species of unimproved grassland were consistent with a de-intensifying effect of the measure and the scenario of a reduction soil pH and an increase in soil C:N ratio. Hence habitat suitability was projected to increase substantially for *Lotus corniculatus, L.pedunculatus, Centaurea nigra* and *Trifolium pratense* (see Appendix 2.1.).

For the 'Bracken Control' option the MultiMOVE framework was applied to seven species, four associated with an acid grassland target and three associated with a lowland heathland target. For all species modelled, the direction of change toward an Acid grassland target was consistent with the reduction in competitive effect of bracken as a result of regular cutting. However the definition of target conditions requires re-assessment since for all except *Viola riviniana* the target indicated lower habitat suitability than the Bracken-dominated starting point.

In the Conwy and Plynlimon, bracken control was projected to increase the suitability of conditions for the desirable forage grasses *Agrostis capillaris* and *Anthoxanthum odoratum*. However, *Viola riviniana* was projected to decline in habitat suitability with a reduction in bracken cover. This species is an important larval foodplant for a number of Fritillary butterfly species although it is patchily distributed being less common in the more acidic bracken assemblages derived from a previously hard grazed precursor (Rodwell *et al.* 1991). Where *Viola* is frequent, the modelling results suggest that modest bracken cover is in fact more favourable for this species than a wholesale change to Acid grassland. Since it is unlikely that the prescription applied over large areas will eradicate bracken entirely the result may be a more beneficial mosaic of acid grassland and patchy Bracken dominance.

When applied to a Bracken-dominated heathland starting point habitat suitability for all three modelled species were projected to increase as expected but for the typical moss *Hylocomium splendens* and the desirable heathland dominant *Calluna vulgaris*, this increase was only associated with one cut per annum. Decreased habitat suitability was projected in response to two cuts per annum.

2.5.1.1.2 Rare Species

MultiMOVE provides models for many less common species enabling us to explore whether Glastir impacts result in a shift to more favourable condition for many species that may well be rarely observed at scheme monitoring sites but nevertheless are known to occur in the local species pool and so ought to benefit from a shift to more benign abiotic conditions. Driving MultiMOVE by observed soil data from monitoring sites associated with the habitats favoured by rare species could provide a useful indicator of change in conditions for these taxa. We therefore also explored projections for less frequent but desirable indicator species including *Ophioglossum vulgatum, Serratula tinctoria* and *Stachys officinalis* in response to low input grassland and *Jasione montana* in response to Bracken control on heathland. Results for *O.vulgatum* and *J.montana* were dominated by large variations in habitat suitability. Hence more work needs to be carried out in defining the starting and target condition for these specialised plants. Results for *S.tinctoria* and *S.officinalis* showed more promise but again more work is needed to define the target vegetation for both taxa (Table 2.5.1.1.1.2)

2.5.1.2 Woodland Connectivity

For broadleaved woodland, both greater overall area and improved connectivity are considered to be ecosystem management objectives. To evaluate impacts from the ‘Woodland Edge’ and ‘Streamside Corridor’ options, LUCI followed the calculation procedure recommended by UK Forest Research (Eycott *et al*., 2007), a cost-distance approach considering maximum estimated dispersal distances between patches of habitat above a specified area (assumed to be 2ha for this study). Improved ecosystem service provision is associated with a reduction in the overall cost-distance for any species. The value estimation method first calculates cost-distances for species crossing unsuitable terrain from each habitat patch, with individual landcover types having specified “permeabilities” for the species of interest. Permeability parameterisations provided with LUCI are based on studies from focal species in broadleaved habitat in Wales, and the land use in proximity to those species.

Management option	Scenario	Percent (%) gain in accessible area
(9b) Streamside Corridor	High	11.7
	Medium	9.7
	Low	5.9
(24) Woodland Edge	High	3.7
	Medium	3.1
	Low	2.9

Table 2.5.1.2.1 VUW/CEH LUCI model results for the change in the national woodland area accessible to broadleaf woodland focal species as a result of maximum implementation of relevant land management options under scenarios of farm participation in Glastir

Table 2.5.1.2.1 shows that a measurable change in woodland connectivity was achieved. The projected impact of the 'Streamside Corridor' options was particularly large, with the high update scenario estimating an 11.7% increase in accessible area over Wales for "generic" broadleaf focal species. It is unsurprising that the streamside corridor option generally achieves higher connectivity for a similar area of planting, as the chance of long narrow strips achieving a connection between established woodland habitat patches is far greater than the chance that a small expansion of existing habitat will create such a connection. However, the effect of the woodland expansion is still significant, with a projected increase in accessible area over Wales of 3.7% for the high uptake scenario. Figure 2.5.1.2.1 displays both the national output for Wales, and a close-up within the Conwy catchment showing the changing connectivity and opportunity for further habitat expansion that occurs between the baseline and the high take-up scenarios.

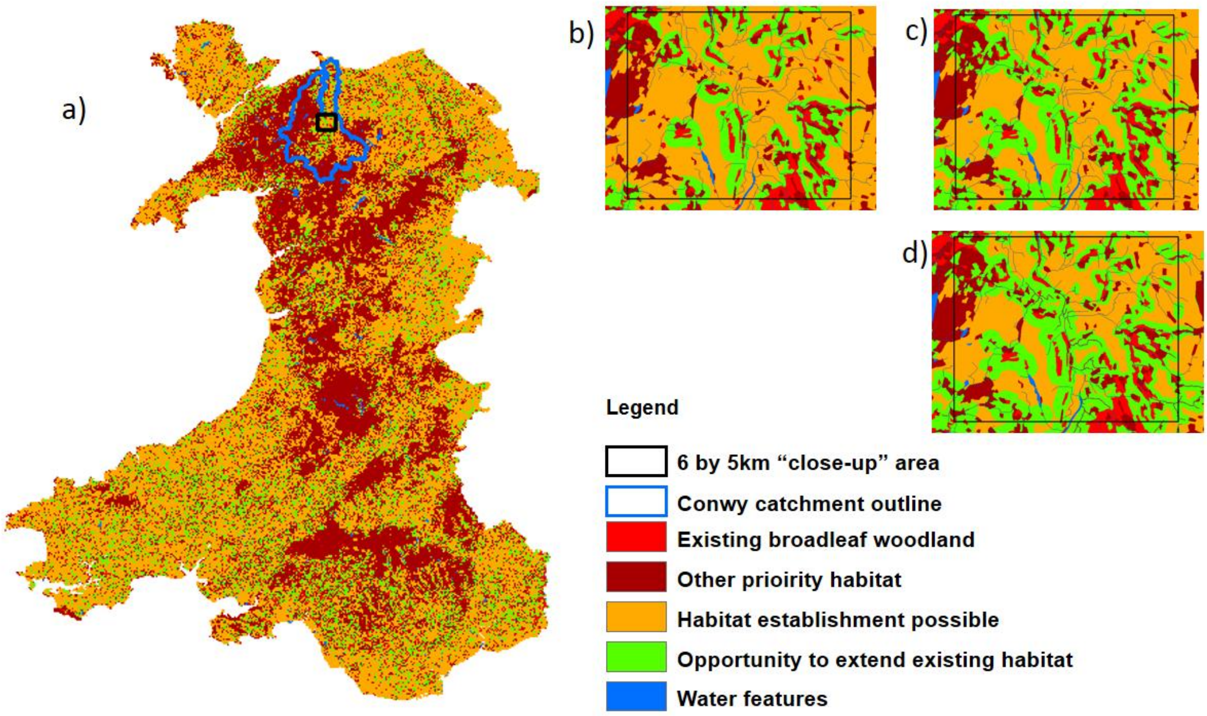


Figure 2.5.1.2.1 LUCI model outputs showing existing broadleaf woodland and other priority habitat areas, along with areas where further broadleaf woodland establishment is possible and where such establishment will augment accessibility of species in existing woodland. a) shows the baseline output over the whole of Wales while b) to d) zoom in on a 6 by 5km^2 area within the Conwy for the baseline scenario (b), woodland expansion scenario (c) and the streamside corridor planting (d) respectively. Note the key indicates red = stop as good service being delivered, through to green = opportunity to improve service delivery.

2.5.2 Soil Quality, Water Flow and Quality

The potential for improvement was modelled using the WDP-EMF framework to quantify changes in sediment and nutrient inputs to rivers in the context of up-stream and non-agricultural sources, and the LUCI framework to quantify changes in sediment and nutrient losses following strategic placement of options that also maximised the reduction in the area of flood generating land and the connectivity of erodible land to rivers.

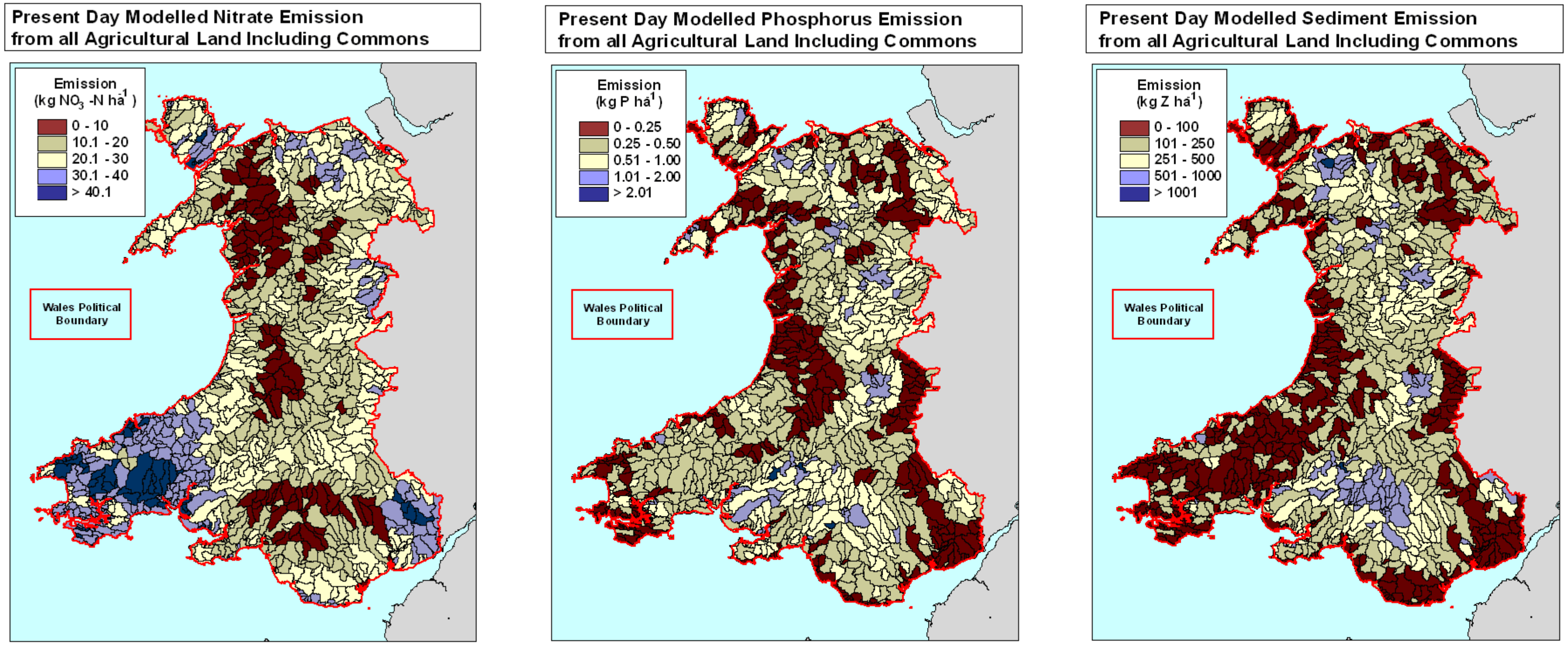
2.5.2.1 General Uptake of Land Management Options

The WDP-EMF model was used to calculate the impact of land management options on sediment and nutrient emissions from agricultural land, and place these in the context of the non-agricultural source contribution to total pollutant loads impacting on freshwaters. The scheme scenarios distributed the option area across all relevant land on participating farms, without any bias towards critical areas for control of pollutant mobilisation and delivery, except where the 'Streamside Corridor' option required placement of the option area adjacent to a watercourse by definition

Figure 2.5.2.1.1 maps the baseline nutrient and sediment emissions arising from agricultural land in Wales, calculated by the WDP-EMF framework. Total emissions of nitrate are 34.38kt, of phosphorus are 0.73kt and of sediment are 320.38kt (Table 2.5.2.1.1). Agriculture is calculated to contribute 42% of total phosphorus, 85% of total nitrate and 62% of total sediment emissions to rivers and lakes when including estimates of inputs from non-agricultural sources including sewage effluent discharges, river bank erosion and urban and road runoff (Anthony *et al*., 2012).

a) Nitrate Emission b) Phosphorus Emission c) Sediment Emission

Figure 2.5.2.1.1 ADAS WDP-EMF modelled annual total a) nitrate; b) phosphorus; and c) sediment emissions from agricultural land in Wales within each



Water Framework Directive river catchment. The pollutant loads are averaged over the total agricultural land area including common land (Anthony et al., 2012).

Agricultural Pollutant	P	N	**Z
Pollutant Loss (kt)	0.73	34.38	320.38
*Pollutant Load (kg ha^{-1})	0.46	21.53	200.64

*Load is expressed per hectare of all agricultural land including sole rights and commons rough grazing.
**Sediment load is the mineral component of soil erosion only, *i.e*. excluding organic matter.

Table 2.5.2.1.1 ADAS WDP-EMF modelled baseline national total sediment and nutrient emissions from agricultural land, prior to implementation of any of the representative land management options.

Calculated national reductions in nutrient and sediment emissions under the ‘Low’, ‘Medium’ and ‘High’ scenarios were in proportion to the levels of scheme participation (Table 2.5.2.1.2). The achieved local reductions in pollutant emissions reflect the relevance and spatial targeting of the options. The ‘Retain Winter Stubbles’ has a relatively low impact on total phosphorus emissions at catchment scale (<2%) that is confined to the Welsh borders and coastal areas of arable cropping (Figure 2.5.2.1.2a). The ‘Create Streamside Corridor’ option achieved reductions in sediment losses of up to 10% (Figure 8b) that are focussed within the Priority Catchment areas for Water Quality improvements (Figure 2.4.2.2.1). The ‘Permanent Pasture No Inputs’ option achieves reductions of up to 16% in areas dominated by cattle and sheep farms (Figure 2.5.2.1.2c).

The maximum local reductions for the options are between three and seven times the national average reductions listed by Table 2.5.2.1.2. The spatial targeting does not have a large impact on overall pollutant reductions, in the sense that reductions are not targeted in catchments where baseline emissions are higher than the national average. However, the targeting results in pollutant reductions within the Priority Catchment areas that is up to 50% higher than if scheme participation had been evenly distributed across Wales. The targeting is less effective for the ‘Permanent Pasture No Inputs’ option as the combined Water Quality and Carbon Storage priority area covers a greater proportion (66%) of the total agricultural land area than does the Water Quality priority area alone (32%).

Management Option	Scenario	P	N	Z
(28) Retain Winter Stubble	High	0.23	0.39	0.45
	Medium	0.20	0.33	0.37
	Low	0.20	0.27	0.30
(9b) Streamside Corridor	High	2.69	0.95	3.16
	Medium	2.24	0.79	2.63
	Low	1.79	0.63	2.10
(24) Woodland Edge	High	0.47	0.37	0.37
	Medium	0.39	0.31	0.32
	Low	0.31	0.24	0.25
(41a) Open Country	High	0.43	0.52	0.40
	Medium	0.42	0.51	0.38
	Low	0.41	0.50	0.36
(15) No Inputs	High	1.35	7.29	0.00
	Medium	1.15	6.18	0.00
	Low	0.89	4.82	0.00

Table 2.5.2.1.2 ADAS WDP-EMF modelled percent (%) reductions in national sediment and nutrient emissions from agricultural land as a result of maximum implementation of representative land management options under scenarios of farm participation in Glastir.

The percent reductions in national emissions achieved by the management options (<1 to 8%) are considerably less than the site level impacts of up to 80% that can be achieved. This is a reflection of the maximum level of participation in the Glastir scheme by targeted farm types (38 to 61%) and the proportions of fields meeting relevancy criteria such as the 50% of fields adjacent to a watercourse that limited uptake. These two factors alone reduce the maximum national impact of the 'Streamside Corridor' option to *ca.* 25% of the site level impact.

Just as critical was the apportionment of pollutant emissions between farm types, source areas and delivery pathways. The modelled baseline source apportionment of agricultural pollutant emissions Table 2.5.2.1.3a shows that only 60% of total nitrate leaching occurred on the CS-LFA and CS-LOW farm types that was addressed by the 'Permanent Pasture No Inputs' option. Table 2.5.2.1.3b shows that only 60% of the total sediment loss occurred on improved grassland that would benefit from implementation of the 'Streamside Corridor' option, and Table 2.5.2.1.3c that 30% of total methane emissions were from dairy animals and unaffected by changes in pasture area and beef cattle and sheep numbers under the 'Woodland Edge' option.

a) Retain Winter Stubble (28) *b) Create Streamside Corridor (9b)* *c) Permanent Pasture No Inputs (15)*

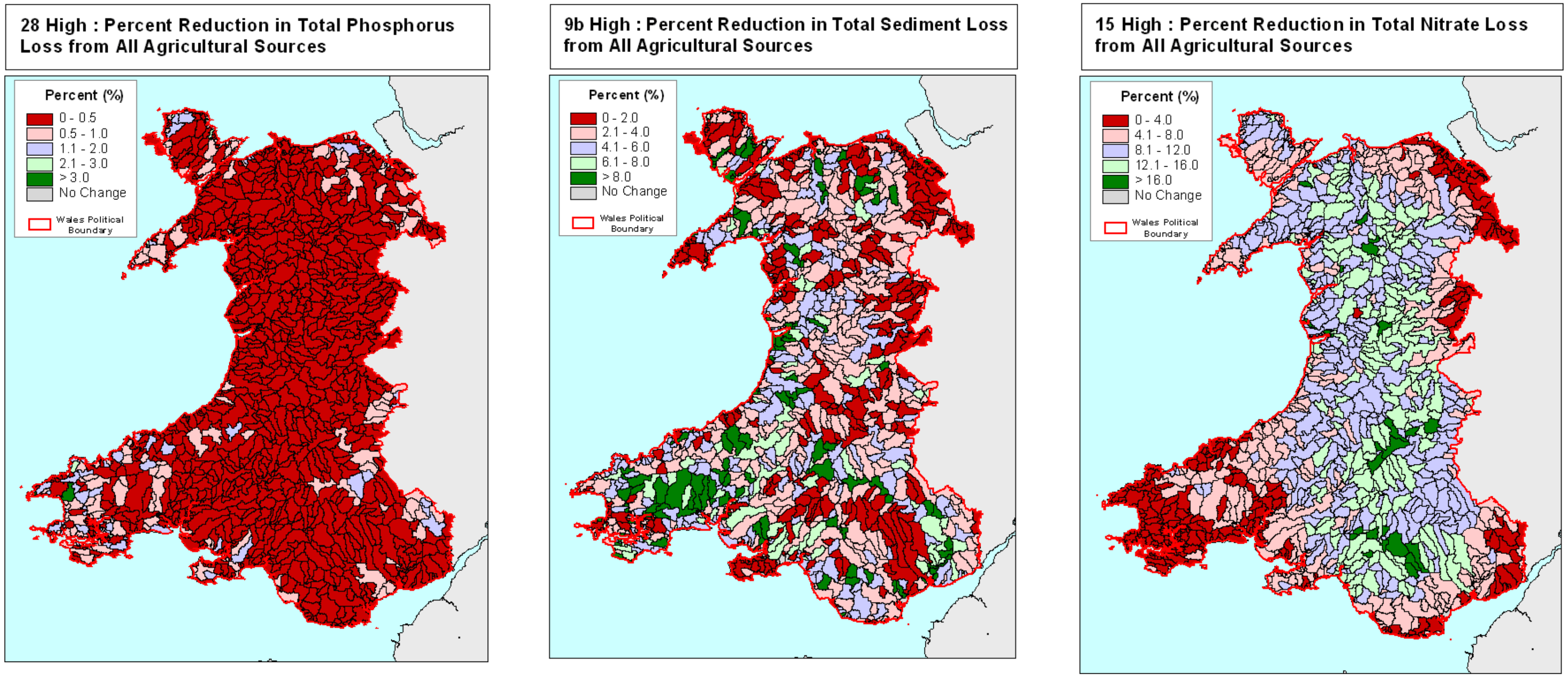


Figure 2.5.2.1.2 ADAS WDP-EMF modelled percent reduction in total pollutant emissions arising from agricultural sources, as a result of full implementation of land management options under the 'High' scheme participation scenario: a) Impact of 'Retain Winter Stubble' on phosphorus emissions; b) Impact of 'Create Streamside Corridor' on sediment emissions; and c) Impact of 'Permanent Pasture No Inputs' on nitrate emissions.

a) Farm Type

Farm Type	N	P	Z
POULTRY	2.7	0.8	<0.1
CEREAL	1.9	1.8	2.8
GENERAL	1.0	0.7	1.0
HORTICULTURAL	0.2	0.2	0.4
PIG	0.2	0.2	0.1
DAIRY	31.4	19.2	11.7
CS LFA	49.6	66.3	74.0
CS LOW	9.2	7.4	5.6
MIXED	3.8	3.4	4.4

b) Source Area

Area Type	N	P	Z
Arable	10.9	7.8	12.6
Grass	82.7	73.2	58.6
Rough Grazing	5.2	14.4	28.8
Other	1.2	4.6	0.0

*Other includes farm hard standings

c) Source Type

Source Type	N	P	Z
Dairy Animal	18.5	8.4	0.0
Beef Animal	21.2	11.8	0.0
Sheep Animal	16.0	8.8	0.0
Pig Animal	0.2	<0.1	0.0
Poultry Animal	3.0	0.8	0.0
Fertiliser and Chemical	19.8	8.3	0.0
Soil	21.3	61.9	100.0

d) Delivery Pathway

Pathway Type	N	P	Z
Surface Runoff	10.8	40.3	61.3
Preferential / Drain Flow	11.7	43.6	38.7
Leaching	76.8	10.7	0.0
Gaseous	0.0	0.0	0.0
Direct Input	0.7	5.5	0.0

Table 2.5.2.1.3 ADAS WDP-EMF modelled percent (%) of national total baseline sediment and nutrient emissions arising from agricultural land in Wales, a) by farm type; b) by source area on farm; c) by general source type; and d) by delivery pathway.

The highest national reduction achieved was a 7% reduction in nitrate leaching following uptake of the 'Permanent Pasture No Inputs' option, benefiting from a reduction in livestock number (33% of the effect) as well as the reduction in fertiliser inputs. The second most effective option was the 'Streamside Corridor' because of its surface runoff interception function that reduced national phosphorus and sediment losses by up to 3%. This can be compared to the lower (<0.5%) reductions achieved by the similarly placed 'Woodland Edge' option that did not introduce any new buffering capacity as it was an extension to existing woodland. The least effective was the 'Retain Winter Stubble' option because of the small area of arable land relative to grassland, even in the lowland areas of Wales. However, this option achieved the greatest reduction in nutrient and sediment emissions of all the options on the fields directly affected by the option. Nitrate leaching losses were reduced by 15 kg N ha^{-1} and sediment by 160 kg Z ha^{-1} as a result of delayed cultivation and retaining over-winter soil cover.

2.5.2.1.1 Impact on Total Pollutant Loads

The achieved pollutant reductions contribute to a direct improvement in water quality in the first-order streams and ditches immediately down-stream of the agricultural fields within each Water Framework Directive river catchment. To assess the significance of the reductions for water quality on the main river stem requires integration with and accumulation of non-agricultural pollutant loads from head-water to catchment outlet.

Agricultural land is estimated to contribute only 42% of total phosphorus emissions to rivers and lakes in Wales. Other important sources are river bank erosion (5%), urban and road runoff (6%), sewage effluent (41%) and septic tanks (4%). These sources have been mapped by the Wales Diffuse Pollutant Emissions Modelling Framework, based on a number of empirical models and registers of licensed discharges. Agriculture also contributes 85% of total nitrate and 62% of total sediment emissions nationally (Anthony *et al*., 2012).

Figure 2.5.2.1.1.1a maps the agricultural contribution to the baseline total phosphorus load within each river catchment. Figure 2.5.2.1.1.1b maps the reduction in the agricultural phosphorus load alone that results from full implementation of the 'Create Streamside Corridor' option within each river catchment. This is contrasted with Figure 2.5.2.1.1.1c that maps the reduction in the accumulated phosphorus load from both agricultural and non-agricultural sources. The achieved reductions in accumulated phosphorus load impacting on water quality are generally lower, especially on the coast and borders of Wales. These example outputs are presented as illustration of the WDP-EMF modelling framework's capability to place agricultural reductions in the context of contributions from other sectors and the need to consider up-stream pollutant contributions when assessing the environmental significance of local reductions in agricultural pollutant emissions.

a) Percent agricultural contribution. *b) Percent reduction in agricultural load* *c) Percent reduction in total accumulated load*

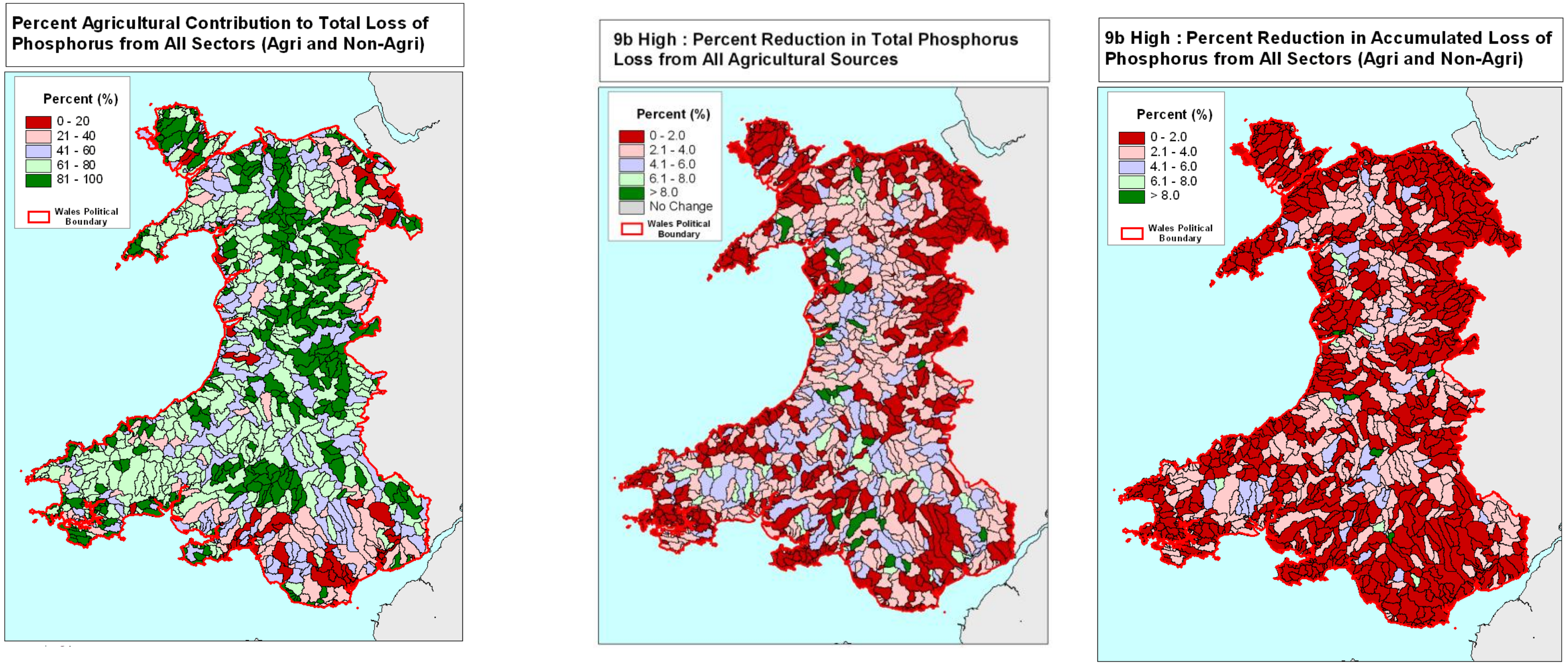


Figure 2.5.2.1.1.1a) ADAS WDP-EMF modelled percent contribution of agriculture to baseline total phosphorus emissions from all sources within individual river catchments, including sewage effluent discharges, river bank erosion and urban and road runoff; b) Percent reduction in phosphorus emissions arising from agricultural sources, as a result of full implementation of the 'Create Streamside Corridor' land management options under the 'High' scheme participation scenario; and c) Percent reduction in the total accumulated emissions from combined agricultural and non-agricultural sources.

2.5.2.2 Strategic Placement of Land Management Options

The LUCI model was used to calculate the benefits of strategic placement of land management options to reduce the area of flood generating land and the connectivity of highly erodible land, and the subsequent impacts on sediment and nutrient inputs to rivers.

Table 2.5.2.2.1 .shows the calculated reductions following the implementation of the 'Streamside Corridor' and 'Woodland Edge' management options that directly affected the flow pathway for surface runoff by introducing a buffer or break in connectivity between runoff producing fields and the river system. For the case of flood generation, the reduction in area can be interpreted as generally reduced flood peaks for small catchments and reduced overall flood volume for larger catchments. Large calculated reductions in connectivity of erodible land (*ca.* 7%) resulted in similarly large reductions in sediment (14%) and phosphorus (8%) delivery, but were less effective in controlling nitrate (1%) because the surface runoff pathway is much less important for this pollutant. The 'Streamside Corridor' option was more effective than the 'Woodland Edge' option. This is a consequence of LUCI's focus on the spatial placement of interventions. As LUCI tracks the transport and accumulation of water, sediments and chemicals, it takes account of areas of land with high storage and/or high infiltration capacity, which have the capacity to mitigate floods, trap sediment and (at times) modify nutrient budgets. The flood, sediment and nutrient models all focus on the mass delivered to the river network, and the 'Streamside Corridor' option by definition provides a buffer / break in connectivity to the river of significant proportions of arable and improved grassland areas, primary generation areas for flooding, sediment, nitrate and phosphorus.

Management Option	Scenario	Reduction in flood generating land (%)	Reduction in Connectivity of Highly Erodible Land (%)	Sediment reduction (%)	N reduction (%)	P reduction (%)
(9B) Streamside Corridor	High	8.8	6.7	14.3	1.1	8.2
	Medium	7.9	5.8	11.9	0.9	6.4
	Low	6.3	4.4	8.1	0.7	3.9
(24) Woodland Edge	High	1.7	1.5	3.5	0.9	2.3
	Medium	1.5	1.3	2.8	0.7	1.6
	Low	1.2	1.2	2.1	0.4	1.1
(41A) Open Country	High	-	-	-	1.6	2.9
	Medium	-	-	-	1.4	2.8
	Low	-	-	-	1.4	2.8
15 (No inputs)	High	-	-	-	8.2	5.6
	Medium	-	-	-	6.7	3.9
	Low	-	-	-	4.9	2.6

Table 2.5.2.2.1 VUW/CEH LUCI model results for percent change in the national area of flood generating land and the connectivity of highly erodible land to rivers, and the associated reductions in sediment and nutrient pollutant emissions to water bodies across the whole area of Wales following uptake of selected Glastir land management options. The "-" indicates there is too much uncertainty in the supporting parameterisations/scientific knowledge to infer magnitude or direction of change.

Figure 2.5.2.2.1 maps flood generation and opportunity to reduce it over Wales. Interpretation of the national results can be difficult due to the fine scale (5 by 5m resolution) that LUCI runs at, with large accumulation of mass often only visible at finer scales. Figure 2.5.2.2.1a and b show the national picture and a map of the Conwy. Figures 2.5.2.2.1c to 2.5.2.2.1e zoom in on a small area within the Conwy, and demonstrate how maps and opportunity changes between the baseline and option implementations. The changes between baseline and the 'Streamside Corridor' option are particularly striking, with the corridor planting providing mitigation to very significant areas in the selected zoom region. The changes from the baseline to the 'Woodland Edge' option are less striking, but still evident on close inspection.

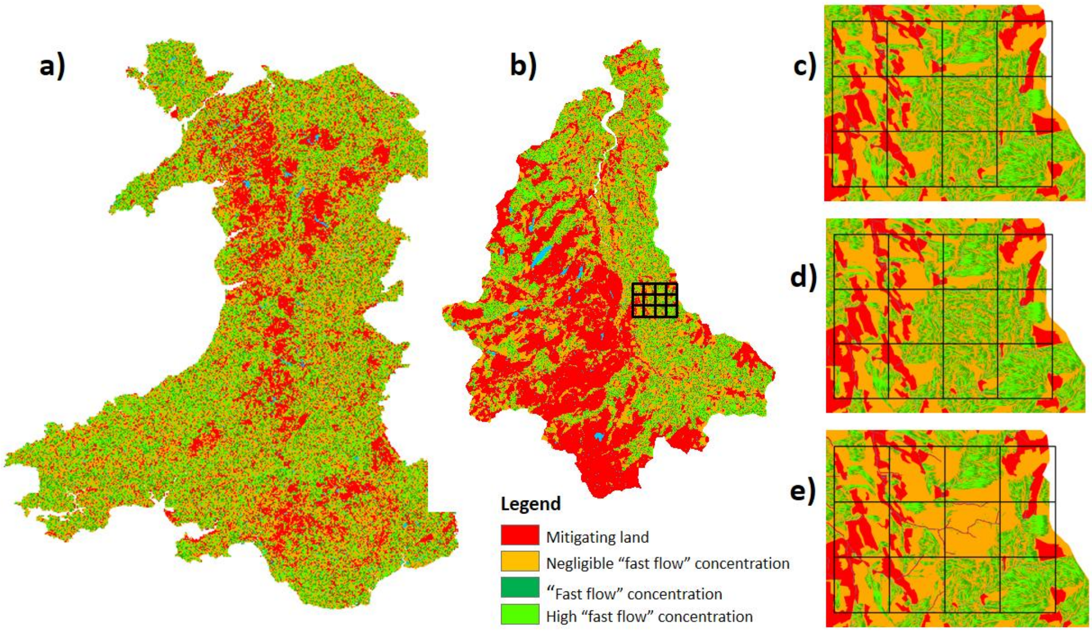


Figure 2.5.2.2.1 LUCI model estimates of flood mitigating land versus flood generating land, with the latter divided into three classes: 1) areas accumulating insignificant water or routing through areas of mitigation before they reach the stream, 2) non-mitigated high water accumulation areas, and 3) non-mitigated very high water accumulation areas, based on soil, vegetation class and topographical routing. a) and b) show output for the baseline scenario for the nation and for the Conwy catchment respectively, while c), d) and e) show a close-up in the Conwy catchment for the baseline scenario, Option24, and Option 9B respectively. Note the key indicates red = stop as good service being delivered, through to green = opportunity to improve service delivery.

The changes in sediment, phosphorus and nitrate loading similarly need to be viewed at a local scale for the differences between scenarios to be evident. Figure 2.5.2.2.2 focuses again on a small region in the Conwy, showing nutrient loading and accumulation in the selected region (Figure 2.5.2.2.2 a and 2.5.2.2.2 b), along with water (Figure 2.5.2.2.2 c) and sediment accumulation (Figure 2.5.2.2.2d). It demonstrates the importance of considering not only nutrient loading at individual points in the landscape (e.g. phosphorus loading in Figure 2.5.2.2.2 a), but also the accumulation of loading in the landscape as it travels towards the water bodies (Figure 2.5.2.2.2 b). Areas generating high load that move through soils or vegetation with intercepting qualities en route can often be of less significance to the overall water nutrient budget than more moderate-generation areas with no interception en route to the river.

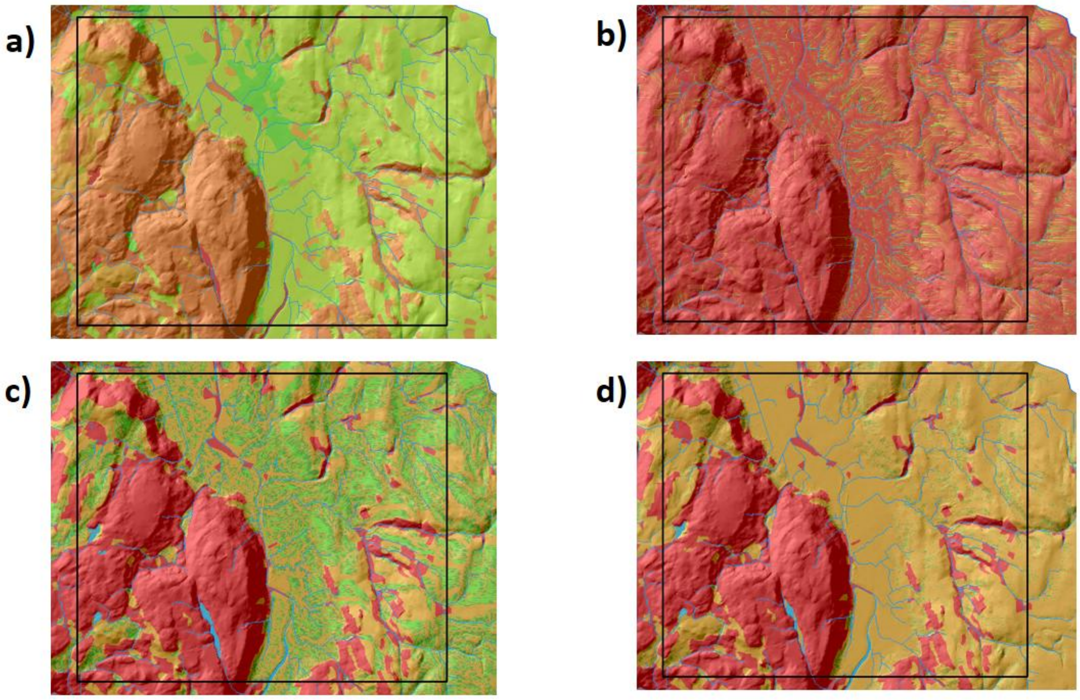


Figure 2.5.2.2.2 *a) LUCI model estimates of phosphorus loading contributed at individual points in the landscape based on soil, vegetation class, stocking rate and fertiliser input; b) accumulation of phosphorus loading in the landscape; c) flood accumulation in the landscape and d) sediment loading. For a) and b), green denotes high loading (or accumulated loading) while red denotes low loading/accumulated loading. For c) and d), red denotes land with capacity to reduce transport of fast flowing water or sediment to water bodies, green areas are target areas for change to reduce such water or sediment loading, and orange denotes land that neither provides significant protection or has capacity to be easily changed to provide such protection.*

The LUCI framework was also used to calculate the changes in nutrient losses resulting from reductions in fertiliser use and livestock numbers for the 'Open Country' and 'Permanent Pasture No Inputs' options (Table 2.5.2.2.1). The 'Permanent Grassland No Inputs' option was notable in that it provided the greatest reduction in nitrate loading of the four modelled scenario options; consistent with the intent of the specific option and with the WDP-EMF model results. The calculated reductions in nitrate were more similar to the WDP-EMF model results than the sediment and phosphorus predictions, as the majority of nitrate losses are sub-surface and therefore less sensitive to option placement.

2.5.2.3 Comments on Similarities and Differences between WDP-EMF and LUCI Modelling Frameworks Estimates

In general, the three modelling frameworks used have limited overlap in environmental measures considered, but in the case of the water quality and sediment the WDP-EMF and LUCI models do produce results that can be compared. The overall message from both frameworks for these environmental measures is similar; that impacts are generally positive, but that the magnitude of impacts on any single measure is not remarkable, with change generally of the order of 1 to 10% at national scale. However, at least for the admittedly limited set of interventions and environmental measures considered, the cumulative impact over multiple outcomes becomes more significant.

LUCI projects a greater magnitude of change versus the WDP-EMF model. This is assumed to be a consequence of two main differences. Firstly, the WDP-EMF model considers detail on emissions from a wide range of farm practices and acknowledges indirect impacts on emissions as well as direct changes, including phosphorus from soil; LUCI only considers the direct impacts of stocking and fertiliser changes so therefore is biased towards (over)-emphasising outcomes relating to these measures. Secondly, LUCI explicitly recognises the spatial placement of interventions, and therefore often predicts very significant impacts from interventions that intercept or interrupt flow of water, sediment and/or chemical mass from large areas of "up-hill" land whilst WDP-EMF measures connectivity as a statistical measure of the whole landscape and in its current form does not calculate the benefits of targeted option placement under scenarios of partial rather than complete uptake of a management option on the relevant land area. This explains the most significant difference between the two frameworks; the inconsistency between the streamside corridor predictions.

2.5.3 Climate Change Mitigation

The potential for improvement was modelled using the LUCI framework to quantify the change in carbon storage following habitat creation, and the WDP-EMF framework to quantify the change in greenhouse gas emissions following change in farm inputs and livestock numbers.

2.5.3.1 Carbon Storage

The LUCI carbon sequestration model component seeks to identify specific areas of the landscape that are prone to carbon losses and could be protected, as well as those that have potential to be modified to store additional carbon. Increased carbon sequestration is identified with an improved ecosystem service. Figure2.5.3.1.1. shows the carbon opportunity maps for Wales under the baseline (LCM2007) scenario. Figure 2.5.3.1.1.a maps estimated carbon levels based on the IPCC tier 1 protocols (IPCC, 2006), considering carbon in above ground biomass, below ground biomass, dead wood, litter, and soil carbon based on input soil and land cover information. Figure 2.5.3.1.1.b maps expected change in carbon levels once the land use/management regime has been in place long enough for the carbon fluxes to be at equilibrium. It therefore identifies where the current management regime is likely to be either significantly decreasing or augmenting stocks of soil carbon left by previous regimes - correlating to probable emissions or sequestration of CO_2 respectively.

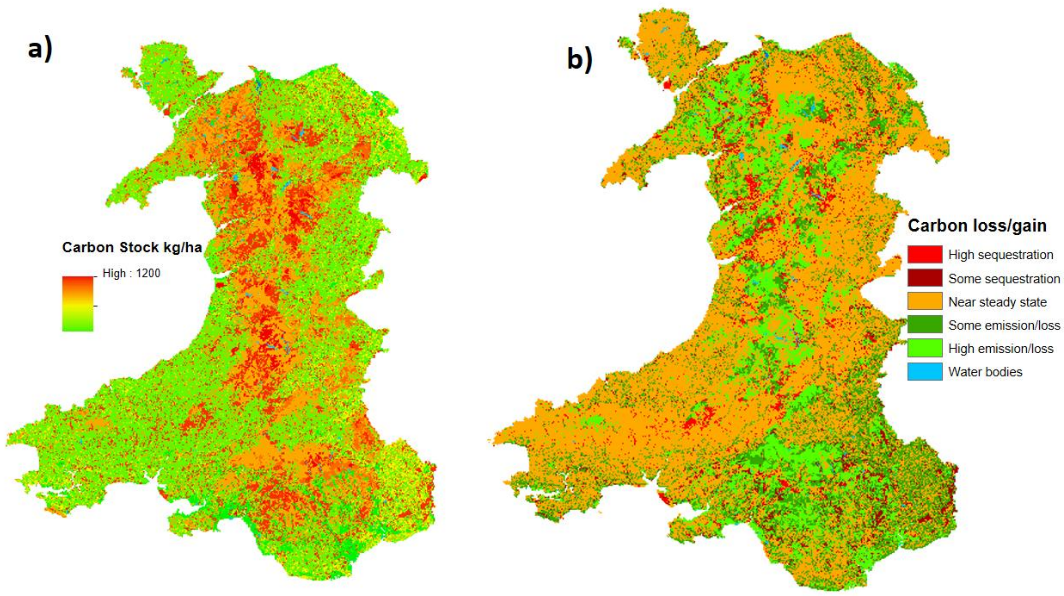


Figure 2.5.3.1.1 LUCI carbon model outputs showing existing carbon stocks and estimate of direction and magnitude of change in carbon stocks as the current management regime moves towards an equilibrium. a) shows the stock estimate over the whole of Wales, while b) estimates whether the stock is gaining, losing, or steady state under the current management regime. Note the key indicates red = stop as good service being delivered, through to green = opportunity to improve service delivery.

Table 2.5.3.1.1 shows the calculated increase in carbon stocks from the 'Streamside Corridor' and 'Woodland Edge' scenarios, which correlates to an expected reduction in CO_2 emissions. Although the increase is small nationally, it is relatively significant given the small area actually modified, reflecting that the areas targeted (improved grassland and arable) have generally low soil carbon so the impact of woodland planting is positive. Note estimates were not attempted for the 'Open Country' and 'Permanent Pasture No Input' scenarios, as there is not yet a scientific consensus on the impact of such measures on soil carbon.

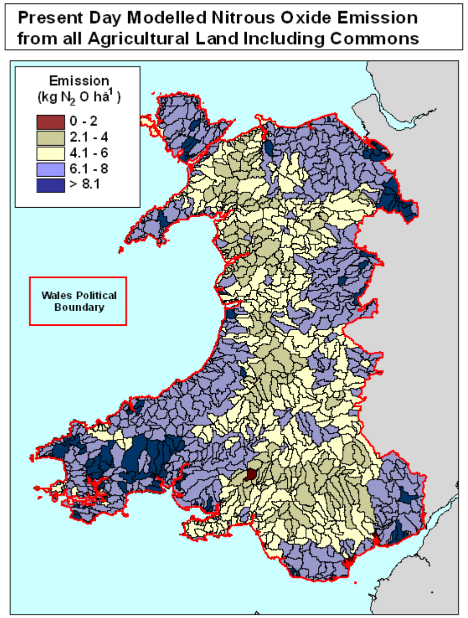
Management Option	Scenario	Percent (%) Increase in Stored Carbon
(9b) Streamside Corridor	High	0.52
	Medium	0.43
	Low	0.36
(24) Woodland Edge	High	0.41
	Medium	0.36
	Low	0.30

Table 2.5.3.1.1 VUW/CEH LUCI model results for the change in the national carbon storage resulting from creation of woodland habitat as a result of maximum implementation of the 'Stream side Corridor' and 'Woodland Edge' land management options under scenarios of farm participation in Glastir.

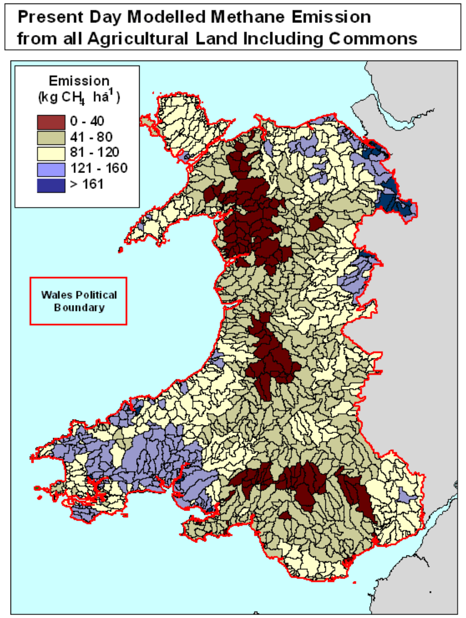
2.5.3.2 Greenhouse Gas Emissions

The WDP-EMF model calculated greenhouse gas emissions arising on farm, excluding embedded emissions in farm inputs. Figure 2.5.3.2.1 maps the baseline greenhouse gas emissions arising from agricultural land in Wales, calculated by the WDP-EMF framework. Total nitrous oxide emissions are 9.20kt and methane are 131.99kt (Table 2.5.3.2.1). Methane and nitrous oxide are each responsible for *ca.* 45% of the total on-farm greenhouse gas emissions (when expressed as $CO_{2\text{-}e}$) and carbon-dioxide from energy usage the remaining 10%.

a) Nitrous Oxide Emission



b) Methane Emission



c) Carbon Dioxide Emission

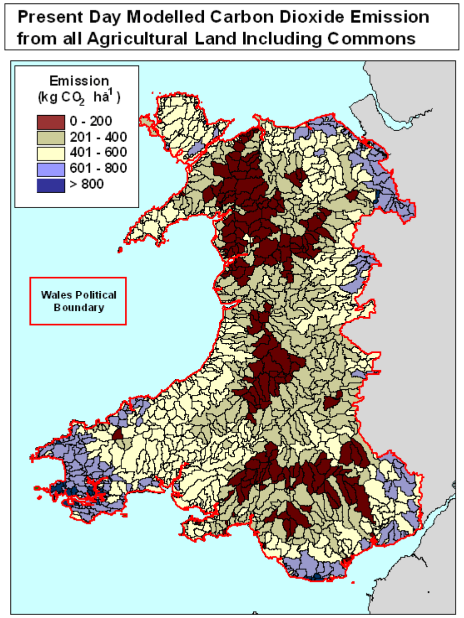


Figure 2.5.3.2.1 ADAS WDP-EMF modelled annual total a) nitrous oxide; b) methane; and c) carbon dioxide emissions from agricultural land in Wales within each Water Framework Directive river catchment. The pollutant loads are averaged over the total agricultural land area including common land (Anthony et al., 2012).

Agricultural Pollutant	**N_2O	CH_4	***CO_2
Pollutant Loss (kt)	9.20	131.99	622.01
*Pollutant Load (kg ha^{-1})	5.76	82.66	389.54

*Load is expressed per hectare of all agricultural land including sole rights and commons rough grazing.
**Includes indirect emissions from leached nitrate.
***On-farm energy usage only.

Table 2.5.3.2.1 ADAS WDP-EMF modelled baseline national total greenhouse gas emissions from agricultural land, prior to implementation of any of the representative land management options.

Calculated emissions of methane and nitrous oxide are largely determined by animal numbers and forage production rather than fertiliser inputs (Table 2.5.3.2.2a and 2.5.3.2.2b). Although the relevant land areas for the 'Streamside Corridor' and 'Woodland Edge' options were high the reductions in forage area and livestock numbers due to land-take on the option area were a maximum of 2 to 4% at site level. Similarly, the 'Open Country' option was calculated to result in a reduction of *ca.* 230,000 ewes that represented only *ca.* 4% of the total number of adult sheep in Wales (see Appendix 2.1). The maximum farm level reduction in livestock numbers following withholding of fertiliser nitrogen from permanent grassland under the 'Permanent Pasture No Inputs' option was estimated to be 15%. However, this requires an unrealistic implementation of the option across all fertilised pasture on a farm. Analysis of scheme uptake statistics indicated that uptake is unlikely to be more than 50% of the maximum relevant land area.

a) Farm Type

Farm Type	N_2O	CH_4	CO_2
POULTRY	0.9	0.5	<0.1
CEREAL	1.1	0.0	4.9
GENERAL	0.5	<0.1	2.1
HORTICULTURAL	<0.1	0.0	0.3
PIG	0.2	<0.1	0.2
DAIRY	24.3	35.8	23.7
CS LFA	59.9	52.1	50.2
CS LOW	9.9	9.4	12.9
MIXED	3.1	2.2	5.6

b) Source Type

Source Type	N_2O	CH_4	CO_2
Dairy Animal	8.3	29.5	1.4
Beef Animal	15.9	33.4	1.2
Sheep Animal	19.4	36.5	0.2
Pig Animal	0.1	<0.1	<0.1
Poultry Animal	1.0	0.5	<0.1
Fertiliser and Chemical	12.8	0.0	25.6
Soil	42.5	0.0	71.4

Table 2.5.3.2.2 ADAS WDP-EMF modelled percent (%) of national total baseline greenhouse gas emissions arising from agricultural land in Wales, a) by farm type; and b) by general source type.

As a consequence, these management options could not result in reductions of greenhouse gas emissions greater than *ca.* 5% nationally, and the scenario levels of participation in Glastir resulted in calculated actual reductions that were generally less than 1 (Table 2.5.3.2.3). Reductions in calculated carbon dioxide emissions were also generally small (<1%), but the framework did not account for embedded emissions associated with the manufacture of fertiliser. See Section 5.4 for a farm-level analysis which includes these embedded losses. The exception was an 8% reduction in on-farm emissions resulted from withholding all fertiliser emissions under the 'Permanent Pasture No Inputs' option, resulting in fewer tractor operations.

Management Option	Scenario	N_2O	CH_4	CO_2
(28) Retain Winter Stubble	High	0.06	0.00	0.00
	Medium	0.05	0.00	0.00
	Low	0.04	0.00	0.00
(9b) Streamside Corridor	High	0.39	0.33	0.28
	Medium	0.33	0.28	0.23
	Low	0.26	0.22	0.18
(24) Woodland Edge	High	0.54	0.49	0.56
	Medium	0.46	0.41	0.47
	Low	0.36	0.32	0.37
(41a) Open Country	High	0.74	1.36	<0.01
	Medium	0.73	1.34	<0.01
	Low	0.71	1.30	<0.01
(15) No Inputs	High	7.22	4.44	7.74
	Medium	6.12	3.76	6.56
	Low	4.77	2.94	5.11

Table 2.5.3.2.3 ADAS WDP-EMF modelled percent (%) reductions in national greenhouse gas emissions from agricultural land as a result of maximum implementation of representative land management options under scenarios of farm participation in Glastir.

2.6 Discussion and Next Steps

2.6.1 MultiMOVE

The MultiMOVE model projected large changes in habitat suitability scores towards the target values for selected plant species over a period of 10 to 23 years. The model outputs are interpreted as changes in habitat suitability rather than changes in probability of a species actually occurring. However, we are more generally interested in whether the changes in habitat suitability could be realised as actual changes in species abundance. Although all of the species selected in this exploratory analysis were all present in the wider 10x10km square species pool this is still likely to be limited by dispersal constraints. These constraints are likely to be especially important where population sizes are small and where species are inherently poor dispersers such as ancient woodland indicators (Kimberley *et al* 2013) and stress-tolerant perennial forbs of unimproved grassland (Verkaar *et al* 1991). The consequence is that Glastir impacts may result in a more favourable mosaic of ecological conditions but unless enough of the intervening matrix is made favourable, small existing populations are made bigger and dispersal is assisted, then many species may only reach these patches over very long timescales if at all. More common and widespread but nonetheless desirable indicator species are likely to be more responsive. Most responsive of all will be species that are *in situ* in the patches of habitat subject to intervention.

Both the size and shape of targeted areas will also have a bearing on whether managed changes in conditions translate into observed changes in species abundance. Larger areas of uptake will constitute a bigger target for dispersal and, for a given perimeter:area ratio, will have lower edge effects. In many situations large edge effects and exposure to enriched run-off will slow the expected change to less productive higher C:N and lower pH conditions. Again both the literature evidence and the modelled projections suggest that appreciable changes in soil and then in vegetation require a long term perspective. The most rapid effects are likely to be where dispersal limitation is absent such as for tree and shrub species associated with planted buffer strips and woodland expansion. The effects on herbaceous species growing *in situ* will vary. Shade-tolerant indicators of unimproved grasslands can be buffered by increasing woody species cover but shade-intolerant species are unlikely to prosper (Smart *et al* 2006). Shade-tolerant wetland species and tall-herbs of the riparian edge are also likely to benefit from the establishment of a new 3.5m wooded buffer strip and if already present will obviously be less restricted by dispersal limitation yet may have to contend with the competitive effects of other nitrophilous tall herbs particularly where edge effects expose the buffer strip to nutrient surpluses from adjacent farmland.

2.6.1.1 Next Steps

Although only applied to the Conwy and Plynlimon catchments for this study due to resource constraints, the MultiMOVE model can be applied at any scale at which input data is available. Projections will vary spatially at the 5x5km square scale since this is the scale at which climate data were used to train the niche models. Other inputs are essentially translated by the models into points in ecological niche space.

Our next key objective is therefore to apply the model to the whole of Wales, and explore whether regional soil status and climate conditions significantly affect progress towards target species for each management option. One approach to this up-scaling would be to generate habitat and land-class specific values of soil input data from GMEP plots and then to match these plots with their local climate data. Then input data could be drawn from these distributions for each combination of land-class and climate. The result would be a census map of projected change for a species list with a spatial structure defined by land-class boundaries and climate gradients within each land-class. Projected census maps could then be readily analysed within the LUCI platform alongside its other output layers.

2.6.2 Wales Diffuse Pollutant Emissions Modelling Framework

Overall, the impacts of the individual management options calculated by the ADAS WDP-EMF modelling framework are similar to those calculated in other modelling studies of diffuse pollution control, with the majority of options having small effects at national scale (see, for example, Anthony *et al*., 2012, MacLeod *et al*., 2010). The results are positive, but large and consequential reductions are achieved only by taking up a large number of options, and this may require consideration of competition between options for effect. The modelling framework demonstrated in this scoping study is capable of calculating the impacts of a wider set of Glastir management options, or providing custom outputs to evaluate novel management options proposed for inclusion in the Glastir scheme to better address policy priorities.

Even so, the calculated impacts are generally believed to be an over-estimate resulting from modelled implementation across all of the relevant land on the farm systems. This is despite an element of inefficiency in the assumptions of scheme participation by some farms without any relevant land. Scheme records show that, with the marked exception of the ‘Permanent Pasture No Inputs’, less than 3% of the 2,200 farms participating in the All Wales element to date have taken up any of the representative options despite the large estimated relevant land areas (Welsh Government, 2013). The ‘Permanent Pasture No Inputs’ option has been taken up by 59% of the participating farms, and the contrast with uptake of the other options suggests a low level of additionally.

A key feature of the ADAS modelling framework is the ability to explain potentially large differences between site level and catchment scale impacts of management options by reference to the explicit source apportionment. The importance of the pollutant sources, areas and delivery pathways targeted by an option are quantified relative to total pollutant emissions from all agriculture. The spatial constraints on impact set by differing levels of scheme participation and implementation of options across the relevant land area can also be quantified, allowing exploration of alternative targeting mechanisms to improve the efficiency of a scheme.

A potential constraint on the usefulness of the ADAS modelling framework is that it does not operate with sufficient spatial resolution to explicitly represent the effects of targeting land management options at critical source areas within farms, at field sites with the most risky combinations of cropping, soil type and topography. This is by design and is a reflection of the spatial accuracy of survey data on farm management, but means that the model cannot scope the benefits of finer scale spatial targeting. The structure of the landscape is also not represented, which means the model cannot be easily extended to assess benefits of land management options for habitat connectivity and water storage. The more spatially explicit LUCI modelling framework further develops the eco-system services concept and may deliver an appropriate framework for spatially interpolating and down-scaling relationships derived from both this diffuse pollution modelling framework and the MultiMOVE framework for modelling species habitat suitability.

2.6.2.1 Next Steps

A key objective is to analyse uptake data for the Advanced Element and survey change in farm management to determine actual levels of uptake on relevant land and to quantify the true level of additionality. This will be carried out in partnership with the anticipated Wales Farm Practice Survey (see Section 5.5.4) and will support a more realistic assessment of the more typical subscription to multiple management options as required by the points system for scheme eligibility.

We also recommend that the ADAS Wales Diffuse Pollution Modelling Framework continue to have a role in scoping the impact of novel management options, as part of a programme to enhance the potential impact of the Glastir scheme on Water Quality and Climate Change Mitigation outcomes. This will complement the existing Biodiversity focus of the scheme options. This deliverable may be more efficiently achieved by an adaptation of the ADAS FarmScoper model to use the outputs from the Wales modelling framework as inputs to describe baseline pollutant emissions. FarmScoper is an easy-to-use tool for calculating the impacts of a library of *ca.* 100 land management options on diffuse air, water and climate change pollutant emissions from representative farm systems. The tool uses the same explicit source apportionment system as the Wales Diffuse Pollution Modelling Framework. The management options are described by Newell-Price *et al*. (2011) in the *User Guide of Mitigation Options*, and policy analysts with basic computer literacy can easily expand the library. The FarmScoper tool would enable a more rapid exploration of land management options for Welsh farm systems and complement the spatially explicit eco-systems services model under development by Victoria University Wellington and the Centre for Ecology & Hydrology.

2.6.3 Land Utilisation and Capability Indicator Modelling Framework

Our evidence suggests that based on current scientific knowledge, the impact of the Glastir scheme is generally positive with small but multiple outcomes for many interventions. LUCI's capability to represent the spatial positioning of interventions is particularly highlighted by the differences between the streamside corridor planting and woodland expansion scenarios, where similar areas of direct intervention produce very dissimilar results.

Although LUCI represents the spatial routing of pollutants in fine detail, it has not to date considered detail of farm management such as specific crop or stocking type, slurry treatment, *etc.,* (in contrast to the ADAS modelling framework, for example). Significant augmentation of our models is underway to allow a broader range of Glastir interventions and objectives to be accounted for and evaluated within LUCI, specifically to allow the framework to better differentiate landscape functioning by land *management* as well as land use and soil type. The incorporation of this level of management detail is however raising many questions regarding the quality of the input data. These include uncertainties and errors in spatial data, aggregations in land categorisations and privacy issues that have resulted in available input management data being spatially aggregated to a level far coarser than is required for input to LUCI. All these affect the reliability of impact predictions, and the aggregation of the input data also demands that multiple realisations of LUCI should be carried out to understand the uncertainties resulting from the necessary spatial disaggregation of input data to drive LUCI.

2.6.3.1 Next Steps

A large effort was required to set up LUCI to run at the national scale, requiring parallelisation and other modification of code. A scheme to spatially distribute appropriate proportions of intervention locations and/or farm types to allow scenario analysis was also designed and implemented. With these changes complete, future scenario analysis for Glastir interventions over Wales will be more straightforward to carry out. Looking forward, development priorities for Year 2 of GMEP and associated more general development within the same timeframe, are as follows:

Work is ongoing to improve LUCI's capacity to represent detail in farm management and potentially link to frameworks with yet more capacity such as the ADAS suite of models. We are also exploring the potential of linking the habitat suitability and connectivity capabilities present within LUCI to the biodiversity estimates produced by MultiMOVE. We are including more capabilities to explore and display the effects of climatic and meteorological variability on predictions of water quality and quantity estimates (e.g. nutrient pollution, floods and droughts), and intend to explore the impact of suites of both design and historical rainfall and other climate events on these predictions for Year 2.

There is significant uncertainty surrounding some of the parameters informing LUCI's carbon stock and sequestration/emission predictions, which rely on literature estimates. Increased demand to establish national inventories for international reporting in recent years has led to further literature and knowledge becoming available, and this improved knowledge will be incorporated into future estimates. We will also explore ways to communicate the uncertainty where estimates are particularly uncertain.

Finally, web enablement of LUCI is underway, which may allow broader access and engagement in scenario exploration.

2.6.4 Plan for Year 2

- Application of all models to wider set of existing Glastir scheme options, and development of literature evidence base to support and test projections.
- Analysis of scheme option uptake statistics and refinement of model projections.
- Application of WDP-EMF model to scope additional options not included in the current scheme design for consideration by the Welsh Government.
- Application of LUCI model to calculate the benefit of targeted placement of management options on farm, to maximise the multiple outcomes of small areas of option uptake.
- Enhancement of LUCI to enable web-access and stakeholder engagement in scenario exploration.
- Application of MultiMOVE model to whole of Wales to calculate change in habitat areas that achieve desired plant community structures and explore regional sensitivities.
- Consideration of opportunities for integration or leveraging knowledge embedded in MultiMOVE and WDP-EMF models into over-arching LUCI framework model.
- Dissemination and publication of results for peer review.

2.7 Conclusions

This study has demonstrated the application of three separate modelling frameworks to quantify the multiple outcomes of selected Glastir management options.

The MultiMOVE model was used to project the response of selected target plant species to changes in vegetation management and soil status. The majority of expected changes were consistent with the expected de-intensifying impact of each option. Driving the model by evidence-based scenarios of changing soil condition and vegetation height created a useful transparent link back to the experimental literature. Increasing the power of this approach simply requires identification and inclusion of more studies. Given a long term commitment to management intervention, sought after changes in the suitability of ecological conditions for local target species appear to be achievable, with significant progress towards target habitat suitability scores made within 10 to 23 years of uptake of options.

The LUCI model projected significant reductions in the connectivity of erodible land to rivers and lakes, following uptake of 'Streamside Corridor' option. This was a consequence of LUCI's explicit recognition of the importance of spatial placement of interventions, and resulted in up to a 15% reduction in soil and phosphorus delivered to rivers. Woodland creation more generally had the potential to increase the national stock of woodland by *ca.* 10,000ha and carbon storage by up to 1%, increasing the connectivity of wildlife habitat and reducing flood risk by 1 to 9%.

The WDP-EMF model generally projected smaller reductions in pollutant emissions, reflecting the calculation of emissions from sources not directly related to fertiliser inputs and animal manures. The largest calculated reductions in emissions (<10%) were for nitrate leaching, nitrous oxide and methane following with-holding of nitrogen fertiliser and reducing stocking rates on the improved grassland area. The explicit source apportionment system used by the model allowed for flexibility in characterising the management options and insight into the reasons for large differences between site level and catchment scale impacts of improved management.

Individual Glastir prescriptions generally resulted in national reductions in pollutant emissions in the range <1 to 10%. Local pollutant reductions were several times greater within catchments with large areas of relevant land, reflecting the distribution of farm system types with soil and climate. Spatial targeting under the Advanced element of Glastir resulted in reductions within the Priority Catchment areas that were up to 50% higher than if scheme participation were distributed evenly across Wales.

The scale of the model results suggests that the cumulative impact of uptake of a number of Glastir prescriptions can be significant. However, the model outputs presented here are based on the assumption of maximum implementation of options across all of the relevant land area on a farm. This will over-state the potential impacts of the Glastir scheme. There is a critical need for detailed analysis of the pattern of option uptake and a survey of actual changes in farm management to quantify the limits to uptake and the true level of additionality on participating farms.

3. Field Survey Design and Implementation

Garbutt, A[1]., Henrys, P[2]., Astbury, S[1]., Biggs, J.[3], Brown, M. [2], Cosby, BJ[1]., Edwards, F.[4], Edwards, M[5]., Emmett, BA[1]., Ewald, N.[3], Halfpenny, I.[6], Hall, J.[1], Maskell, L[2]., Norton, L.[2], O'Hare, M. [7], H., Peyton, J[4]., Pywell, R. [4]Roy, D., [4] R., Scarlett, P[4]., Scott, A[2]., Scott, R [2]., Siriwardena, G[8]., Smart, S. [2], Swetnam, R[9]., Taylor, R.[8], Tordoff, G[10], van Breda, J.[11] Wood, C[2]., Watkins, J[2]. and Wright, S[2].

[1]CEH Bangor, [2]CEH Lancaster, [3]Freshwater Habitats Trust, [4] CEH Wallingford, [5]Edwards Ecological Services Ltd, [6]CADW,[7] CEH Edinburgh, [8]BTO, [9]Staffordshire University, [10]Butterfly Conservation, [11]Biodiverse IT,

The Glastir Monitoring and Evaluation Programme (GMEP) is a novel and highly ambitious programme, which brings 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. 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. The GMEP field survey covers three of the six key elements of the overall GMEP programme namely:

- A rolling survey programme involving a Targeted Component specifically for Glastir priority areas and a Wider Wales Component which aims to capture the national trends, counterfactuals and key baseline comparisons throughout the course of the survey;
- Integration of data from existing and ongoing monitoring programmes into the GMEP analysis;
- A data portal to make data publicly available in a user-friendly web interface maintaining farmer confidentiality and provide access to model outputs and in time, two of the models used by the team will be web-enabled for more general use together with tools to enable submission of data by the public to the GMEP data portal.

A full range of data collected, modelled or integrated can be found in Appendix 3.1.

3.1 Major achievements in Year 1:

- Statistically robust and flexible nationwide survey designed, based on rolling programme and sampling unit chosen to include a the Wider Wales Component (WWC) used for baseline estimation, national trends and national reporting of Glastir, and a Targeted Component (TC), which specifically links to the priority areas and aims of the Glastir scheme.
- Power Analysis run to determine sample number needed in each year of survey over the rolling cycle.
- All national WWC squares for 4 years selected using design method and optimum allocation algorithm and all TC Squares for year 1 selected proportional to the Welsh Government priorities (*i.e*. points based) with scripts written to automate selection in subsequent years as priorities change.
- Recruitment of data analysts, administrators, liaisons and surveyors for the GMEP programme.
- Development of geo-processing scripts for automated data analysis, management and mapping. The advances made in year one mean that tested procedures are now set in place to repeat processes for subsequent years, and produce consistent outputs.
- Obtaining the 50 external datasets required for use by internal and external GMEP collaborators. GIS datasets, data tables, and databases have been obtained and licensed

through the Welsh Government and our programme partners, meeting a wide range of data needs across work packages.

- Setup of a secure spatial database as a centralised source for GMEP data distribution.
- 331 spatial data files uploaded to the secure spatial database.
- Development of 7 new and existing bespoke software application for field survey.
- Gaining permission to survey the holdings of land owners within GMEP 1km squares with 88% of contacted landowners approving access.
- Completion of the biophysical, pollinator and bird field surveys for 60 1km squares for within the time allocated by field surveyors.
- Data from all 60 survey squares checked and loaded into secure spatial database ready for analysis.

3.2 Introduction to the GMEP Survey Design

In the Glastir monitoring and evaluation programme the key aim is to evaluate the benefits that Glastir interventions have on the five key outcomes identified by the Welsh Government and the EU, namely: biodiversity, climate change mitigation, soil quality and water flow and quality, landscape and historic features and woodlands. This implies that the monitoring survey needs to capture multiple measures and metrics and be able to integrate across these metrics. Hence a full ecosystem based approach is required where data operating at multiple scales are captured, where possible, at the same time in a single snap-shot visit. 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 sufficient power and spatial scale to detect changes and trends in these measures set against an appropriate population of counterfactuals, and detect their inter-dependence, enabling trade-offs and co-benefits to be quantified.

One difficulty with investigating multiple indicators and metrics is that the metrics vary over differing scales. Some measures will have high spatial yet low temporal variability, whereas for others the opposite may apply. For example, soil carbon has low temporal variability as it does not generally change quickly over time, but high spatial variability as peats are vastly different to arable land, for example, whereas the abundance of some butterfly and bird species can be rather consistent across large areas but vary markedly between years. In each of these scenarios a completely different design of survey would be optimal: one that puts more effort into capturing as many spatially different sites as possible with little or no temporal element, or one that puts more effort into surveying the same sites over time intensively, respectively. Thus, designing a single survey to enable detection of changes in multiple metrics across time and space is difficult but essential if the budget is to be met and an ecosystem approach is to be maintained.

Kish (1990) developed the concept of a rolling sample design intended to collect data over space and time. He advocated its use due to the inherent flexibility and the ability to serve multiple purposes. In many countries around the world, this form of survey has now replaced the national census due to its flexibility and cost-effectiveness. For the Glastir monitoring and evaluation programme, we have adopted 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, such that spatial variation and temporal changes and trends can be detected cost-effectively. This design gives the best balance for a survey that aims to deliver across multiple metrics and compare against estimated baselines and trends over time. While aligning surveys of multiple metrics at the same set of survey locations inevitably entails compromises in respect of the optimal approaches for each metric, it critically allows inter-relationships between the metrics to be considered, as well as the responses of all of them to the same environmental influences.

We decided on a 4-year cycle for the rolling programme in order to meet reporting requirements, to maximise spatial and temporal coverage and to provide sufficient flexibility to the Welsh

Government. An example of the proposed rolling programme is plotted in Figure 3.2.1, demonstrating the ability to estimate trends and changes over time, whilst at the same time providing robust spatial baseline estimates.

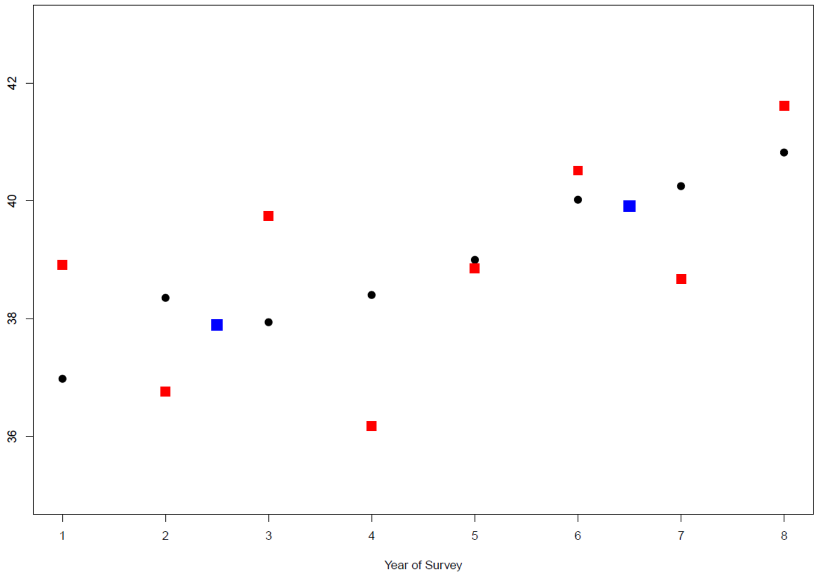


Figure 3.2.1 Plot of simulated continuous data based on a rolling programme design over 4 years. Black dots represent the true underlying value of the indicator, red dots represent the within year estimate and blue squares represent the estimated indicator value across a full cycle of the rolling programme.

Testing the effects of environmental interventions is commonly done using a case-control or before-after-control-impact approach, *i.e*. where interventions are made in some locations and monitoring of responses is undertaken both there and at other (often matched) locations free of the intervention concerned. Our design for the GMEP survey differs considerably from this approach, avoiding important problems with using a case-control approach in a context such as GMEP. First, it can be difficult reliably to select appropriate controls in complex landscapes because numerous factors, including field contents, field boundary characteristics, landscape context, topography, field sizes and areas of semi-natural and anthropogenic habitats, need to be held constant across matched pairs. Second, in long-term monitoring, control areas need to remain out of scheme indefinitely, which can be both difficult to ensure and counter to the principles of open-access schemes intended to deliver environmental improvements at broad scales. Third, managed areas are likely to have had a degree of “environmentally friendly” management before a scheme like Glastir began and long-term, unmanaged areas may remain so for reasons unrelated to the scheme, potentially introducing bias to comparisons. Our approach involves comparing areas with different quantities of managed areas within a stratified random selection of survey plots of a standard size. The stratified random selection allows unbiased inference about background or baseline conditions and comparisons between managed (Glastir) and unmanaged areas remains possible while both are represented sufficiently in the data set. Further details of this stratification is given in section 3.4.2 The use of a random sample stratified by landscape variables means that results can readily be scaled up to estimate patterns of spatial and temporal variation at regional and all-Wales scales. Further details of the methods we have used and support for their adoption are provided below.

3.3 Baselines and Counterfactuals

In their well-cited article, Kleijn and Sutherland (2003) discuss the problems with drawing robust inference from land management schemes and suggest that a good monitoring scheme should aim to:

(i) Collect baseline data.
(ii) Examine trends in time.
(iii) Try to reduce systematic differences in initial conditions between scheme and control sites as far as possible.

It is clear that Kleijn and Sutherland (2003) were stressing the importance of the counterfactual and that this should be considered when designing a new survey. The implications of this for the GMEP survey were that we needed to collect data that would form a suitable baseline to assist comparisons as well as collecting data to directly inform on the relationship between metrics and Glastir measures. This baseline needed to be representative of the wider scale at which we want to draw inference. The baseline information necessary to answer the specific questions of interest can therefore be thought of as consisting of two elements. Firstly, current baselines or "starting points" which take into account any effects of legacy schemes or historic management and, secondly, temporal baselines showing how the general state of specific metrics are changing over the course of the survey independent of Glastir interventions.

The current baseline or starting point is important so that we know typical values of indicators and metrics before any land management or Glastir intervention. These are evaluated using existing monitoring data collected over the past 20+ years that we can overlay and compare with the data collected from this survey. This allows us to account for legacy scheme effects and ensure that all comparisons can be made relative to a consistent level. A key prerequisite of the GMEP design is therefore the ability to integrate with existing monitoring schemes that are to be used to inform the historic baseline. Where little or no data have been previously collected, additional information and data will be collected to inform and provide context for robust estimation of current baselines for these metrics. An example of this is greenhouse gas emissions, more detail of which is given in section 3.7.1.

The temporal baseline provides information to allow measurement of how metrics and indicators change over the course of the survey, independent of any management or intervention. This must be estimated from the initial data collected under the GMEP survey itself. There is therefore a requirement for the survey to have the ability to produce national and sub-national estimates at given time points and also trends over time to represent the baseline status of specific indicators and metrics. Any effects of Glastir measures are relative to this baseline so that any advantage or positive effect of the measure can be detected even if the indicator in question is not responding in the way that one may hope.

The chosen design was therefore a rolling programme based survey with two key components: the Wider Wales Component used for baseline estimation, national trends and national reporting of Glastir, and the Targeted Component, which specifically links to the priority areas and aims of the Glastir scheme. Across both of these components, integration of survey data is essential and therefore a common spatial unit has been adopted.

3.4 GMEP Sample Selection

3.4.1 Sampling Unit

In order to integrate across multiple metrics, provide a true ecosystem base approach and provide robustness to any future changes in the Glastir scheme design, a common spatial unit was needed across the whole survey. Furthermore, as a clear aim of this programme is to make inference at a national scale and broad conclusions on management options are required, it was crucial that the sampling unit was sufficiently representative of this wider population so that any extrapolation and upscaling required for future reporting was feasible. Hence, our focus is on comparing effects of different management interventions by comparing contrasting fixed sampling units (with different amounts of specific management options), not contrasting individual farms. Thus, we average over the variation between farms within squares, but consider variation between farm types across the whole sample. This approach will be more powerful and more future-proofed than individual, farm-based in scheme / out scheme comparisons. Moreover, site selection is not compromised as farms enter into different management options, providing variation in management quantities that allows tests of the influence of the management on the metric under consideration. Box 3.4.1 provides an example of this.

Box 3.4.1 BBS agri-environment scheme analysis.

Baker *et al*. (2012) used BTO/JNCC/RSPB Breeding Bird Survey (BBS) data to investigate the influences of management options in the English Environmental Stewardship (ES) scheme on bird population growth rates. The BBS is an annual, volunteer scheme that samples bird abundance in units of 1km squares, selected at random. It has national coverage in England and is designed to monitor dispersed, wider-countryside populations, making it well-matched spatially to ES, which is dominated by a "broad-and-shallow" tier intended to enhance the wider environment. ES has also reached uptake over 70%of the usable agricultural area in England, so areas with no ES management are rare. However, ES agreements for individual holdings are made up of landowner-selected sets of management options, so there is considerable spatial variation in the quantities of individual management types within 1km squares. Baker *et al*. exploited this variation to look for associations between bird population changes and forms of ES management that could have had biologically plausible effects on individual species. The results showed the first landscape-scale evidence for effects of agri-environment management on widespread components of biodiversity, with the clearest effects involving influences of options providing over-winter seed food for granivorous birds. These patterns reflect the resource factors that are known to limit the populations concerned, but they were subtle, representing reductions in the rates of population decline, rather than reversals of the declines. Nevertheless, this study provides proof-of-concept for study designs of the kind being employed in GMEP, notwithstanding differences in the detail of the survey approaches being used.

As a common sampling unit, we chose the 1km square. The 1km square scale is important as it is the scale the Countryside Survey (CS) of Great Britain (Carey *et al.*, 2008), which also adopts a whole ecosystem based approach and records data on multiple metrics. As CS data will provide a key baseline for many metrics measured in this GMEP survey, it is crucial to remain with the 1km scale. The 1km scale also complements existing environmental monitoring programmes such as the Breeding Bird Survey (BBS, Risely *et al*., 2013; Box 3.4.1) and the Butterfly Monitoring Scheme (BMS, Botham *et al*., 2013), which will provide important baseline and contextual data where necessary. As such, existing data sets dating back decades can easily be integrated and provide historical reference data to which the GMEP survey will add. Using historical data such as BBS, BMS and CS allows us to contextualise any changes that we may see and, given suitable integration work, may significantly improve our ability to detect trends over time.

While different metrics are ideally monitored at different scales, any given sampling unit will be more appropriate for metrics than for others and some metrics are best measured for whole-farm units, as opposed to random parcels of the landscape, a common sampling unit offers important benefits in respect of identifying inter-relationships between metrics and common responses to environmental drivers. It was not feasible to monitor in other ways in addition to the 1km square sampling units and we consider the latter approach to be optimal for coverage of the wider environment with representative sampling.

Data for many indices can be scaled up or down to the 1km square scale, if the sampling is designed appropriately and we will apply correction factors to convert data that cannot be collected at this scale to fit to it. For example, we will rescale farm-scale data on economics or chemical inputs (a measure of diffuse pollution) by correcting for the proportion of the farmed land surface that is in the 1km square, having collected data from a representative sample of the farms in the square. To capture the required information for this rescaling, the protocol adopted is the current Countryside Survey methodology that records the detailed habitat composition of each 1km square and we are also using data collected from remote sensing methods, as in LCM2007 (Morton et. al., 2011), to capture habitat composition at wider scales alongside catchment modelling approaches to capture connectivity of streams up and downstream from our sample squares. Having detailed information of the habitat mosaic in and around the 1km square will enable necessary scale corrections.

3.4.2 Wider Wales Component

The first component of the sampling is the Wider Wales Component (WWC), which aims to capture the national trends, counterfactuals and key baseline comparisons throughout the course of the survey, as well as the effects of the aspects of Glastir with broad uptake. As such, the selection of WWC sample sites (1km squares) needed to be representative of Wales as a whole and remain independent of any farm ownership or management uptake. The rolling programme design of the WWC squares means that each individual year of the survey needs to be representative and independent in this way.

To ensure statistical robustness, we must have a sufficient number of sites sampled in each year such that changes can be detected with an appropriate level of statistical power. To investigate this in detail, we conducted a power analysis looking at the power to detect changes over time in multiple metrics based on differing sample sizes within each year. The power analysis was performed using existing information from the Countryside Survey (CS) and is described in detail in Appendix 3.2. The results from the power analysis showed that a sample of 45 1km squares per year over 4 years would provide sufficient power to detect expected changes over a similar period.

The selection of the sample of squares for monitoring was accomplished following the same procedure as used for the Countryside Survey of Great Britain, which aims to provide robust estimates of indicators at national and sub-national level across GB and constituent countries. Using the same methodology builds on previous knowledge and will enable integration of the two surveys in future analyses.

The 45 squares in each year, over the four year cycle, were randomly sampled within strata defined according to the Land Classification of Great Britain (Bunce et. al., 2007) – a derived classification of the landscape based on its topography, geology, climate and physical attributes. Environmental heterogeneity is minimized within each stratum of the Land Classification and is maximised between strata. Figure 3.4.2.2 shows the Land Classification over Wales. The rationale behind using such stratification was the long term aim of the survey. The Land Classification remains unchanged over time and therefore the initial sampling scheme and selection of squares are sufficient for the long term requirements of the study. Conversely, stratification according to other environmental attributes, such as habitat, would have been subject to change over time and could therefore have damaged the sampling protocol. Although stratifying by land class is not equivalent to stratifying by habitat, because there are many more variables that contribute to stratum definition, there is a clear overlap between the land class strata and their habitat composition. In other words, the different land classes contain different habitats. A clear example of this would be coastal land classes compared to the more upland defined land classes. The land classification differentiates these two classes due to altitude, climate and underlying geology. Figure 3.4.2.1 shows the habitat composition of two such landclasses in Wales with Landclass A representing a more upland defined class and Landclass B representing a coastal class. This relationship between land classes and habitats, coupled with the fact we are sampling by the land class strata, ensures that all main habitat types are suitably sampled.

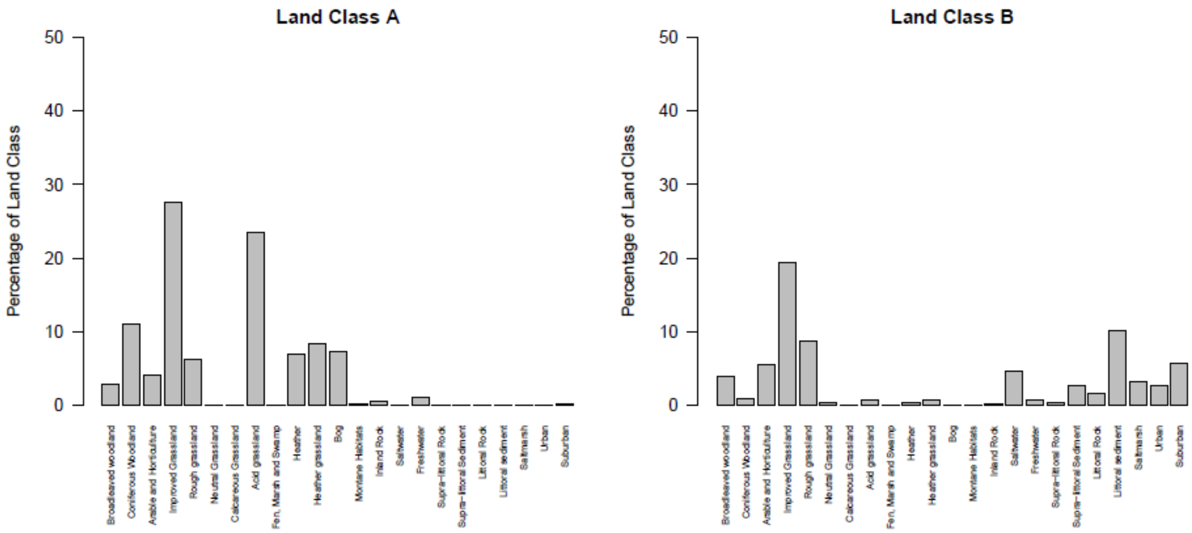


Figure 3.4.2.1: *Habitat composition of two Welsh land classes demonstrating the different composition of habitats across the land classes. Land class A represents an upland defined class while land class B represents a coastal stratum.*

The proportion of the 45 1km squares randomly sampled from within each stratum was proportional to the size of the stratum in order best to allocate survey effort. Any square randomly selected that contained more than 75% of urban land or that was more than 90% sea (defined by LCM2007 and the UK Census mean high tide data) was excluded. This criteria ensures that we do not remove important coastline squares, which contain a significant number of priority habitats and comprise a high proportion of total land in Wales. The random sampling within these strata for each year of the rolling survey ensures that the square selection is unbiased and representative of the wider environment.

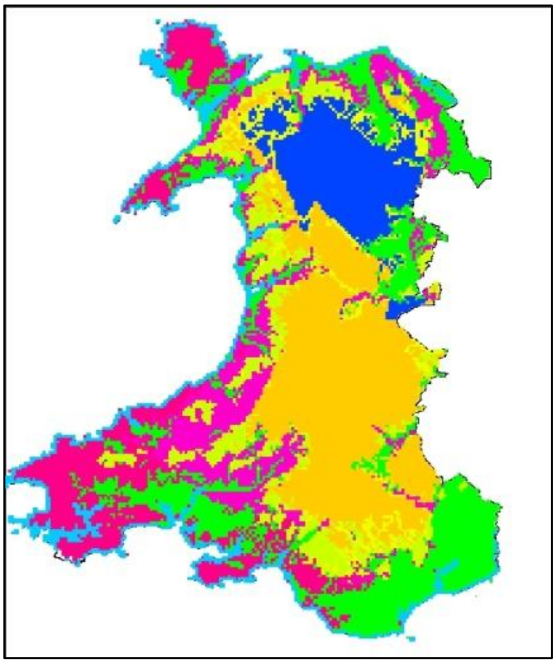


Figure 3.4.2.2: *The ITE Land Classification of Great Britain, as used for CS2007, mapped over Wales. Each colour represents a different land class. As the numbering of the classes / strata is arbitrary, no key is provided*.

The rolling survey design requires for the 45 1km squares sampled in Year 1 (2013) to be re-sampled in Year 5 (which is year 1 of the second rolling period in 2017). Similarly the squares surveyed in Year 2 will be resurveyed in Year 6 and likewise for the Year 3 and 4 squares. In this first year, we have selected all 1km sample squares for each year of the 4 year rolling programme constituting the WWC element of the survey which will remain fixed to provide representative information across our range of metrics. Figure 3.4.2.3 shows the distribution of these 180 (45 x 4) squares plotted a 5km x 5km resolution to ensure confidentiality.

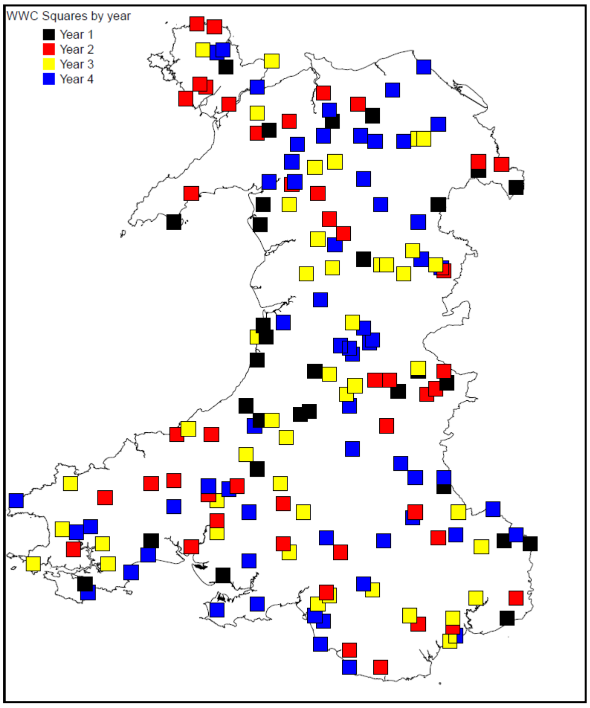


Figure 3.4.2.3: Location of the 180 (45 x 4) WWC squares for the 4 years of the rolling programme plotted at 5km x 5km resolution to ensure data confidentiality.

3.4.3 Targeted Component

Alongside the randomly sampled WWC component of the monitoring, we also monitored a similar number of 1km squares targeted specifically at Glastir priority areas. This is important because the stratified random sampling for the WWC may not cover the management options prioritised by the Welsh Government to allow inference about changes in relevant metrics. As we wish to compare squares from the targeted monitoring to squares from the WWC monitoring, it was important that we preserved the same spatial scale. The targeted squares were chosen specifically to map onto areas that the Welsh Government have emphasised as priorities for Glastir Advanced land management scheme delivery. The selection of squares was therefore based on the target areas identified by the Welsh Government, using the scoring system that they have adopted in order to combine maps of Glastir priorities.

Each 1km square Wales was overlaid onto the target layers of the Glastir Advanced scheme (94 separate layers, a full list of which is provided in Appendix 3.3) and if the square was inside the target area then it was assigned the corresponding score attributed to it by the Welsh Government. This was done for all 1km squares across all target layers and the resulting scores were summed for each square. This provided a map of the total Glastir Advanced score for every 1km square in Wales, which effectively represented the areas of Wales where the Welsh Government have put the emphasis on delivering benefits across the 5 key outcomes from Glastir. This map is shown in Figure 3.4.3.1

Having obtained the total Glastir score for every 1km square in Wales, survey squares for the Targeted Component were randomly selected with selection probability proportional to their total Glastir Score. Therefore, squares with twice the Glastir score of other squares were twice as likely to be selected. As with the WWC squares, any square with greater than 75% urban or 90% sea coverage was excluded. The selection of squares was independent of Glastir uptake because we are maximising the likelihood of coincidence with the Glastir Advanced element due to the way Glastir Advanced entry is implemented, without selecting Glastir farms specifically. Keeping the selection independent of Glastir uptake means that the Targeted Component squares also provide important counterfactual information and that the survey is robust to changes in uptake over time.

The key advantage with this selection procedure for the Targeted Component squares is that it directly reflects the priorities of Glastir according to the Welsh Government. The targeted squares are selected on a yearly basis to be consistent with the most up to date scoring defined for the Glastir Advanced scheme on all the target layers. This ensures that the Targeted Component remains flexible, though there is obviously a trade off between how often the priorities change and our power to detect specific intervention effects related to these priorities. The only constraint is that, to generate measures of change in these priority areas, we must have sufficient sampling in these areas over the period one wishes to estimate change for. This targeted component of monitoring can otherwise remain flexible over the course of the first 4 years of the survey with different sets of survey squares being readily selectable as and when the Welsh Governments priorities move on. An example of the flexibility in the design and the ability to adapt to the Welsh Government's priorities is shown in Box 3.4.3.1. Providing we have selection probabilities (that is the probability that any 1km square is included in the GMEP survey)and equivalent maps of priority areas for the whole of Wales, the targeted Squares and Wider Wales squares can easily be integrated, modelled and analysed together.

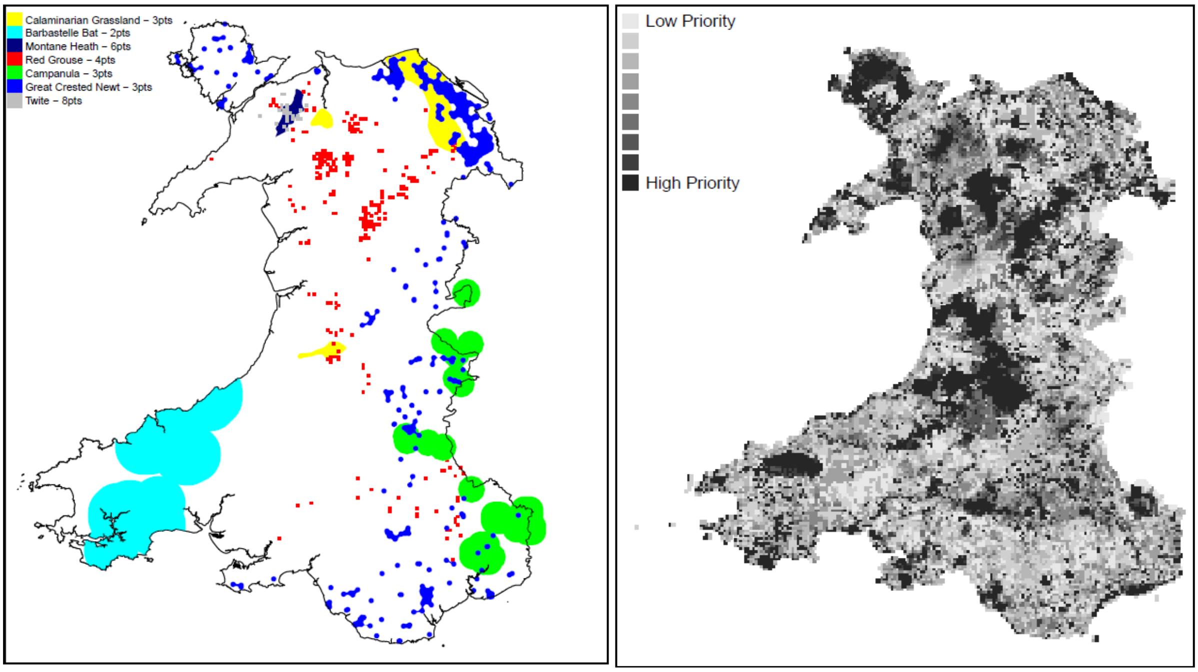
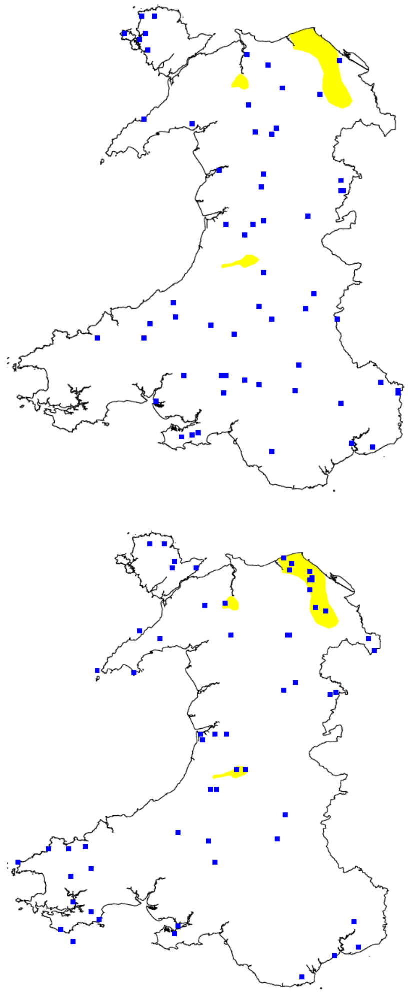


Figure 3.4.3.1 a) An example showing seven of the Glastir Advanced target layers overlaid on top of each other with their corresponding score shown. b) A map of the Glastir Advanced priorities having added up the scores for every 1km square across Wales.

Box 3.4.3.1 Example of flexibility of TC Square selection



As an example of the flexibility of the square selection algorithm adopted for the Targeted Component, a hypothetical set of squares were selected by changing the Glastir Advanced score of Calaminarian Grassland from its current score of 3 to 60 (currently the highest score). The plot on the top left shows a hypothetical set of targeted squares using the current scoring system and the plot on the bottom left shows the squares selected using this new scoring system. Both show the area of Calaminarian grassland identified by the Glastir target layer in yellow. One can see how there are clusters of squares and a high proportion of overall squares in the areas of Calaminarian grassland identified. Squares outside these areas are also still present as other layers still have associated Glastir Advanced scores.

This process is applicable to all such layers and therefore, provided the scores attributed by the Welsh Government to the different layers accurately reflect their priorities, the TC squares themselves also reflect these priority areas.

In the first year of survey, the contract start date and preparation time required prior to survey meant that we have had a shorter field season (June to September). It was agreed with the Welsh Government prior to starting the contract that a total of 60 squares would be surveyed in the first year. The 60 comprises an equal mix of 30 WWC and 30 TC squares. Although the power analysis suggested 45 squares would be optimal, 30 of each type still provides sufficient information and the number of explanatory and contextual variables collected at each square, together with a model based analysis approach, means that inference can still be made with sufficient power.

The two-tier (WWC and TC) approach to the design of the field survey means that the survey is flexible over time and can adapt and be responsive as and when the Welsh Government priorities move on. This, coupled with the type of information being collected, also means that the design ensures that the survey is flexible enough to adapt to a changing policy agenda. As the future policy design changes, the survey is flexible enough to adapt. This is because the design of the survey has not been dictated by current political pressures or by specifically chasing Glastir farmers. Rather it is based on collecting raw indicator information which, due to the design, can be packaged together in a way to adequately reflect the current questions of interest. The flexibility means that the designed survey is fit for the long term. This is exemplified by Countryside Survey, which over the past 35 years has come through a highly changing political landscape, yet has always been able to stay relevant and reflect the current policy design due to its robust sampling strategy and data being collected.

3.5 Analysis

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. Delivery of these robust estimates of change are essential for the economic efficiency, cost effectiveness and distributional effect to be undertaken. The example in Box 3.4.1 used a similar analytical approach, namely generalized linear models of Poisson-distributed count data with respect to agri-environment management and background environmental variables, specifically with a parameterization meaning that the outputs were expressed as annual proportional changes in abundance.

This analysis approach taken therefore examines the response of outcomes relative to Glastir measures. More power will therefore be obtained if we have squares with ranges of uptake, with some squares containing very little to squares with a high proportion of Glastir uptake. We project 45-55% of our total sample population will be in scheme once the expected uptake of Glastir of *ca.* 4500 individual farms is achieved and we have completed our first cycle of our full survey. This overall proportion of approximately 50% would, for the type of analysis proposed, be considered optimal.

3.6 GMEP field survey methods

3.6.1 Overview of methods

The national surveillance monitoring programme to quantify on-going change in the Welsh countryside and impacts of Glastir interventions was implemented from May through to September

2013. The main biophysical survey was managed by CEH; pollinator surveys (butterflies, bees and hoverflies) were managed by Butterfly Conservation (BC); and bird surveys were managed by the British Trust for Ornithology (BTO). A full time Farmer Liaison Officer was appointed by CEH to coordinate the movements of all field teams and arrange land access permissions.

Landownership within each 1km square was identified using the Land Parcel Identification System (LPIS) database provided by the Welsh Government. In total, there were 404 individual land holdings contacted within the 60 1km squares surveyed in 2013. Of these, 358 were obtained directly from the LPIS database, with the remaining 46 identified from a combination of Internet-based research, local authorities, Government agencies, estate management services and Commons associations. Initial contact with landowners was made by letter outlining the objectives and timing of the field survey (see Appendices 3.4 and 3.5 for letter and accompanying GMEP 'flier'). The letter emphasized that the land selected for survey was randomly selected and not related in any way to any compliance inspection process for Glastir, Single Payment Scheme or any other scheme. It was also emphasized that personal data is protected by the Data Protection Act 1998 and information gather through the survey is the property of the Welsh Government, subject to the appropriate data security. Landowners were also asked for information on any animal or plant diseases on their property and bio security measures they would like survey staff to comply with.

3.6.2 Bio security

Bio security measures were put in place for all GMEP surveys following the Welsh Government guidelines. Landowners were asked for specific bio security requirements when visiting their land. Dipping buckets at the farm gate were used on two occasions. Farm Fluid HD Row, a broad spectrum, multipurpose phenolic disinfectant was used to control the spread of diseases as recommended by Defra. Footwear was cleaned and disinfected on arrival/leaving and between landholdings. Survey vehicles were kept clean throughout the field season and disinfected before entering landholdings and on the edge of premises on leaving. Disinfectant was only applied after dirt had been cleaned off. Increased concentrations of Farm Fluid HD Row were used when the survey teams were in areas known to have incidents of TB.

In addition to controlling for animal diseases with disinfectants, landowners were asked if there were any plant or tree diseases on their land. If there were no known plant or tree diseases, Forestry Commission Level 1 bio security measures were followed *i.e.* clean footwear (see http://www.forestry.gov.uk/pdf/FC_Biosecurity_Guidance.pdf/$file/FC_Biosecurity_Guidance.pdf for further information). If plant and tree diseases were known to be present the surveyor teams avoided infected areas. No plant or tree diseases were reported by any of the landowners to the survey teams throughout the survey.

3.6.3 Biophysical survey

Thirteen experienced botanists/field surveyors were appointed in May 2013 by CEH to cover the main biophysical survey. A comprehensive, three week training programme was held in to cover all aspects of data collection, Health and Safety, first aid and off-road driving before surveyors started work in the field. The surveyors were split into three teams of four with a 'floating' surveyor to cover holiday leave and provide extra support where needed. Each team was allocated 20 1km squares to survey across three regions (north, mid and south Wales). Within each region the 1km squares were visited in order from either east to west or west to east which, along with the north/south division, was designed to avoid longitudinal/latitudinal bias in climate and seasonality. To maximize the efficiency of the field teams, a wide number of ecosystem characteristics were recorded on each visit under seven different activities. Dedicated helpdesks were set up to enable the survey teams to phone in with method and logistical queries for farmer liaison, mapping habitats and linear features, placement and recording of vegetation plots, IT hardware/software issues, bird surveys, and pollinator surveys. Feedback was given to the survey teams by programme staff by telephone and email. Programme staff visited the survey teams at regular intervals during the field season to give and take feedback.

All measurements collected as part of the biophysical survey have been mapped to specific or bundles of interventions and one of the five Glastir outcomes: climate change mitigation, 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.

3.6.3.1 Historic Environment Assets

These measurements will contribute to the Glastir outcome: Managing and protecting the Welsh landscape including the historic landscape.

There were two Historic Environment Assets recorded as part of the survey work to provide data in the future on how Glastir interventions impact our historic landscape (further detail of which is provided in Chapter 6); Scheduled Ancient Monuments (SAMs) – nationally important with statutory protection (The Ancient Monuments and Archaeological Areas Acts, 1979, legislation similar to SSSI legislation) and Historic Environment Features (HEFs) – regionally important but no statutory protection. A basic condition assessment of SAMs and HEFs were recorded where they occurred within a 1km square. Excluding one square, which contained over 200 such features arising from historic mining in the area, the maximum number of features in a square in year 1 was 5. This information was gathered in the office prior to field deployment and meant that the surveyors were able to record all known features within our sample squares. In light of the vast quantity of information already being collected, an agreed maximum of 7 features per square is used for guidance for the surveyors and in squares where more than 7 occur, advice is sought from Cadw as to which 7 to survey. Given a limited amount of available training time, surveyors were not necessarily familiar with the appearance of every monument type in their survey areas. Therefore, the data collection focused on producing basic condition information for the land within a defined polygon area. Both Cadw and the Welsh Archaeological Trusts assisted in the production of field sheets giving extra information on description of the feature, its location and potential issues to ensure an accurate assessment. Data collection covered two areas. Firstly, assigning a basic condition assessment for the feature (excellent condition; sound with long standing defects; sound with minor defects; signs of potential deterioration; major signs of deterioration; and damaged). Secondly, threats to the integrity of the feature were assessed under four headings; stock (e.g. poaching, burrowing animals); agricultural operations (e.g. tracks, ploughing); vegetation (e.g. scrub, bracken), and an ‘other’ category (e.g. vandalism, fly tipping, natural decay). General photographs of the site were taken along with detailed images showing any specific condition issues identified.

In total 47 historic features were recorded across 60 squares in 2013.

3.6.3.2 Landscape photography

These measurements will contribute to the Glastir outcome: Managing and protecting the Welsh landscape including the historic landscape.

To support the work to be undertaken to quantify the impact of Glastir on landscape quality and how that is linked to ecological quality (see Chapter 6), fixed point photographs were taken within each 1km square. These provide repeatable, fixed-point images to monitor landscape change over time and a resource for assessing the planned work to link the perception of landscape quality by the public and ecological quality as assessed through our rolling national survey. See Chapter 6 for further information on this topic. The photograph methodology ensured an objective photographic record of the 1km field survey sites, capturing the typical rather than most photogenic view. Each 1km survey square was divided into four 500 x 500m quadrants: NE, SE, SW, NW. At the centre point of each quadrant four photographs were taken looking N, S, E, W.

A total of 960 landscape photographs were taken across the 60 squares in survey year 1.

3.6.3.3 Mapping habitats, linear and point features

These measurements will contribute to the Glastir outcomes: Maintaining and enhancing biodiversity; Managing and protecting the Welsh landscape including the historic landscape; creating new opportunities to improve access and increasing the area and management of woodlands.

Collection of detailed spatial data on extent and composition of habitats and features across the entire 1km square was recorded to feed into the assessment of a multitude of Glastir measures associated with habitat and to provide underpinning, contextual data for other areas of GMEP. Further details are provided in Chapters 4 and 7. Information on habitat type and landscape features were recorded on a digital map, held on the ruggedized field computers (see section 3.7.2.).

Habitat areas (>20m x 20m) were mapped and classified using the Broad and Priority Habitat classification (Maddock *et al* 2008). Additional attributes were recorded using a comprehensive range of pre-determined options which relate directly to Broad and Priority Habitats, vegetation types and landscape features (e.g. Agriculture, Forestry, Buildings and structures); supporting attribute data (e.g. grass ley, burnt vegetation), indicative species presence and cover; and land usage (e.g. stock, cattle, sheep, timber production).

Linear features are landscape elements less than 5m wide that form lines in the landscape and have a minimum length of 20m and may include gaps of up to 20m. Linear features recorded include woody linear features (e.g. managed hedgerows and unmanaged lines of trees), streams and ditches, grass strips, banks, walls, fences and footpaths and tracks. In addition to mapping the length of linear features, a comprehensive condition assessment and secondary attributes are recorded. For example, for hedgerows extra information is recorded on height of base of canopy, management, trees, species composition and gappiness.

Point features are individual landscape elements that occupy less than an area of 20x20m. They include: forestry features such as individual trees, clumps of trees, patches of scrub, veteran trees; inland water features such as springs and ponds; inland physiography such as cliffs and rocky outcrops and structures such as buildings, quarries and wind turbines. Additional attributes are recorded for individual features. Attributes recorded for trees include the species, presence of dead wood, habitat boxes (bats/birds) and presence of a buffer zone.

One additional feature to be added in 2014 includes the condition of public rights of way. Basic information was captured by the bird teams in 2013 and a very preliminary analysis of the data suggests valuable information could be gained if this becomes a standard component of the full survey in a way similar to that of the historic features.

3.6.3.4 Vegetation plots
These measurements will contribute to the Glastir outcome: Maintaining and enhancing biodiversity

Plant species presence and abundance was recorded in different sizes and types of vegetation plot allowing vegetation change to be expressed by habitat type, landscape location and whether in or out of the Glastir scheme (Chapter 4). In the first four years of GMEP plots will be located and recorded for the first time in all 1km squares. Plots can be located in any semi-natural vegetation; this includes amenity. For each vegetation plot general information was collected including species presence, cover and height. A photograph of each plots was taken and a GPS reference and sketch map drawn to aid relocation. Random points marking the position of the five 'nested' plots in each square were determined prior to the field survey. The locations, type and numbers of certain kinds of plot will be determined based on predetermined rules using the 'nested' plots as a starting point or from the findings from the mapping exercise. Ten plot types were used to record vegetation:

- Nested plots to provide a random sample of common vegetation types;
- Targeted plots to sample Priority Habitats and locations eligible for Glastir;
- Unenclosed plots to sample unenclosed Broad Habitats;
- Boundary plots running adjacent to field boundaries;
- Arable plots on field edges;
- Field margin plots to record new arable field margins that form part of land management agreements;
- Hedgerow plots recording diversity alongside hedgerows;
- Hedgerow diversity plots to record woody linear features and their physical condition;
- Streamside plots to record streamside diversity and;
- Stream bank plots to record the upslope habitats.

Mapping of these measurements to specific Glastir outcomes is available in Appendix 3.1 and interventions in Appendices 4.5a and 4.5b.

3.6.3.5 Soil sampling
These measurements will contribute to the Glastir outcome: Combating climate change through soil carbon storage assessment; improving water and soil management due to the direct link between soil and water quality; and also underpins modelling work to forecast maintaining and enhancing plant biodiversity as soil quality is a key constraint on habitat suitability for a range of plants. In addition, the soil sampling assesses major components of soil natural capital which underpins the delivery of ecosystem services, particularly provisioning and regulating services. In the way that financial capital can be assessed by the quantity of money in the bank, soil natural capital can be assessed by the stocks of nutrients, biomass and organisms etc in the soil (for further discussion see chapter 8).

Soil samples were collocated from each 1km square to enable changes in several key topsoil characteristics in response to Glastir interventions to be studied (Chapter 8). The soil samples were co-located with each of the five nested vegetation plots. Four soil samples (for chemical, physical, and soil biological analysis) were collected from the top 15cm of the soil profile and a fifth, for the invertebrate sample from the top 8cm. Many of the methods were comparable with those of Countryside Survey to enable comparison with the 25 year record of topsoil change (Emmett *et al*. 2010). Soils were analysed for 20 main parameters (see table 8.5.2.4.1), including a range of new biodiversity measurements to try and better understand controls of soil function. This included: DNA for microbial diversity and function (testing new methods); and Microbial Diversity estimates using terminal restriction fragment length polymorphism (TRFLP) which provides information on the relative abundance of different bacterial and fungal species.

A total of *ca.* 1,500 soil samples were taken across the first year of survey.

3.6.3.6 Headwater stream survey

These measurements will contribute to the Glastir outcome: Improving water and soil management; Maintaining and enhancing biodiversity.

The physical, biological and chemical condition of headwater streams was recorded to assess the impact of Glastir interventions on water quality (Chapter 8). To be eligible for inclusion within the GMEP survey streams had to be 1st or 2nd order, at least 500m long, with most of its catchment in the square. Where squares had more than one stream suitable, the most representative of the square (based on length of stream in the actual square) was selected. Water chemistry, diatom community, macroinvertebrate community, aquatic plant community, hydromorphological and physical characteristics of the watercourse (River Habitat Survey Amended) were recorded. The length of the headwater stream sampling site is 500m of watercourse which defines the limits of the River Habitat Survey area. A 100m aquatic plant survey, 10m macroinvertebrate and diatom survey and water chemistry sampling points were all nested within this length centred on the mid-point (Figure 3.6.3.6.1). The River Habitat Survey is a description of over 150 potential river characteristics recorded on a one 500m stretch of river in each 1km^2 such a pools and riffles, overhanging trees and physical structures. The macrophyte survey recorded species presence and abundance over a 100m length to give a mean trophic rank index of water quality. Five diatom samples were collected and bulked from the central 10m reach –diatoms for assessing ecological status (DARES) timed searches for macroinvertebrates across a 10-15m reach were undertaken using standard RIVPACS methodology (Wright et. al., 2000). Environmental variables such as stream width, depth; surface velocity: substrate; algae; plants; street lighting; sketch + photo; GPS were recorded with the 10m reach. The conductivity and pH of the water was recorded on-site; and an additional water sample taken and filtered on site before being sent for alkalinity, soluble reactive phosphorus and total oxidisable nitrogen analysis the in laboratory.

The number of features measured and scale of survey mean that this is most likely the most comprehensive freshwater survey ever conducted in the UK.

In the first year of survey 42 out of 60 squares were sampled for freshwater streams.

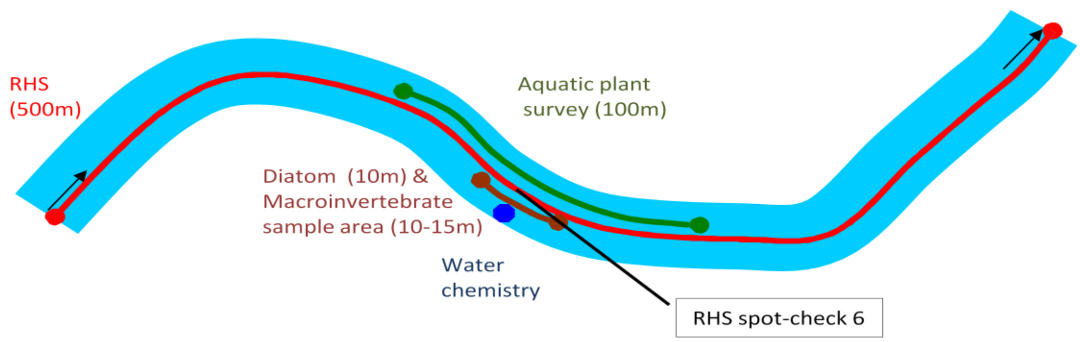


Figure 3.6.3.6.1.*The nested spatial arrangement of sampling stretches for the different tasks at each headwater sampling site.*

Analysis of the data will take full account of the context of the sampling location within the wider catchment upstream.

3.6.3.7 Pond mapping and sampling

These measurements will contribute to the Glastir outcome: Improving water and soil management; Maintaining and enhancing biodiversity.

Two Glastir interventions relate to pond creation and condition and measures were included in order to assess the success of these interventions. A pond was defined as body of standing water 25m^2 to 2ha in area which usually holds water for at least four months of the year. All ponds present within the survey were mapped as part of the habitat mapping exercise from which one was selected for a detailed physical, biological and chemical condition assessment. Physical characteristics recorded included pond area, sediment and water depth, potential sources of pollution, surrounding land use. Conductivity, pH and turbidity measurements made on site were and a filtered water sample was set for laboratory analysis for soluble reactive phosphorus, total oxidisable nitrogen & alkalinity. The presence and abundance of wetland plant communities was recorded along with timed searches of surface and subsurface invertebrates.

3.6.4 Description of QA activities

Despite every effort to ensure consistency between field surveyors by rigorous training, detailed methodologies outlined in the field handbooks, quality control and frequent communication, there will inevitably be some variation. It is therefore important to produce a quantitative measure of consistency and reliability of the data. As such, a QA exercise was carried out to capture and understand this variation and to ensure that there was no significant bias in the data collected.

In order to apply quantitative assessment of the quality of data collected, a series of Quality Assurance visits were made to selected 1km squares throughout the survey period. It was decided, to enable robust statistical results, to survey just over 10% of the total sample size for QA (7 out of 60 squares). QA squares were selected to represent the range of Land Class strata, to comprise squares from both the WWC and TC components of the survey and chosen to be evenly spaced throughout the summer. The result was that 7 squares were selected each from a different land class stratum, 4 of which were WWC squares, 3 of which were TC squares and all 7 were spread evenly across the full field season.

The QA surveys were carried out the week after the field surveyors had completed their assessments. This both minimised any differences resulting from temporal changes to vegetation and ensured minimal disturbance to land-owners/managers. QA squares were resurveyed by CEH experts in botany, habitat mapping and freshwater ecological senses techniques. Habitat mapping was repeated over the whole 1km square where possible. All vegetation plots placed in the southeast corner of the 1km square were rerecorded, if this was not possible then the sample moved to the next quadrant in a clockwise direction. The vegetation plot QA used photographs and sketch maps to re-find the plots and then recorded all of the species found. During this exercise we were also able to check the choice of location of plot types (those that were not randomly chosen e.g. Y plots and D plots) and assess whether they were appropriate to capture all elements of Glastir. The physical and botanical elements of the freshwater streams and pond survey were also resurveyed.

Vegetation plot QA data will be analysed by comparing a series of metrics i.e. species richness, species frequency and abundance, species composition and will look for patterns in the data of under or over-recording of species and variations between team members.

Mapping QA data will be analysed in several ways.

- Comparison of the number and type of Broad Habitat at the 1km square level (including metrics such as habitat diversity and mean patch size)
- Commonality assessment of attribute tables associated with individual point locations within the square.
- Detailed investigation of shapes and patterns of parcels and spatial configuration, also including analysis of associated attributes.
- More detailed analyses comparing linear and point features and attributes used to describe them
- Surveyor efficiency- checking that equivalent numbers of features have been surveyed, that surveyors had not missed recording features.

3.6.5 Bird survey

These measurements will contribute to the Glastir outcome: Maintaining and enhancing biodiversity

Six field surveyors were appointed by the BTO in February 2013, drawing on a pool of previously known fieldworkers and new recruits, most of who were already based in Wales. All had performed well at interview and in specific audio-visual tests conducted to assess their bird identification skills for species found in Wales (photographs, sound recordings and a field test). The surveyors all had previous experience of bird monitoring, but were given training in the specific survey protocol to be used at a session in Bangor in March to ensure that they understood the approach and to standardize how they would conduct it as far as possible. They were then each assigned a set of survey squares near their Welsh bases, in order to minimize travel time.

The survey protocol was designed to provide a robust estimate of the total numbers of breeding pairs of birds of each species found in each survey square and thus of change over time in future surveys, as well as information on the habitat patches in which individuals were recorded. Thus, the results provide information on local abundance and the selection of habitat types, such as Glastir habitat management. The protocol operates at the same spatial scale as the national BTO/JNCC/RSPB Breeding Bird Survey (BBS), but involves more intensive fieldwork, so it provides more accurate measures of local abundance and is more appropriate for surveying smaller samples of squares (60-90, versus thousands) with lower rates of repetition (four-yearly, rather than annual). Mapping of the likely success of the survey to directly record priority species is presented in Table 4.6.1 with others reported using proxy measurements from habitat condition, quality combined with species distribution data (Chapter 4 and Appendices 4.5a and 4.5b).

The surveys consisted of four visits to each square, equally spaced through mid-March to mid-July. On each visit, the surveyor walked a route that passed within 50m of all parts of the survey square to which access had been secured, beginning at around 06:00 and taking up to five hours. Weather conditions were recorded, but surveys were not conducted in conditions known to affect the detection of birds, *i.e.* strong winds and more than light rain. The survey route was started in different places on each visit, so that all areas were visited at least once before 08:00. All birds seen or heard were recorded on high-resolution field maps using standard BTO activity codes. The survey route followed was also mapped, including recording of areas that had been poorly covered (e.g. an open area of 200m across with survey routes along either edge, such that large species could be seen but small ones not flushed) or not covered (e.g. a woodland to which no access had been secured). Recording and standardizing route coverage (where surveyors actually walked) was important both between visits and to ensure comparable repeat coverage when squares are revisited in four years' time.

The outputs of the survey fieldwork were, therefore, four completed field maps per 1km square, which were completed as planned. The maps are now back at BTO headquarters in Norfolk and will be processed over the next few months, but no bird count data are yet available for summary analysis or presentation. It is expected that systems for doing this will be more clearly established after the first year in 2013 and that summary bird count data will be available more quickly in the future. The approach to processing the field maps will be GIS-based, whereby bird locations, species identities and activities are digitized on detailed land parcel maps. The data will then be summarized to output best estimates of total numbers of each species per square (integrating the data from each visit) and can be analysed to reveal associations with any land-use or habitat maps that are available in a GIS format at a suitable resolution from CEH, including the locations of Glastir management, although it only makes sense to invest time in such analyses after a few years of data have been collected. Further details of the analytical approaches that we plan to use with these data are given in Chapter 4.

Finally, all the 2013 fieldworkers expressed enthusiasm for participating in the survey again next year, although it is never certain that contract staff will be available for work in subsequent years of a survey. If they are available as we would hope, it would aid consistency of survey effort and survey efficiency because training requirements would be minimised.

3.6.6 Pollinator survey

These measurements will contribute to the Glastir outcome: Maintaining and enhancing biodiversity

Butterfly Conservation subcontracted nine experienced ecologists to survey 1km squares across six regions of Wales. A further region was covered by a BC employee. Pollinator surveys focused on three main pollinator groups: butterflies (*Lepidoptera: Rhopalocera*), bees (*Hymenoptera: Apoidea*) and hoverflies (*Diptera: Syrphidae*). Butterflies were recorded to species level, whilst bees and hoverflies were recorded as groups based on broad differences in morphological features associated with ecological differences. In addition, the abundance of common flowering plant groups (identified at the time of survey) was also recorded using the DAFOR-X scale. Surveys were split into two independent parts: a standardised 2km transect route through each 1km^2 followed by a timed search in a 150m^2 flower-rich area within the square. Surveyors undertook the biosecurity procedures defined for the programme as a whole.

Transect routes: transects were established following the Wider Countryside Butterfly Survey (WCBS) method. Surveyors established a 2km transect route through each square. This route was split into two approximately parallel 1km routes separated by at least 500m and where possible at least 250m in from the edge of the square. These routes were subdivided into ten 200m sections. In each section the number of each butterfly species and bee and hoverfly group within a 5m^2 recording box were recorded as the transect route is walked at a steady pace. The DAFOR-X abundance of flowering plant groups was recorded for each transect section. At the end of the transect walk the weather conditions were recorded: temperature (^{o}C), sunshine (%) and wind speed (Beaufort scale).

Timed searches: surveyors identified a 150m^2 flower rich area within the 1km square. In this area numbers of butterfly species and bee and hoverfly groups (the same as for the transect recording) seen within a 20 minute period were counted. Surveyors recorded whether these pollinators were visiting flowers or not, and which flowering plant group they were visiting.

Weather criterion: surveys were only conducted between 10:00 and 16:00, or between 09:30 and 16:30 if >75% of the survey area was un-shaded and weather conditions were suitable for insect activity. The criteria for suitable weather were: temperature between 11 and 17^{o}C with at least 60% sunshine or above 17^{o}C regardless of sunshine, and with a wind speed below 5 on the Beaufort scale (small trees in leaf sway).

Mapping of the survey to Glastir priority species is presented in Appendices 4.5a and 4.5b. Future versions of this table will identify if the Target species is directly monitored or reported through proxy measurements from habitat extent and condition combined with species distribution data (Chapter 4 and Appendices 4.5a and 4.5b)

3.6.6.1 Quality Assurance

A training workshop was held for all surveyors to familiarise them with the method. Data for the surveys were entered using a website setup for the programme. Surveyors submitted photographs of butterfly species and pollinator groups seen during their surveys for ID confirmation. Photos were reviewed by experts to verify identification. In addition, quality assurance visits were conducted to the seven 1km squares selected for QA. Visits were undertaken by experienced CEH surveyors, repeating the surveys using the same transect routes as the surveyors at a similar time to their second survey visit in August.

3.7 GMEP Data acquisition

3.7.1 New baseline data

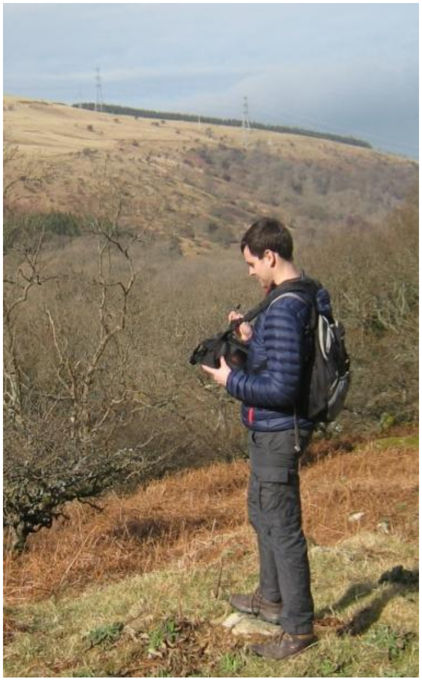
Two areas of high uncertainty were identified for monitoring the effects of land-management interventions on the carbon balance. Firstly, carbon accumulation and loss cannot be monitored in peat soils via the conventional 'topsoil' monitoring used by the Countryside Survey or other UK soil monitoring programmes, because the carbon stored in peats can extend to a depth of several metres, making a 'stock change' measurement approach ineffective. In order to enable us to infer rates of peat carbon accumulation, we are developing a proxy-based approach, whereby the composition of the vegetation community can be used to estimate change in accumulation rates. The method requires a calibration dataset of representative short peat cores on which recent carbon accumulation rates will be quantified, by measuring carbon accumulation between a set of dated horizons within the peat, determined using a combination of radio-isotope and carbonaceous particle analysis. By relating peat accumulation rates to current and past vegetation cover, we will derive a simple empirical model which can then be used to indirectly monitor peat carbon accumulation rates by recording changes in vegetation cover as part of existing plant surveys.

A second area of uncertainty is the role of grassland management (such as fertilizer addition and grazing intensity) on CO_2, CH_4 and N_2O sequestration or emissions. We are constructing trailer-mounted continuous gas flux monitoring systems which will be deployed initially across a range of grassland types to identify which grassland types and under what conditions they act as a sink or source of the three different greenhouse gases. This is necessary as there is no national consensus currently upon which we can report current trends. In future years, a 'paired' approach will be used (*i.e.* a site at which a selected Glastir intervention has taken place and one remaining under conventional management) in order to assess whether the intervention has altered greenhouse gas fluxes. These results will be used to test and if necessary enhance the performance of the models being used within the programme to simulate the effects of management change on emissions. Although the mobile flux systems will be used to study the effects of grassland management during the current monitoring and evaluation programme, they have been designed with the flexibility to be deployed to other areas (for example areas of woodland planting) should this be considered a priority in future. These sensors will be deployed with landscape scale soil moisture sensors (COSMOS) for which a national network with live streaming has just been deployed by CEH (http://www.ceh.ac.uk/cosmos/live-data.html.) Soil moisture is a critical factor which drives rate of greenhouse gas emissions from soils and thus will significantly increase data interpretation and model parameterisation.

3.7.2 Informatics associated with the survey

The integrity, security and auditability of data and analysis results are fundamental to the success of GMEP. Laying foundations to ensure this has required considerable effort in data management and field survey systems preparation. This approach has provided well managed, quality survey data, with a clear audit trail for subsequent analyses. Tasks to achieve this have included:-

- Preparation of data management systems and security protocols for data access
- Development of internal Web sites and wikis for programme communications and field survey support
- Acquisition of reference data sets from third parties including Glastir data
- Conditioning of data required for preliminary analyses and for supporting field survey
- Software development of new and existing software systems to enable digital data capture in the field
- Hardware procurement and configuration for use in the field
- Support of field survey teams for software and hardware fixes and maintenance (including visiting teams in the field)
- Checking in and validation of field data returning from the field.
- Loading and integration of field survey data with other references data sets in a geospatial database in preparation for analysis



The GMEP programme has benefited considerably from the team's experience and facilities for national survey and analysis but considerable effort been necessary in preparing and supporting data management for this new programme. This has put the programme in a good position to start developing the analyses required by a wide range of stakeholders.

New databases have been established to enable the validation, safe storage and dissemination of GMEP data, including the protection of site locations and personal information. Web sites with secure logins have been produced to share documents and transfer data to and from remote teams in the field. The programme has procured 17 ruggedized field computers and developed 7 different software applications for digital capture of field data. The main mapping application has been adapted from approx. £6M software investment from Forestry Commission and NERC. This now supports the field protocols required by GMEP. The other applications have been developed in-house as part of the Informatics work package to ensure integrity of each area of field survey (e.g. River Habitats Survey). Further information on all of the field applications is given in Appendix 3.6

These applications and hardware have all been maintained and supported through the first field season by the informatics team ensuring safe capture and storage of data despite any software and hardware issues.

As a result of the preparation of data management systems, development of Web sites for survey support and data transfer, deployment of field data capture systems and support for field survey teams, the first year's data of the GMEP field survey has been captured, validated and loaded into integrated databases. These data can be audited through each validation stage and are a strong foundation for the next stage of analysis and model development.

3.7.3 Integration with existing data sets

To meet the data requirements for each work package of the GMEP programme, CEH have worked with the Welsh Government to license and obtain a range of existing datasets from various organisations and government bodies such as NRW, CCW, EA, Ordnance Survey, NSRI, Cadw, Defra, Intermap and more. All GMEP datasets are held on secure network within confidential folders, with access only permitted for a limited number of staff from the informatics team. Any other staff that require access to datasets must submit requests to data managers and sign a data license agreement. Spatial data access can then be granted through the GMEP spatial database (SDE), with each user permitted read-only access to the specific datasets requested. Obtained datasets consist of GIS spatial data, complete databases, lookup tables, and spreadsheets, which can be grouped into 8 major types, as shown in Table 3.7.3.1. Descriptions of the 50 primary datasets within these groups that have been requested for the GMEP programme are listed in Appendix 3.7.

Data Type	Description
Contextual	Base data for mapping and field surveying such as Ordnance Survey MasterMap and aerial photography.
Habitats	Habitat survey results, land cover mapping and forestry.
Soils	Soil type locations and properties data.
Designated Areas	Extents of special sites and protected areas.
Hydrology	Elevation, catchment, and water quality and extent data.
Historic	Historic sites, landscapes, and environment features.
Farm Holdings	Land parcel boundaries and ownership details.
Glastir and Past Schemes	Agri-environment scheme target areas, and scheme uptake extents and options.

Table 3.7.3.1 Types of existing data sourced for the GMEP programme.

3.8 Rationale for modelling

The GMEP programme exploits models to address six programme needs:

I. *Models will be used to provide estimates of variables for which direct measurement at all sites is problematic or impractical.*
   Direct measurements of certain variables at all sites may be problematic for a number of reasons. There may be analytical constraints due to lack of laboratory or field instruments or procedures that can directly measure the variable of interest (e.g., field scale estimates of C

fluxes). Sampling constraints may arise from the spatial or temporal context of the variable of interest (e.g., measuring photosynthesis of tree top leaves; measuring daily C fluxes without affecting the plot, *etc*.). Logistical constraints may present difficulties when transporting time-sensitive samples from remote field plots to laboratories (e.g., P analyses need to be completed within 24 hours). Even if sampling and analysis techniques for a variable are feasible for each site, it may not be practical to make direct measurements at all sites due to limited time and/or budget constraints (e.g., GHG emissions by eddy covariance methods) or due to lack of ancillary data at the plot or field scale (e.g., water discharge for direct measurement of pollution runoff). In such cases, models can provide estimates of the problematic variables at all sites based on the measured values at a few sites using empirical methods (*i.e.,* regression models) or process-based simulation (e.g., diffuse pollution models).

II. *Models will be used to contextualize and upscale sampling results.*
The GMEP program is underpinned by a statistical sampling frame based on 1km squares. Within each of the randomly selected or targeted 1km squares that are surveyed, many of the variables of interest are sampled at one or a few points (e.g., soil C content, GHG emissions, water quality *etc*.) or plots (e.g., NPP, species composition) within the square. GIS modelling techniques are used to derive the landscape context (habitat, soil type, elevations, upstream activities *etc*.) of each of the sampling points or plots within the square and its surrounding area. GIS, empirical and process-based models are then used to extrapolate the results to the full 1km surveyed square and quantify the importance of the surrounding area on the responsiveness of the variable. The conceptualised results for each surveyed square form the basic metrics that will be used in assessing effectiveness of Glastir measures in that locality. To provide a national assessment for the whole of Wales, the information obtained from the surveyed squares must be upscaled to the national level. This upscaling will be accomplished using GIS, statistical and process-based models to provide a statistically rigorous, scientific, evidence-based framework for evaluation the Glastir program. In subsequent years of the GMEP program, additional squares will be surveyed (and exiting squares will be resurveyed). The modelling framework provides a means of incorporating the new data and updating the national-scale results each year to provide increasing statistical power and robustness for the program outputs.

III. *Models will be used to explore scenarios of land management interventions and their expected benefits.*
A key outcome of the GMEP program will be evidence-based, landscape-scale models (e.g., LUCI, ADAS; see Chapter 2) that can be used to simulate the effects of changing land management practices on the landscape of Wales providing early feedback on the likely success of Glastir to WG. Scenarios of future changes in farm management in response to the Glastir program can be incorporated into the models at the sub-catchment scale (ADAS) or sub-field scale (LUCI). The effects of prescribed Glastir measures can be simulated individually or in various simultaneous combinations. The effects of different rates of uptake of Glastir measures can be evaluated. The spatially explicit basis of the models allows the targeted nature of the Advanced Glastir program to be assessed. Applying the models over time allows examination of the rate at which expected benefits appear under various uptake scenarios. At the national scale, the models will allow Glastir managers to examine ranges of alternate implementation scenarios, considering simultaneously the measures implemented, the rate of uptake, and the spatial locations of participating farmers. The consideration of such alternate scenarios can provide a basis for selecting an optimal Glastir implementation strategy. At the farm scale, the models can be used in consultation with individual farmers to develop efficient, cost effective local measures. At the farm and community scale, the model scenarios can be used to engage individual Glastir participants and local farmers associations in discussions of alternate implementation plans leading to a wider perspective on and public appreciation of the Glastir program.

IV. *Models will be used to explore potential synergies and trade-offs in benefits derived from Glastir.*
The LUCI model (see Chapter 2) can provide spatially explicit forecasts of the simultaneous changes in a number of variables in response to the simultaneous adoption of a number of Glastir measures. This provides a powerful tool to identify the locations and spatial extents of regions where the outcomes of multiple Glastir measures are all positive (win-win situations) or are mixed with some measures providing benefits at the expense of losses in other desired outcomes. In the latter case, the model can make explicit the nature of the trade-offs and conflicts, leading to a more informed decision in terms of implementation of measures. The spatial output of LUCI provides further information concerning whether the trade-offs arise from local landscape conditions (only certain areas in Wales showing the conflict) or whether the measures may be mutually exclusive in pan-Wales applications. With LUCI's ability to run alternate implementation scenarios, Glastir managers could be provided with a tool to examine alternate implementation schemes that would minimize or eliminate trade-offs and maximize benefits. Given the broad range of prescribed interventions and desired outcomes in Glastir, it may be unlikely that many clear "win-win" situations can be realized. Faced with an inevitable trade-off, LUCI can provide important information and guidance in setting priority measures and areas for Glastir adoption.

V. *Models provide a framework for generating hypotheses against which the field data can be checked.*
The GMEP programme is grounded in the scientific approach using hypotheses to objectively frame questions and evaluate outcomes. Models represent current scientific understanding *i.e.* hypotheses and therefore provide a framework to test the GMEP data. Inconsistency between data and models will highlight where further exploratory work is needed in either checking the validity of the data and/or improving our models. This iterative process provides both an independent method for data quality assurance and a pathway to improve predictive tools.

VI. *Models provide rapid feedback on interventions and their effectiveness*
Many of the Glastir interventions under investigation within the monitoring and evaluation programme relate to outcomes which could potentially be slow in responding. Hence the time taken to feedback on the effectiveness on some interventions to the Welsh Government could be slow. The design of the field survey and sampling scheme means that this long term trend and response will be captured and reported in future years. However, it is often necessary, especially with a new scheme such as Glastir, to respond quickly and adapt some measures and interventions to ensure the environmental goals of the scheme are met. Using modelling techniques will help to provide some feedback on Glastir interventions without the need to wait long term for a response from the field data. Using the collated set of models, as previously described, the effects of some interventions on environmental indicators will be examined and hence rapid feedback, albeit with uncertainty and caveats, can be provided.

NERC Centre for Hydrology & Ecology and programme partners would like to thank all the landowners, farmers, and other land managers who gave permission for the field surveyors to collect data and samples from their land. Without such cooperation, scientific field studies like the Glastir Monitoring and Evaluation Programme would not be possible.

Special thanks are due to Anthea Owen our Farmer Liaison Officer who arranged access permissions with landowners and coordinated the biophysical and pollinator field teams. Our thanks also go to Kelvin Jones who coordinated the bird field teams. Bronwen Williams and Emma Waters provided invaluable project support to the management of the field survey.

Field survey team:
Biophysical survey: Aspey, N., Davies, C., Everingham, E., Fells, A., Fitos, E., Harvey,A.[3], Jackson, E., Koblizek, E., Meilleur, E., Nuttall, P.[5], Pedashenko, H., Ryan, F., Seaton, R., Vasilev, K., Wallace, H.[8], Winder, Jan.
Bird survey: Bamford, R., Carter, D., Everett, C., Small, J. and Vaughan, D.
Pollinator surveys: Clarke, S., Ellison, M., Green, D., Haycock, A., Haycock, B., Kelsall, J., Knight, T., Sazer, D., Smith, A. and Tordoff, G.
Quality assurance field team: Garbutt, A., Maskell, L., Mountford, O., Norton, L., Scarlett, P., Smart, S., Williams, P. and Wood, C.

4. Biodiversity

Smart, S.M.[1], Astbury, S[2]., August, T[3]., Botham, M[3]., Cooper, J[1]., Emmett, BA[2]., Hall, J[2]., Harrower, C., Henrys, P[1]., Isaac, N.[3], Jarvis,S.[1], Maskell, L[1]., Norton, L.[1], Peyton, J[3]., Powney, G[3]., Rorke, S[3]., Rowland, C[1]., Roy, D.[3], Scholefield, P[1]., Siriwardena, G[4]., Wagner, M[3]. and Wood, C[1].
[1]CEH Lancaster, [2]CEH Bangor, [3]CEH Wallingford, [4]BTO

Why biodiversity? The conservation of biodiversity[4] in Wales recognizes the value people place on a rich heritage of wild species and habitats. Some habitats and species have a stronghold in Wales whilst being rare or absent elsewhere in the UK and Europe so that Wales has a particular responsibility for their monitoring and conservation[5]. While the importance of biodiversity reflects the values placed on it by people, some of these values are harder to quantify than others. They are nonetheless important, including for example conservation of wild species and habitats for their cultural, spiritual, aesthetic and recreational importance. In 2007 the Environment Agency Wales estimated that "wildlife-based activity" contributed a total output of 1.9 billion per year to the Welsh economy which exceeded the total agricultural output in 2011 of 1.3 billion (EA Wales 2007)[6]. Therefore the contribution of biodiversity to prosperity, well-being and job creation in Wales should not be underestimated.

Policy context

Policy drivers for the conservation of biodiversity in Wales reflect both global to regional trends and the need to engage with the human drivers of these trends. The goal of sustainable rural development within the EU Rural Development Program seeks to achieve economically and ecologically sustainable use of land and water. This recognizes a requirement for reversing ecosystem degradation and the loss of underpinning biodiversity. In Wales, the Glastir scheme is a significant component of the Rural Development Program and so contributes to fulfilling a number of statutory obligations and targets relevant to biodiversity. These are derived from agreements at global (Aichi targets), European (European Union Biodiversity Strategy (EUBS) plus Habitats and Birds Directives) and UK levels (Wildlife and Countryside Act and Natural Environment and Rural Communities Act). Of particular significance is target 3 of the EUBS that aims to 'increase the contribution of agriculture and forestry to biodiversity'. Since 81%[7] of Wales is farmed, agri-environment scheme funding is seen as one of the most important mechanisms for delivering a large-scale re-balancing of production, ecosystem service supply and biodiversity to achieve sustainable rural development. The remainder of this chapter describes progress and future plans for assessment of the outcomes of the new Glastir agri-environment scheme on Welsh biodiversity. We apply a combination of approaches including data collection within the 4 year rolling monitoring programme, modelling and analysis of existing monitoring schemes.

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[4] Biodiversity is defined as the number, variety and variability of living things (http://www.unep-wcmc.org/what-is-biodiversity_50.html). It encompasses species, genetic and ecosystem diversity.

[5] http://www.biodiversitywales.org.uk/en-GB/Section-42-Lists. The Section 42 list for Wales builds on the Priority Species and Priority Habitats originally identified in the UK Biodiversity Action Plan. The section 42 lists focus activity on the conservation of species and habitats required to discharge the "biodiversity duty" under the Natural Environment & Communities Act (2006).

[6] This figure did however include biodiversity-related support via agri-environment schemes within the "wildlife-based activity" side.

[7] According to the 2010 June Agricultural Census, the total agricultural area in Wales is 1,709,714 ha (including sole rights and common grazing, and woodland and unproductive areas on farmland). Only 1,210,283 ha is crops and improved grassland, and 409,919 ha is rough grazing. This equates to 81% of the total land area of Wales (2,122,466 ha).

4.1 Achievements in Year 1:

- Habitat, plant, bird and pollinator surveys completed in all GMEP squares with protocols modified specifically to optimize detection of Glastir impacts.
- Habitat keys updated in consultation with NRW including changes to indicator species lists and updates
- Preliminary assessment of the extent to which the distribution of the planned GMEP survey squares overlaps with those of priority species and habitats of conservation interest, exploration of three case studies and mapping of interventions with measurements to identify if direct or proxy measures will be reported.
- Assembly of contextual datasets to enable estimation of future Glastir impacts on biodiversity in light of the legacy effects of past schemes and the past and ongoing impacts of other drivers such as climate, land-use and air pollution.
- Application of the MultiMOVE niche model ensemble to explore forecasting of the effects of Glastir prescriptions on plant species. MultiMOVE was applied to two test catchments and four measures. 21 plant species were modelled where each was drawn from existing Countryside Survey plots representing the catchment land classes and habitats targeted by each prescription in Wales. Of the total number of species and measure-specific projections run for common species, 30 (75%) were consistent with the expected impact of Glastir however these changes were projected over relatively long periods.
- Production of new 10km plant species pools based on distribution data holdings and corrected for over and under-recording using the newly developed FRESCALO algorithm (Hill 2012). These species pools were subsequently used to aid species selection for MultiMOVE modelling.
- Completion of trends analysis for Welsh species groups collected by volunteer schemes. 10 out of 18 taxonomic groups had a net negative trend from 1970 onwards with the remaining 8 taxonomic groups showing a positive net change trend. Common species are out-performing rare species in terms of the change in the probability of observing a species between 1990 and 2000.
- Completion of a first version of a Watchlist Indicator for species trends in Wales
- Preliminary work testing spatial metrics of habitat connectivity
- Compilation of criteria and datasets for testing the definition of High Nature Value Farmland in Wales and measuring its present and future extent and ecological condition
- Initiation of work to extrapolate outside of 1km GMEP squares using remote sensing data so as to enable inference of monitored and modelled quantities across Wales

4.1.1 The role of biodiversity

Increasingly, evidence highlights the functional role of biodiversity. Certain ecosystem processes are vital to human life support on earth, especially in the face of a growing global population and the uncertainties posed by climate change. Given these pressures on ecosystems a precautionary approach to maximizing the ability of landscapes and ecosystems to adapt to suddenly changing human needs emphasizes the maintenance of functional diversity. This can be narrowed down to the importance of specific kinds of organisms such as pollinator plants and insects, nitrogen fixing plants and bacteria, soil organisms that process organic matter releasing nutrients for plant uptake, storing excess carbon in soils and plants, crops and timber trees and their wild genetic relatives and interdependent mycorrhizal organisms (Isbell *et al* 2011). The Wales chapter of the UK NEA for example, stated that biodiversity contributes to social and economic prosperity in Wales by underpinning vital ecosystem services[8].

[8] http://uknea.unep-wcmc.org/Resources/tabid/82/Default.aspx

The ecosystem function argument for conserving biodiversity is a powerful one because it indicates how human needs for food, a stable environment and clean water can be put at risk by depletion of functionally important species populations. Such arguments are also persuasive if it can be demonstrated that expenditure on for example, fertilisers and pesticides can be reduced as a result of husbanding the free services that ecosystems provide (Bonmarco *et al* 2012) However, much is still unknown about which taxa are important in any one place and time (Luck *et al* 2011). The case for conservation of biodiversity as a way of ensuring vital ecosystem functioning therefore adds to but does not replace the argument for conservation of biodiversity for wider moral, cultural and spiritual reasons (Figure 4.1.1). Thus the wildlife of Wales as elsewhere is also valued because species simply exist and we marvel at their diversity and beauty. We value their coexistence with our own species even if most do not yet have an identified role in supplying us with an ecosystem service.

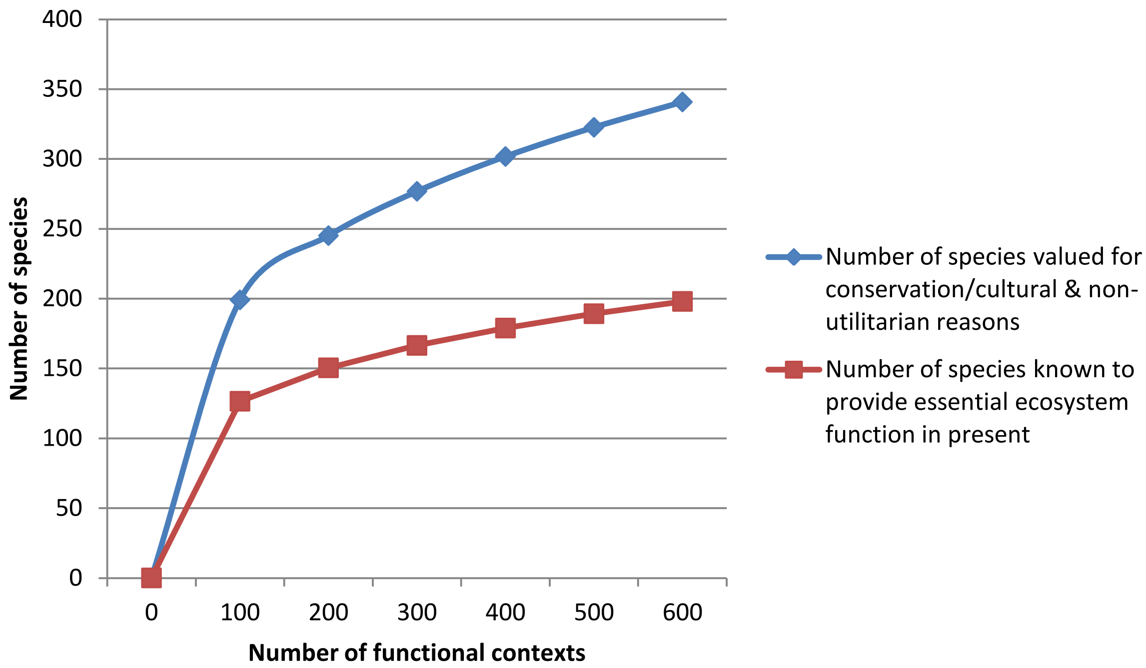


Figure 4.1.1: Adapted from Isbell et al (2011). While an increasing number of species are needed to secure functioning over a larger number of ecosystems there are additional numbers of species that may not yet have a proven functional role yet additional species are nonetheless also highly valued for a range of cultural and aesthetic reasons. These values are likely to resonate much more with people. However, functional importance is a new and often persuasive additional argument for conserving biodiversity.

Efforts to conserve biodiversity in Wales are also motivated by the fact that many wild species have declined in population size (see for example section 4.11.1) and many habitats have become degraded in condition or been converted to less diverse habitat types whose principal function is to produce food and fibre and thus to satisfy essential human needs (Butchart *et al* 2010; NEA). These Wales-wide and UK-wide trends are consistent with global patterns of biodiversity loss typified by the dispersal and establishment of a relatively small number of species that are favoured by human disturbance at the expense of locally distinctive species intolerant of the combinations of high disturbance and elevated productivity associated with intensive land-use (Sax & Gaines 2003; McKinney & Lockwood, 1999; Smart *et al* 2006). However, in Wales as in much of Europe, high biodiversity is often associated with farmed landscapes. This is because many ecosystems and their characteristic diversity reflect many hundreds of years of low-input farming. Yet while many species require conditions associated with low-intensity farming, including mixed farming with no artificial inputs, they are quickly displaced from the most intensive production lands (Bignal & McCracken 1996). Given a growing global population the trade-off between food production, agricultural area and the intensity of production needs to be carefully weighed taking into account variation from place to place in terms of future and current productivity and current biodiversity in addition to existing land use requirements (see chapter 2).

4.2 Benefits from interventions / past schemes.

In Wales, funding from agri-environment schemes (AES) has been available since the early 90s including ESAs, the Habitat Scheme, Woodland Grant scheme, Farm and Conservation grant scheme, Tir Cymen, Tir Cynnal, Tir Gofal and now Glastir. Spatially explicit analysis of the legacy effects of previous scheme impacts on species and habitats forms a core part of the GMEP analytical strategy for quantifying the future impacts of Glastir. This is because lack of change or relatively rapid change could reflect an ecological starting point that has already benefited from a history of agri-environment funding. Detecting these legacy effects of scheme history will be highly dependent on the quality and quantity of the data available. A more precise assessment of legacy effects comes from having information about the exact duration and detail of the measures applied and where the information is resolved at the level of individual fields and features. High quality data from the previous Tir Gofal scheme has been made available to the monitoring and evaluation programme and a next step is to develop the analytical strategy that incorporates these data into the detection and attribution of scheme impacts.

4.2.1 Initial assessment of Tir Gofal coverage within GMEP

Uptake of Tir Gofal has been extensive in Wales with most 1km squares having some level of management intervention on farmland (Figure 4.2.1.1). Note that this figure does not represent total % Tir Gofal uptake in terms of size of farm holdings but represents the proportion of total area in each 1km square actually subject to habitat management interventions at the parcel level. In addition to analysis of parcel areas under habitat management interventions, work will also focus on quantifying the legacy of current and past management interventions on linear features such as streamsides and hedgerow.

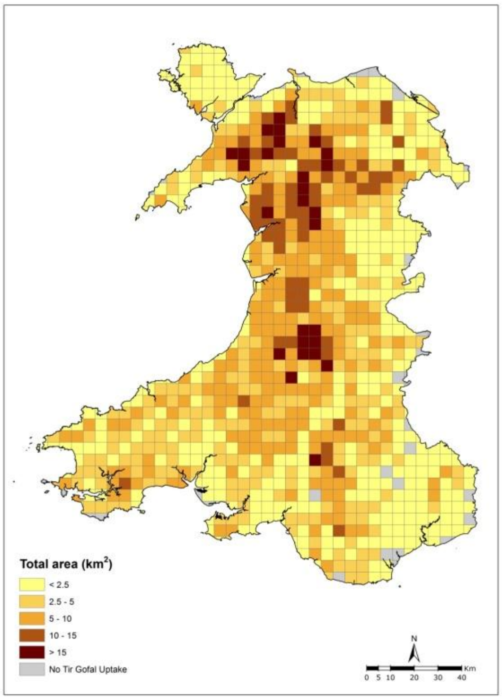


Figure 4.2.1.1: Density of past and current Tir Gofal agreements per 5x5km square. Shading shows the total area of all farms in agreement.

It is interesting to compare this map with the priorities placed by the Welsh Government for Glastir within the Targeted element which may or may not reflect actual uptake as the Glastir scheme moves forward but which has been used to inform selection of our Targeted sample squares (Figure 4.2.1.2).We will be exploring the potential contribution of past scheme such as Tir Gofal in contributing to both baseline conditions or land coming into the scheme and responsiveness of that land to Glastir interventions.

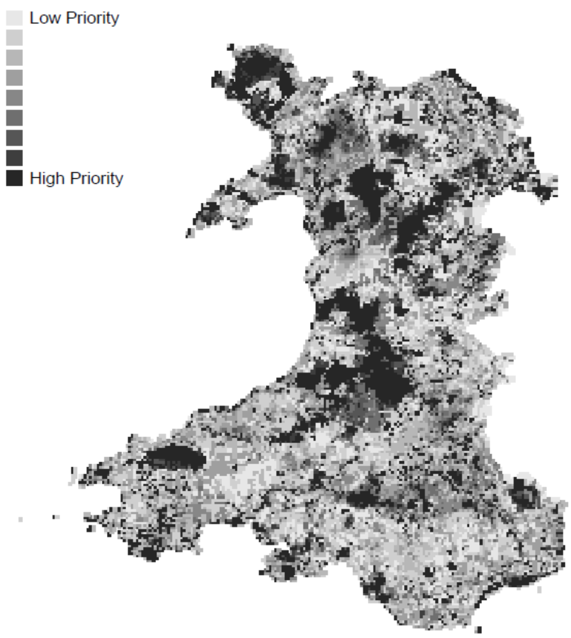


Figure 4.2.1.2 A map of the Glastir Advanced priorities having added up the scores for every 1km square across Wales. See Section 3.4.3 for further information how this map was created)

4.2.2 A review of assessments of the impact of AES schemes on species and habitats based on previous findings for GB

A number of important conclusions can be drawn from recent reviews of the performance of agri-environment schemes across Britain (Boatman 2013) including a review of Tir Gofal (MacDonald *et al* 2012). While there is evidence that AES schemes can generate change consistent with expectation, ecological impacts may often be minor and undetected. Three main reasons emerge from review results. Firstly, generalised measures may not adequately target particular species or habitats. Second, ecological change is inherently slow in habitats dominated by slow-growing perennial species suited to low productivity, climatic extremes or shade. Hence changes have been more readily detected in arable systems where species maybe inherently faster growing and more responsive. For example the review of Tir Gofal noted a greater influence of prescriptions on arable land than grassland. Changes may also be slow because the interventions available constitute a moderate impact on ecological resources and conditions and therefore need long time periods (>10 years) for change to occur and be detectable. For example, Tir Gofal appeared to have resulted in better quality habitat for butterflies than in non-scheme land but with no effect so far detected on butterfly abundance. The presence of such lag effects highlights the importance of measuring changes in beneficial aspects of habitat condition as well as measuring the abundance of the target species. Lastly, given the small size of ecological changes, monitoring designs often lack the high power necessary to detect intervention-driven signals.

The importance of considering the effect of ecological starting points on subsequent responses to interventions has also been highlighted. Good targeting of habitats means that in-scheme land is often more diverse than non-scheme land but if already of high quality this can either limit scope for subsequent ecological responses or in other cases result in more change being likely because interventions coincide with a more diverse and responsive species pool (e.g. Critchley *et al* 2002).

Existing reviews of AES performance offer important considerations for GMEP.

- Uptake of Glastir interventions needs to be extensive enough that sufficient in-scheme land coincides with GMEP squares for detection of ecological impacts.

- Baseline data on scheme legacy is critical to help interpret starting conditions, targeting and subsequent levels of change.
- Scheme legacy must be available at the level of individual features (parcels and linear features). In the case of Tir Gofal, this criterion is fulfilled.
- Prior definition of response variables and criteria by which to measure and evaluate Glastir impacts is essential.

See Appendix 4.1 for a more comprehensive summary of the evidence for the impact and uptake of agri-environment schemes in GB and Wales.

4.3 Biodiversity in Glastir

Bundles of Glastir management prescriptions have been directly linked to specific biodiversity features presumed to benefit from the implementation of each measure. The objective of GMEP is to measure ecological change and reliably estimate what proportion of observed change can be ascribed to the impact of Glastir given the possible influence of other factors such as weather in the year of survey, nitrogen deposition, scheme legacy or other non-scheme land use. This requires analysis of change in biodiversity features alongside detailed spatially explicit information on Glastir uptake in the GMEP squares. While we have access to Glastir information and datasets that quantify other drivers of change the greater challenge will be measuring the abundance of the rarer biodiversity features many of which are a priority precisely because they are rare and localised in Wales. Biodiversity features are also referred to as target objectives and can be grouped into vascular plants, butterflies and moths, mammals, birds and habitats. Three initial assessments are needed to plan for detection of Glastir impacts on these groups;

1. Evaluate the extent to which the GMEP sample surveys of habitats, vegetation, soils, freshwaters, birds and invertebrates were likely to record priority taxa and habitats.
2. Determine for the rarest species whether GMEP 1km squares coincide with their known range in Wales with respect to 10km square biological records.
3. Link the information recorded in GMEP surveys to each of the Glastir interventions that, in turn, already has an established link in supporting delivery of biodiversity target objectives.

The first step tells us how likely we are to actually record the biodiversity feature in GMEP squares, the second indicates whether measured ecological changes are likely to benefit the species even if it is too rare to be recorded in GMEP 1km squares because at least the species has been recorded in the wider 10km square. The third step provides a framework for interpreting different aspects of ecological change in terms of their consistency with the expected impact of Glastir and so helps set the scene for testing the hypothesis that observed ecological change has been driven by Glastir. This step is needed because in most cases the Glastir measure will indirectly impact the target objective via changes in habitat condition and extent and it is these can often be more readily measured and will respond to the intervention before the target organism does. For example the measure 402 Control burning is linked to the target objectives Black Grouse, Red Grouse and Heathland Plants. While all three could be recorded in GMEP squares, habitat mapping allows for the recording of Burnt vegetation as a Primary qualifying attribute in heath and bog (see Chapter 3). Hence signs of burning would be recorded by surveyors yielding polygon level information that could be overlaid to determine coincidence with uptake of the Glastir measure. Given sufficient recording of the three target objectives change in their abundance could then also be analysed alongside both Glastir uptake and evidence for the impact of the measure on heathland condition.

The initial results of the three assessments are in Appendices 4.5a and 4.5b. This lists every biodiversity target objective and every associated Glastir measure. Additional columns then indicate whether the target objective can be measured in GMEP surveys or is too rare and will require assessment of range based on biological records centre data. A first round of provisional analyses using BRC and NBN datasets is presented in the next sections but further work is planned to update these figures. In particular, there is a need to use more recent data and at a finer spatial resolution (i.e. 1km scale) to have greater confidence in the co-incidence of priority species and GMEP survey squares. This will involve collaborative working with the wider recording community in Wales and is especially needed for the animal taxa other than birds. Appendices 4.5a and 4.5b also indicates whether the impact of the management intervention on habitat extent and condition, for example water quality, plant species composition and derived indicators, vegetation height and tussockiness, can be measured in the GMEP survey squares. In 23 out 133 measures habitat mapping is not likely to detect any impact. This may be because the impact is either too subtle to result in a change in habitat extent, in which case the impact may still drive changes in species composition which can be detected in vegetation plots, or the habitat is not well sampled in GMEP, for example saltmarsh and sand dune or because the intervention is too specialised, for example 14B Commit to 75% slurry injection or 28 Retain winter stubbles. A flow diagram illustrating how we have assessed whether GMEP will be able to directly, indirectly or not report on impacts on biodiversity targets is presented in Figure 4.3.1.

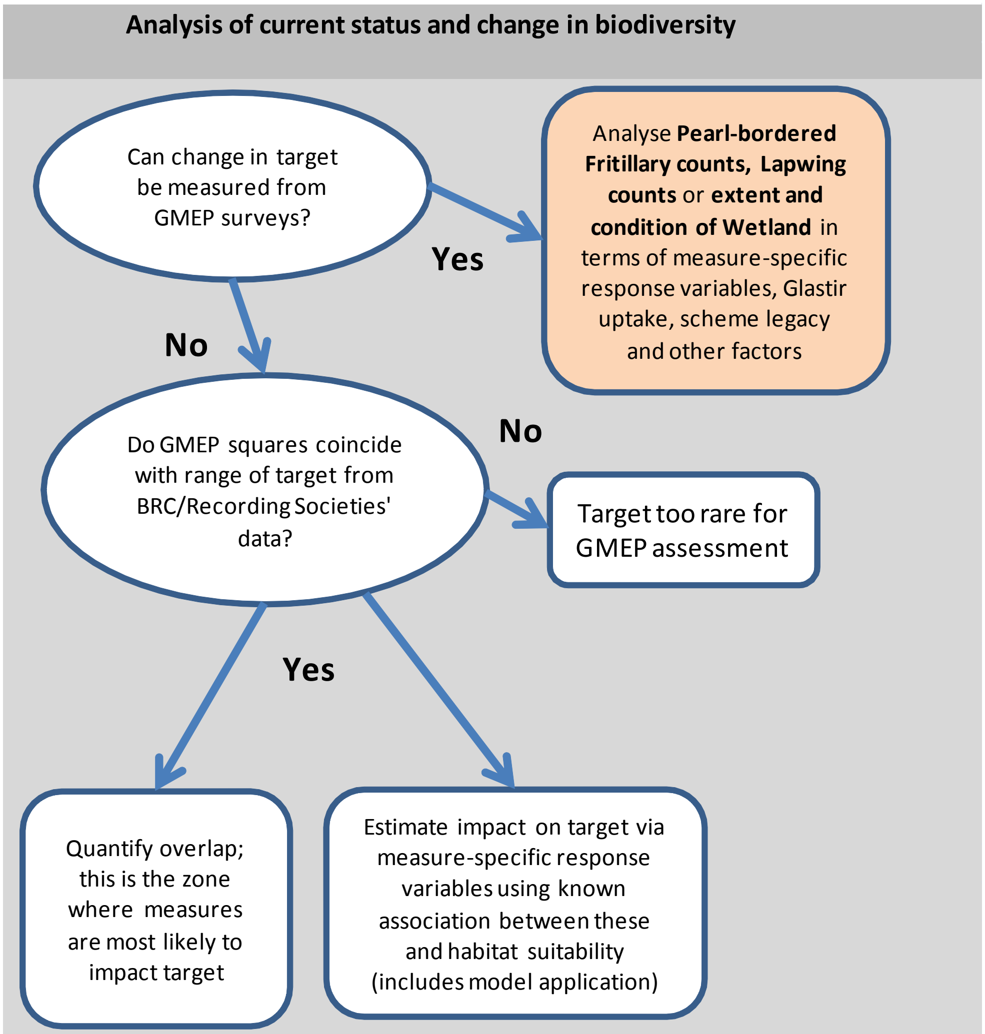
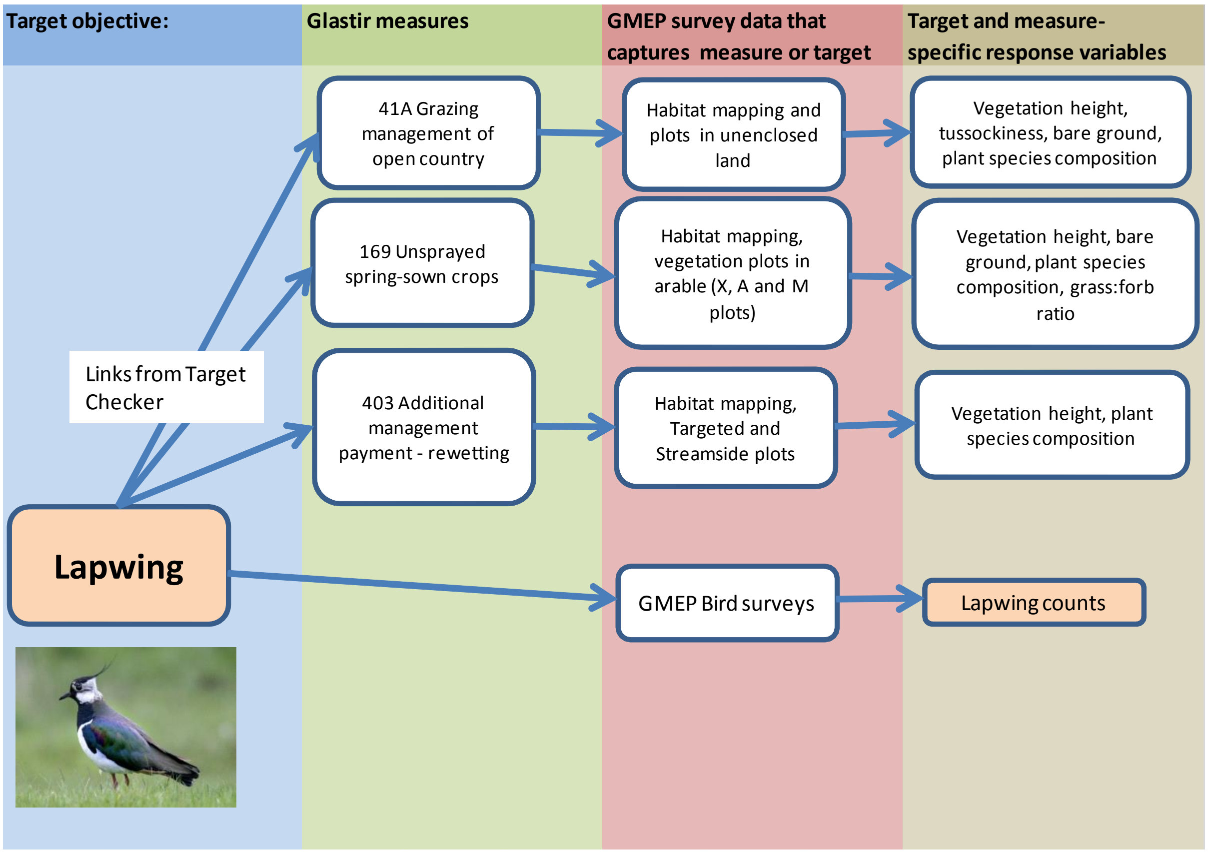


Figure 4.3.1 Flow-diagram assessing whether Glastir impacts on biodiversity target objectives can be measured in GMEP. Examples of target objectives are based on the case studies below.

4.4 Detection of the impacts of Glastir interventions on biodiversity target objectives – case studies

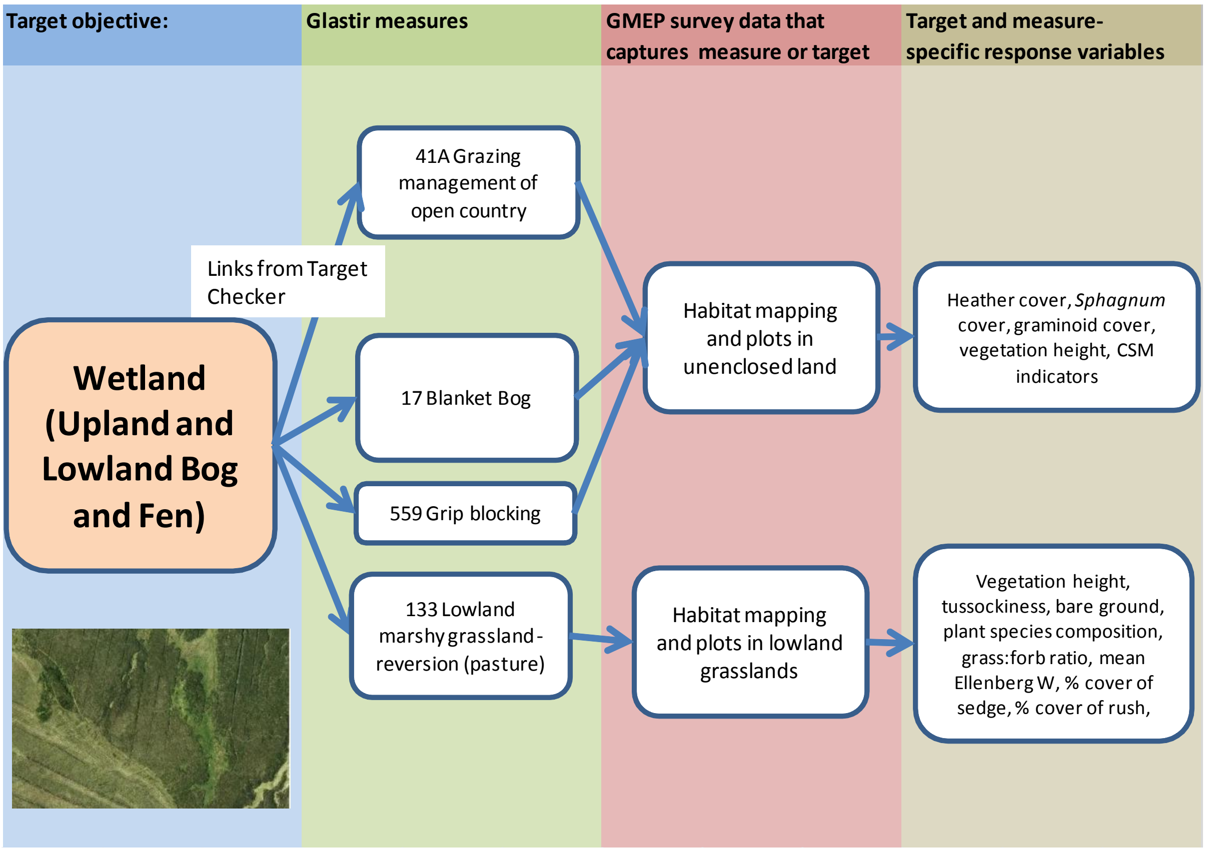
4.4.1 Lapwing

Lapwing is a section 42 species and 62% of the Wider Wales GMEP squares coincide with 10km squares that had breeding evidence between 2007-2011. Lapwing has been linked in the Welsh Government Target checker spreadsheet to 10 Glastir measures of which three are shown here. If implemented then ecological impacts on habitat extent and condition will be detectable from habitat mapping and vegetation plots from which a series of Target and measure-specific variables can be derived for analysis of their baseline status and subsequent change. If present, Lapwing will be recorded in the GMEP bird survey.



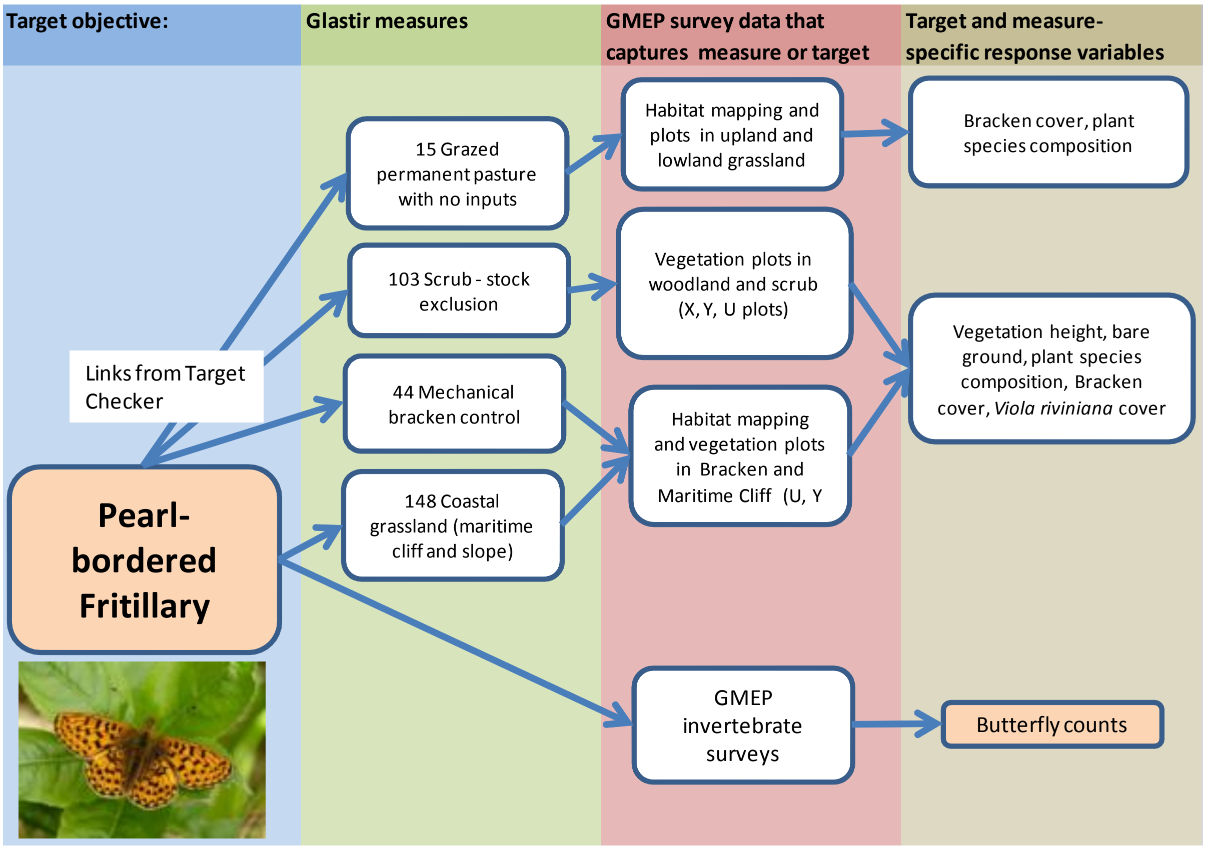
4.4.2 Wetland (Upland and Lowland fen and bog).

The constituent section 42 habitat are largely well represented in the current GMEP sample including Fen 7 Reedbed, Purple Moorgrass and Rush Pasture. However Lowland Raised Bog is scarce. 18 Glastir measures have been associated with the Target objective, four of which are shown here. Expected impacts of the measures can be detected from habitat mapping and vegetation plots and the data readily used to derive indicators of change in conditions such as % cover of Sphagnum, vegetation height or presence of CSM indicator species.



4.4.3 Pearl-bordered Fritillary

Pearl-bordered fritillary is a section 42 species associated with habitats that are well represented in the GMEP sample (see Figure 4.5.2) such as lowland acid grassland, lowland heath and maritime cliff. Also 56% of the GMEP sample of 1km squares fall inside 10km squares with post-1980 records for the butterfly. Shown here are four of the 17 Glastir interventions associated with management for the species. Habitat mapping and vegetation plots will yield data that can be used to derive indicators of the measures on ecological conditions associated with the species, for example presence of the larval food plant.



4.5 Coverage of section 42 habitats in the GMEP sample

The representation of section 42 habitats will vary between the Wider Wales and Targeted GMEP samples. If habitat types are not highly clumped in their distribution then the Wider Wales sample of stratified random squares should represent habitats in proportion to their actual abundance in the countryside. In contrast the Targeted sample focuses on areas subject to packages of measures that support the Welsh Government priorities for Glastir funding (see Chapter 3). An analysis overlaying the GMEP sample squares with data from NRW on the distribution of priority habitats has been carried out. This shows that there is a close correspondence between priority habitat frequency in the WW sample versus frequency in the total population of Wales 1km squares (Figure 4.5.1). Future analysis will provide a more in-depth analysis of both plot and square frequency. It is likely some habitats are so rare that sample size may be too small for analysis.

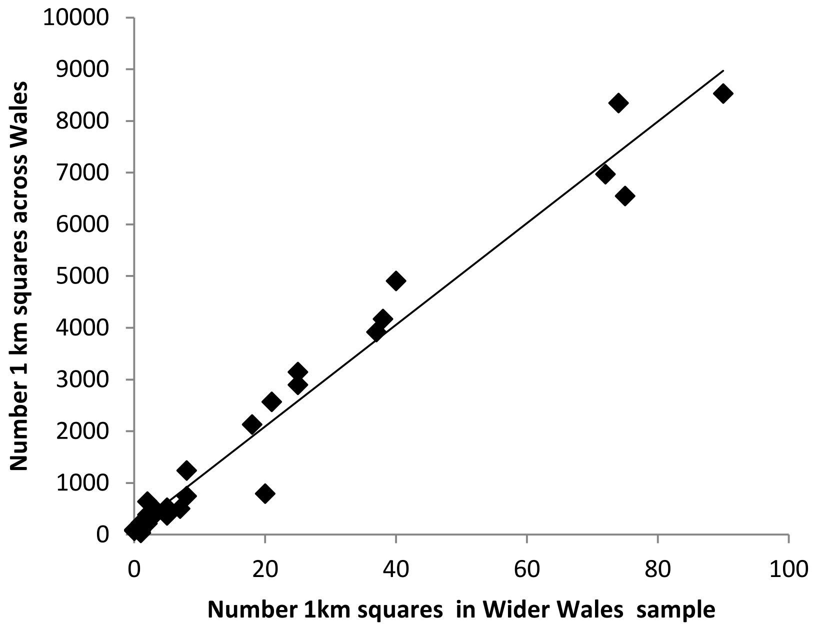


Figure 4.5.1 Frequency of section 42 habitats in the Wider Wales sample for 2013-16 plotted against frequency in all Welsh 1km squares. Data courtesy of CCW LBAP inventory.

Some habitats are better represented than others in the Wider Wales sample but this reflects their abundance in the Welsh countryside. Priority habitats on acidic substrates in both upland and lowland situations are well represented including heathland, lowland dry acid grassland and even blanket bog. Fens, reedbeds, Purple Moor Grass and Rush Pasture, ponds and rivers are also well represented but woodland priority habitats are much less common (Figure 4.5.2). There are a surprising number of traditional orchards in the Wales LBAP dataset which is unlikely to be captured in GMEP as surveyors as the survey does not include gardens which is included in LBAP.

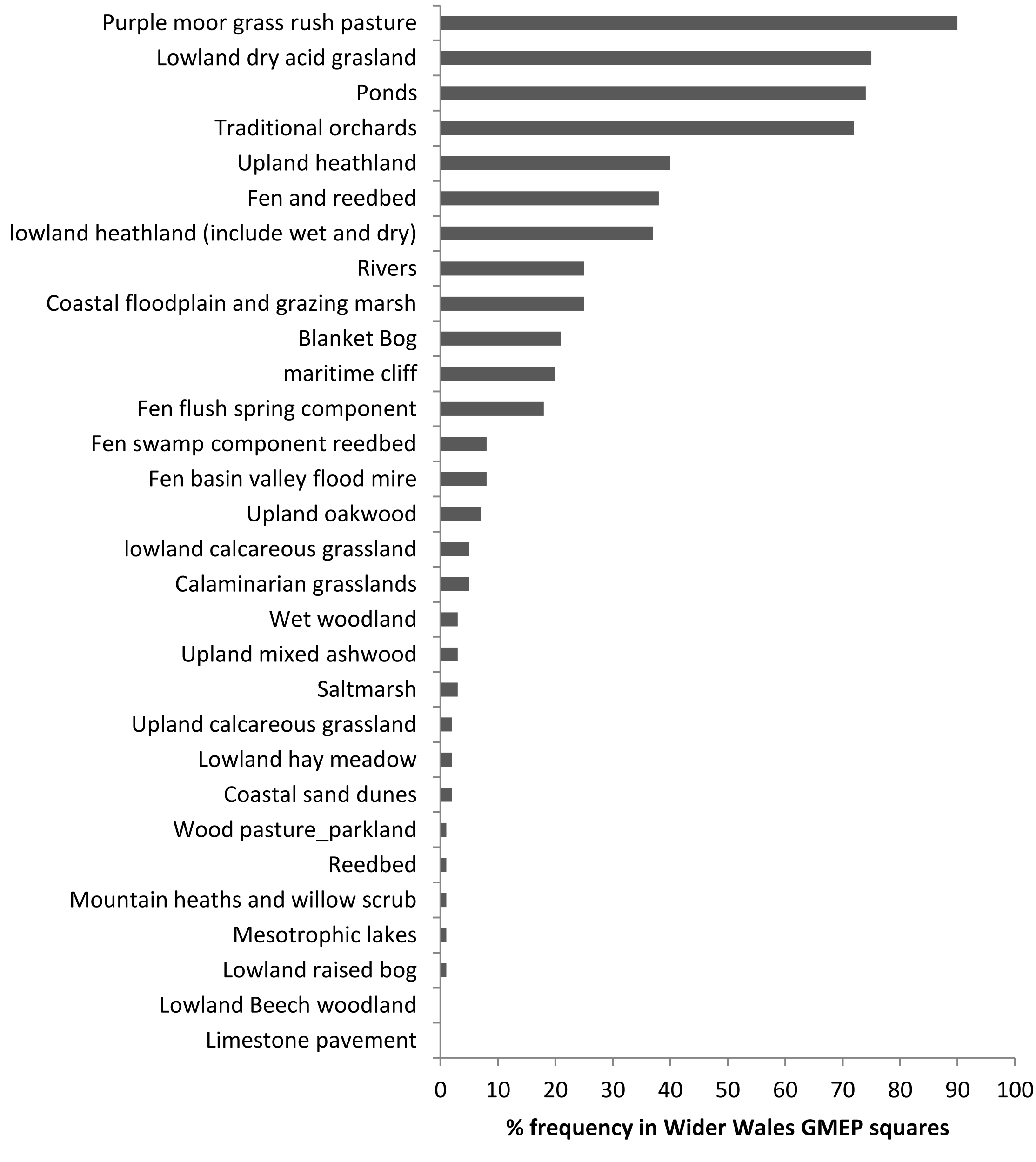


Figure 4.5.2 Frequency of section 42 (Priority) habitats in Wider Wales sample squares selected for survey in 2013-2016. Based on intersecting the Countryside Council for Wales LBAP inventory with 1km sample square locations.

The representation of section 42 habitats in the sample squares visited in 2013 only follows a similar pattern (Figure 4.5.3). Somewhat greater representation of upland heathland, blanket bog and rivers in the Targeted sample reflects the Welsh Government priorities for focusing on soil carbon and water quality in the first 4-year survey cycle. Greater prominence of habitat types associated with these priorities might be expected but it is important to bear in mind that the data plotted are presence in a 1km square, hence area cover may still be high. Moreover, the design targets an unbiased sample of the mosaic of ecosystems associated with the priority layer rather than stratifying by and sampling within each habitat. Changes in the representation of habitats can be readily achieved in future cycles by adjusting the priorities for 1km square selection but with the cost of breaking continuity with different samples of squares surveyed previously (See Chapter 3 for an expanded discussion on this issue).

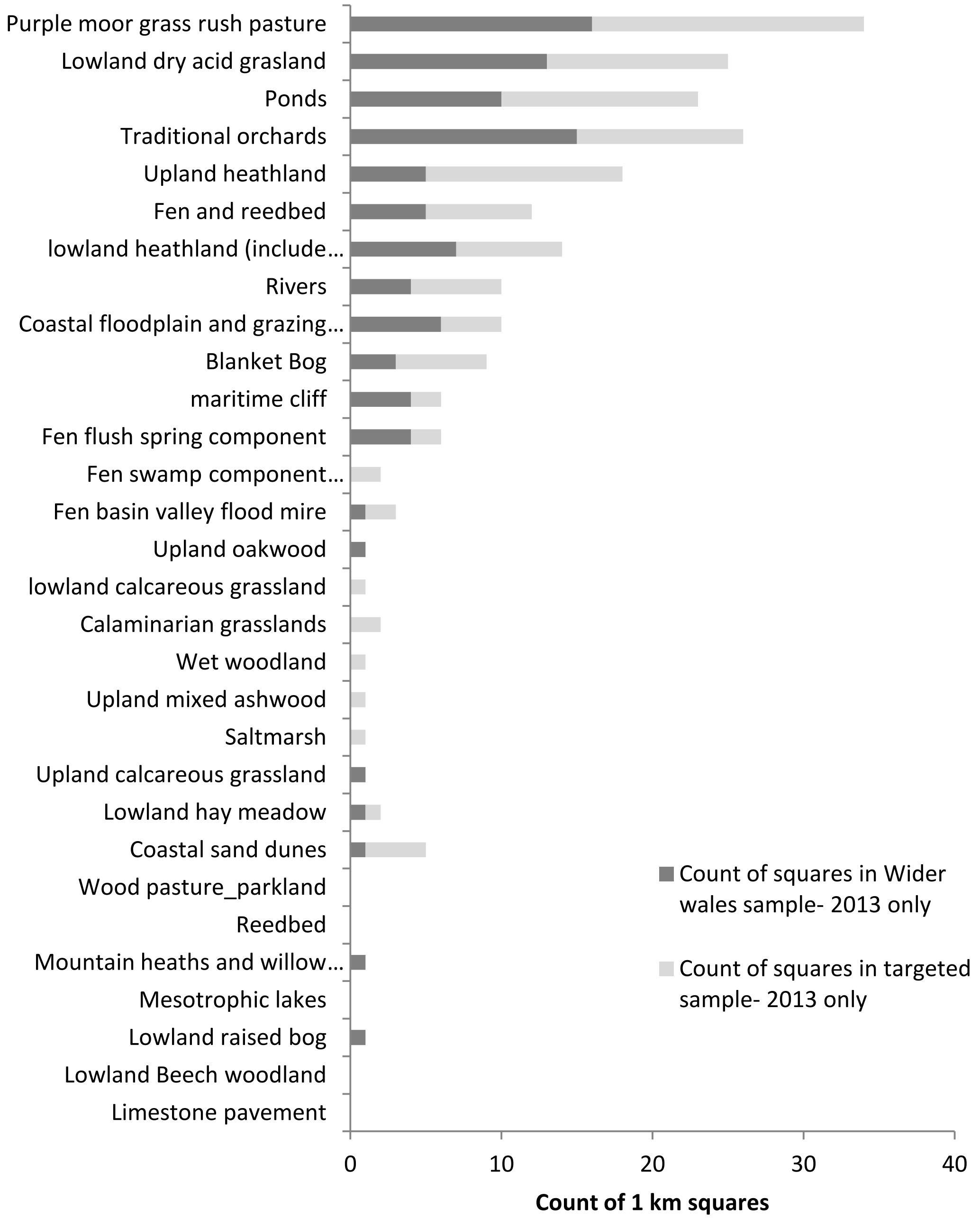


Figure 4.5.3 Frequency of section 42 habitats in the Wider Wales and Targeted samples of 1km square visited in 2013 ***<u>i.e. Year 1 only</u>****. Note that these data are based on intersecting square locations with the CCW LABAP inventory and are not based on the 2013 GMEP field survey results since at the time of writing the survey is not complete. The full 4 year survey will increase coverage.*

The Welsh Government priorities for targeting soil carbon and water quality are also readily seen when the mean Glastir score attached to each 1km square per feature of interest are plotted for each of the samples and for all squares in Wales (Figure 4.5.4). It is immediately obvious that targeting of 1km squares with high scores for the priority areas is reflected as planned in higher mean scores for these priorities within the Targeted sample. Adjusting the scores attaching to each habitat, species, feature or priority zone would immediately result in a new stratified random sample but weighted by the new profile of scores. The relatively high scoring for Biodiversity – Habitats reflects the high weighting given to the priority feature Coastal and Lowland SSSI (Figure 4.5.4). In fact 18 of the 165 Wider Wales squares intersect sea and 3 out of 30 of the year 1 targeted squares ensuring that overall 10% of the sample will sample coastal habitats. Even so saltmarsh and sand dune remain poorly represented (Fig 4.5.2). Intersection of the GMEP sample with SSSI is shown in Table 4.5.1. On average 30% of the Wider Wales squares intersect at least one SSSI while 53% of the year 1 Targeted squares intersect SSSI. While the proportions of the total surveyed area that are SSSI are generally low, there is clearly scope for quantifying aspects of ecological change in the wider landscape around a reasonable number of SSSI and assessing the role of Glastir in driving that change. This decision is with the Welsh Government – it is not possible to cover all requirements to the same extent. Current priorities are reflected by the current GMEP sample.

Square type	Number	Area km2	Cumulative number of WW squares
WW Year 1	11 (0.36)	3.05 (0.10)	11
TG Year 1	16 (0.53)	8.25 (0.28)	
WW Year 2	14 (0.31)	1.76 (0.04)	25
WW Year 3	15 (0.33)	6.87 (0.15)	40
WW Year 4	14 (0.31)	3.34 (0.07)	54

Table 4.5.1 Number and area of GMEP squares (with proportions in brackets) intersecting SSSI.

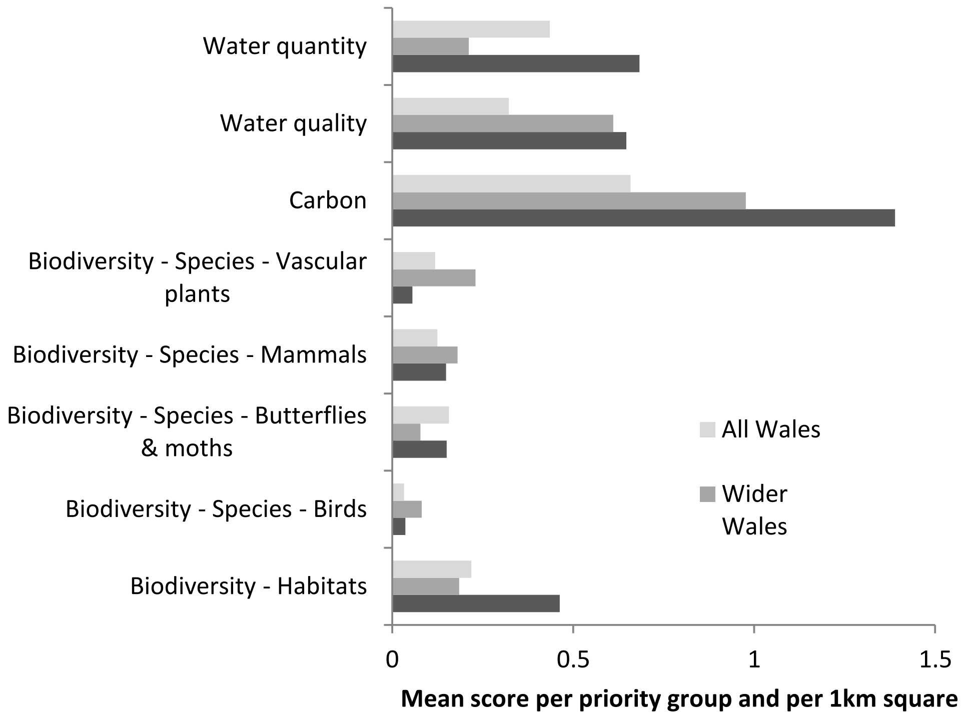


Figure 4.5.4 Mean Glastir scores for the Targeted and Wider Wales samples and for all 1km squares in Wales. The scores originate from the Welsh Government (see Section 3.4.3) and have been applied to each 1km square and each priority feature. The size of the scores reflects current priorities for Glastir intervention and hence for monitoring in GMEP.

4.6 Potential occurrence of targeted bird species in GMEP survey squares

The recently completed Bird Atlas 2007-11 project provides distribution information (winter and summer) for all bird species in Wales at the scale of 10km squares in the national grid. This provides

an independent data set with which to investigate the extent to which the distribution of the planned GMEP survey squares overlaps with those of birds of conservation interest.
For the Atlas, birds were recorded as "present" or with different levels of evidence of breeding (BE) (assessed using standard criteria): "possible", "probable" or "confirmed". In the table below, the numbers of 10km squares in Wales, out of a total of 286 that fall at least partly in Wales, in which each of four species were recorded as at least possibly breeding are listed.

Species	**Total 10km squares in Wales where breeding evidence was recorded**	**2013 GMEP WWC and TG squares**		**2013-2016 GMEP WWC**	
		Number of 1km GMEP WWC + TG squares which fall within 10km Atlas squares with breeding evidence in 2013	**Number of unique 1km GMEP WWC + TG squares as some 10km squares may contain 2 GMEP 1km squares in 2013**	**Number of 1km GMEP WWC squares only which fall within 10km Atlas squares with breeding evidence for whole 4 year programme***	**Number of unique 1km GMEP WWC squares as some 10km squares may contain 2 GMEP 1km squares for whole 4 year programme***
Chough	74	16	14	31	30
Curlew	162	40	36	111	103
Lapwing	148	29	24	92	83
Ring Ouzel	49	13	13	29	27
TOTAL	286	60	-	165	-

Table 4.6.1 Distributions of priority bird species within GEMP 1km squares in 2013, and predicted for 2013-16 in total for the Wider Wales Component squares only, mapped onto Bird Atlas 10km Squares where evidence of breeding has been recorded.
**Targeted squares cannot be selected ahead of survey year as depends on Welsh Government priorities therefore final numbers are likely to increase significantly to approximately double to those shown here when TG squares are added in.*

The distributions of these squares was compared with that of the sample of 60 GMEP 1km survey squares for 2013 (WWC and TG samples) then, separately, also compared with the distributions of the complete sample of WWC squares for all four years available to date (Table 4.6.1). At present analysis of the Targeted sample is only possible for the 2013 squares since the sample for years 2-4 has not yet been selected.

All four species are present in reasonable numbers of 10km squares in which GMEP survey squares are found, suggesting that, provided that the right habitats are present in the 1km squares concerned, there is a reasonable chance of recording the species. This is particularly evident in the comparison of all four years of the WWC sample, when more than half of the 10km squares in which three of the species are currently found feature at least one GMEP monitoring square. A caveat to this conclusion is that the GMEP will only be one or two of the 100 1km squares in these 10km squares, so it is far from certain that the focal species will actually be found in the GMEP square. Nevertheless, the surveys are clearly taking place in approximately the right areas to facilitate recording of these species and measurement of those habitat features and conditions that can be further used to estimate changes in habitat suitability for each bird species.

It is also important to note that the GMEP surveys are additional to existing recording under the BTO/JNCC/RSPB Breeding Bird Survey and the less structured, but probably close to complete, surveys conducted for rarer species like chough by other groups. In addition, the BBS survey effort in Wales is currently being enhanced by dedicated volunteer recruitment and training by BTO Wales, under funding from CCW (NRW). Together, therefore, these various survey resources are likely to deliver better coverage of these species than has ever previously been achieved.

4.7 Potential occurrence of other targeted vertebrate species in GMEP survey squares

10km square records for other animal species listed as target objectives were downloaded from the NBN Gateway on 26/09/2013 and then intersected with the GMEP 1km sample to produce the same analysis as that carried out for priority bird species (Table 4.6.1). These figures are provisional and require updating as a result of further collaboration with the recording societies responsible for collecting observations In particular, a more recent baseline is required for some species that are known to have undergone major declines in Wales, e.g. High Brown Fritillary is now only known from one site Wales. However the figures give an indication of the likely spatial proximity of species' to the GMEP squares. Even though the targeted squares for 2014-16 have been excluded because they are not yet known, the figures are at first glance encouraging. For all species except Water Vole and Bechstein's Bat over 50% of the 10km squares in Wales with a recorded occurrence also coincide with one or more of the GMEP squares. As for the bird analysis the same major caveat applies; the 10km square record may well refer to a small population in any one of the 100 constituent 1km squares.

Species[9]	**Total 10km squares in Wales (post-1980)**[10]	**Number 10km squares coinciding with Targeted (2013)**	**Number 10km squares coinciding with Wider Wales (2013-2016)**
Barbastelle Bat	8	3	4
Bechstein's Bat	0	0	0
Greater Horseshoe Bat	39	6	14
Lesser Horseshoe Bat	125	20	59
Dormouse	57	5	25
Red Squirrel	101	18	54
Water Vole	50	6	17
Great Crested Newt	110	11	47
Freshwater Pearl Mussel	34	6	16

Table 4.7.1 Coincidence between post-1980 10km square records for section 42 vertebrate species listed as Glastir target objectives and the 1km squares in the current GMEP sample.

4.8 Potential occurrence of targeted invertebrate species in GMEP survey squares

Post-1980 records were compiled from the records collected and owned by Butterfly Conservation and the Bees, Wasps & Ants Recording Society (Table 4.8.1). The level of overlap between 10km squares and the GMEP sample is again encouraging. For example 64% of the Welsh 10km squares with records for Pearl-bordered Fritillary and 72% of those with Marsh Fritillary include a GMEP 1km

[9] Data was downloaded from the NBN Gateway and is owned by the following; Amphibian and Reptile Conservation, Biological Records Centre, Bristol Regional Environmental Records Centre, Conchological Society of Great Britain and Ireland, Devon Biodiversity Records Centre, Dorset Environmental Records Centre, Environment Agency, Gloucestershire Centre for Environmental Records, National Trust, Natural England, Natural Resources Wales, Freshwater Habitats Trust, Record, the Biodiversity Information System for Cheshire, Halton, Warrington and the Wirral, Royal Horticultural Society, Shire Group of Internal Drainage Boards, Shropshire Ecological Data Network, South East Wales Biodiversity Records Centre, The Bat Conservation Trust, The Mammal Society, Tullie House Museum, Wiltshire and Swindon Biological Records Centre

[10] The 10km squares used in this analysis include records that may have a date range that extends outside of the required filter 1980-2013, for example 1950-2000. A date range like 1950-2000 for a species observation indicates very little certainty of when it was actually made. This analysis includes such records, as well as records that are definitely within the 1980-2013 date range (eg 2000-2010).

square. The same caveat applies regarding the actual spatial proximity of survey square and species population. These rare targeted invertebrate species will not be detected by the GMEP invertebrate survey for the following reasons: the Pearl-bordered and Marsh Fritillary occur outside the survey period, i.e. their flight period is May and June, whereas the GMEP invertebrate survey occurs in July and August to coincide with the peak period for invertebrate populations in general. High Brown Fritillary only occurs in one location in Wales having undergone major declines. The Welsh Clearwing is an elusive species and is only typically detected through targeted surveys for emergence holes. Bumblebees are only recorded to group level within the GMEP invertebrate surveys.

Species	Total 10km squares in Wales (post-1980)	Number 10km squares coinciding with Targeted (2013)	Number 10km squares coinciding with Wider Wales (2013-2016)
Pearl-bordered Fritillary	78	12	38
High Brown Fritillary	21	2	11
Marsh Fritillary	123	24	64
Welsh Clearwing moth	13	4	8
Shrill Carder Bee	9	2	6
Brown-banded Carder Bee	32	1	18

Table 4.8.1 Coincidence between post-1980 10km square records for section 42 invertebrate species listed as Glastir target objectives and the 1km squares in the current GMEP sample.

4.9 Optimising field survey methods for detection of Glastir impacts on biodiversity

4.9.1 Habitat mapping

Glastir aims to extend the area and improve the ecological condition of section 42 habitats as well as a wide range of more common habitats that have high biodiversity or deliver important ecosystem services such as flood control, food production, recreation and carbon storage. To identify the success of these interventions, the GMEP field survey records the extent of every habitat within the 1km square down to a Minimum Mappable Unit (MMU) of 20m x 20m. Linear features are also important. The total length of linear features is surveyed in each square and attributes recorded that are subject to change as a result of Glastir intervention. For example of those Advanced Glastir options that are linked to delivery of biodiversity, 30% target the management of linear features including field margins, watercourses and hedgerow (See Appendix 2.1 for detailed field methods and Appendices 4.5a and 4.5b). Smaller patches of habitat are not mapped but vegetation plots may be placed in these or some may be described as point features. The classification of habitats is based on the UK Biodiversity Action Plan Broad Habitats with Priority habitats (section 42 habitats) also mapped yet where these can be referred back to a parent Broad Habitat. Habitats are identified in the field using a vegetation key that was originally developed for Countryside Survey and has been circulated to many habitat experts. This key was further modified to reflect Welsh perspectives following consultation with NRW habitat experts in February 2013 following the pilot survey. Additions include a lookup table between Priority habitats, Broad habitats, feature levels, Annex 1 habitats and NVC communities and also taking account of a classification of habitats and definitions for Tir Gofal that was revised for Glastir in 2011. Information from both of these documents was used to shape the final vegetation key and habitat descriptions used in the GMEP field mapping handbook. The outcome of this consultation and revision process was a key to habitats that reflected a Welsh perspective but maintained continuity with previous surveys such as Land Cover Map and Countryside Survey, thus ensuring that joint analysis is possible.

To capture additional land cover information relevant to Glastir interventions, two modifications were made to the mapping software used by the field teams. For each polygon a mandatory field was included to indicate the proportion of vegetation above and below 7cm in height. A tussockiness attribute was also included with supporting information in the handbook. Both modifications were included to allow surveyors to discriminate and record variation in vegetation structure relevant to nesting and feeding for bird species.

4.9.2 Vegetation plots

Plant species composition and abundance is recorded in fixed plots within each square (maximum = 67, average = 27). These plots are small enough to be assigned uniquely to one habitat type, numerous enough to represent all the habitat types in each square, even the rare ones, and sampled in such a way that they form an unbiased sample that can be used to estimate properties of the wider extent of un-sampled habitat in the rest of Wales. The vegetation plot data provides for the analysis of individual plant species changes and also summary variables that are useful in measuring the impact of specific measures. For example total cover of nectar plants in arable field margin plots or total *Sphagnum* cover in Blanket Bog.

Glastir target objectives include specific plant assemblages; Heathland Plants, Rare Plants, Arable Plants and Arctic-Alpine Plants. All these have low scores in the Welsh Government prioritisation of 1km squares relative to priority areas targeted in the first four year roll. Consequently they are currently not the focus of targeted 1km square sampling but could be should the Welsh Government priorities be redirected. However, because survey protocols require that section 42 habitats are specifically targeted in every GMEP survey square, then any occurrence of habitats likely to support the rare plant groups will be sampled such as arable field margins, heathland and montane.

Applying the same approach as that used for rare bird and invertebrate species, analysing change in the abundance of more common species can powerfully convey changes in habitat suitability for rarer plants. Coincidence mapping of the known 10km square range with the location of GMEP squares then indicates where ecological change is most likely to impact the target species. The MultiMOVE model can be used to directly translate abiotic conditions based on soil and plant species composition into an indication of habitat suitability for a large number of the rarer plant species (see section 2.5.1.1.2 and chapter 2). Whilst common plants are a telling indicator of habitat conditions they are also of fundamental functional importance important. This is because the dominant species' in any ecosystem deliver most of the ecosystem service; for example crops, trees, forage grasses, common nectar plants, *Sphagnum* moss (also see case studies –section 4.4).

While the majority of vegetation plot types and their associated recording protocols were adopted from existing Countryside Survey protocols a small number of modifications have been made for GMEP. All are designed to optimize detection of Glastir impacts on plant species composition and vegetation structure.

4.9.2.1. P plots

A large number of Glastir measures apply to the sides of watercourses. The monitoring and evaluation programme aims to record changes in both area and condition of these linear features as this will be critical in whether they are effective in both connectivity and water quality control. Countryside Survey streamside plots only record detailed species composition in a 10x1m quadrat, located with the long axis adjacent to the water's edge and so likely to miss any vegetation changes occurring upslope. A new perpendicular (P) plot was introduced to capture these changes. The P plots project upslope at 90 degrees from the channel with plant species recorded in a 1x10m strip. Given the heterogeneity of the riparian zone, surveyors are asked to note down the number of vegetation types the plot traverses such that this information repeated over time can be used to relate changes in species composition with changes in the zonation of the vegetation and the role of Glastir intervention in driving this change.

4.9.2.1.1 Additional guidance on locating targeted (Y) plots

The targeted plots aim to sample Priority Habitats or other patches of semi-natural habitat not sampled by the other plots in each 1km square. While we are required to maintain the emphasis on sampling these rarer habitat fragments, the plots also provide an opportunity to focus on locations eligible for Glastir intervention. Therefore a list of features and habitats was provided to surveyors for guidance. An example would be where a Y plot location was being considered within Blanket Bog and where unenclosed (U) plots had already sampled the vegetation at random. The surveyor would be advised to position the targeted plot at a random point along the total length of any unblocked grip drains on the basis that these could be subject to blocking funded under Glastir Advanced. Then repeated recording of the plot over time would convey any changes in species composition and vegetation height.

4.9.3 Bird recording

Annual bird monitoring already occurs in Wales, under the BTO/JNCC/RSPB Breeding Bird Survey (BBS), a scheme using volunteer survey effort to cover a random selection of 1km squares every year. This survey is designed to provide long-term, large-scale monitoring of bird and larger mammal populations, and it can be used to test for signals of management, such as agri-environment schemes, at similar temporal and spatial scales (e.g. Davey *et al*. 2010, Baker *et al*. 2012). Up-to-date background population changes for the whole of Wales, together, sample sizes permitting, with regional breakdowns, can typically be extracted from BBS data by early in the following year, e.g. trend analyses including 2013 data will be possible early in 2014. However, the survey method is not intensive and it does not provide reliable information on absolute annual population sizes in local survey squares, or of the locations of bird with respect to fine-scale habitat patches, because coverage comes only via walking linear transects and using only two visits to each square means that counts are potentially subject to considerable stochastic variation.

For these reasons, given the four-year, rolling survey design being used in GMEP, a more intensive survey protocol has been adopted, while retaining the 1km square sampling unit. While such bird survey approaches are well-established for site-specific monitoring, it is novel for them to be applied at the 1km-square scale in a national monitoring programme. The protocol is described in full in Chapter 3, but the critical details are that it involves four visits to the survey square in which all of the square (given access permissions) is visited and bird locations are mapped with respect to the detail of habitat features. This means that the observed annual bird counts are much less subject to stochastic variation due to chance factors influencing the detection of individuals, pairs or flocks than in the BBS, and that the selection of habitat patches by birds can readily be investigated using mapped locations from each survey visit.

Overall, therefore, the effects of Glastir on birds will be investigated in three complementary ways by the GMEP: (i) periodic, long-term analyses of the effects on large-scale bird populations using BBS data and national agri-environment uptake data; (ii) changes in bird abundance or density in GMEP survey squares over the four-year cycle of repeat counts with respect to the Glastir management within squares; (iii) annual or multi-annual analyses of habitat selection using mapped records of birds within GMEP squares with respect to habitat type, including whether habitat patches have been managed or created under Glastir. All these analyses will focus on species predicted to benefit from the management that is in place.

4.9.4 Butterfly and pollinator recording

Butterfly and invertebrate recording is carried out in GMEP squares using methods based on the Wider Countryside Butterfly Schemes, a component of the UK Butterfly Monitoring Scheme. This ensures that joint analysis is possible with existing contextual datasets. Field methods for GMEP were modified so that additional invertebrates could be recorded and also their floral resources. These data are highly novel providing a unique opportunity to link invertebrate records to plant species assemblages and potentially to the impact of Glastir intervention in the square.

An early indication of the extent to which the GMEP invertebrate surveys cover the rarer priority species will not be known until the year 1 data are examined. Many rare species will inevitably not be recorded, particularly because the GMEP invertebrate surveys are undertaken in July and August to coincide with the main season for invertebrate populations; the survey therefore misses the flight period of priority species in Wales (e.g. the main flight season for Marsh Fritillary and Pearl-bordered Fritillary is May-June). However, changes in habitat suitability based on more commonly surveyed features are likely to be beneficial where the rare species is in close proximity. Analysis of the overlap between 10km square records and GMEP squares indicates that this could be the case for a number of species (Table 4.8.1).

4.10 Analytical approaches – examples under development in the next phase of work

A brief summary is given below of analytical work planned for the coming year.

4.10.1 Development of an integrated analytical strategy to detect and attribute changes in biodiversity recorded in the GMEP program

A meeting will be convened in autumn 2013 to begin the process of developing an analytical strategy. This will involve the statistics and informatics Work Package plus statistical consultants from University of St Andrews and scientists from the Biological Records Centre and BTO. We will begin to classify and clarify the questions to be asked of the data while moving toward a more detailed specification of the input datasets available and the statistical models to be applied that reflects both the question and the constraints of the data.

The development of this strategy is likely to be a gradual process as analyses of yearly datasets brings greater accuracy in our estimates of the power of the sample to detect changes in the large range of attributes measured given increasing knowledge about the actual uptake of measures and their coverage in the sample squares.

A basic set of questions comprise the following: What has changed and where? Why has change occurred and how much can it be attributed to Glastir? What is likely to happen in the future? The research team has extensive experience in answering these questions for British landscapes and ecosystems. This makes for efficient deployment of resources for new work. It also ensures use of the best techniques and existing knowledge to optimize detection of the impact of Glastir interventions across Wales given the influence of other drivers both past and present such as the legacy effects of previous schemes. Some of the questions that we will ask of the data are novel because GMEP is the first time a range of newly recorded and existing datasets have been brought together in a way that allows these questions to be answered.

Analysis of changes in habitat attributes and species that are more common in the landscape also offers scope for estimating potential impacts on rare species that may be infrequently encountered in survey squares. Much is already known for example about how attributes such as successional status, patch area, amount of hedgerow, vegetation height, soil productivity, water quality and cover of dominant plants constitute a configuration of conditions that can be good for some species and worse for others. This is the principle behind the use of the MultiMOVE model (see section 2.3.2) that projects the likely impact of an intervention on abiotic conditions and vegetation height and then translates this into changes in suitability for range of plant species. Work will now continue with colleagues from BTO and input from RSPB on how we make further model-based links between changed stocking levels, changes in vegetation height and plant species composition and impact on habitat suitability for priority bird species (see section 2.3.2 and Appendix 2.3). These model projections embody much existing knowledge and so constitute a powerful means of estimating future impacts of Glastir over long timescales. However model projections can also be usefully compared with observed changes in GMEP squares helping to reinforce the results of other analyses that try to attribute signals to impacts such as Glastir intervention and to help identify unusual and unexpected patterns that might not be apparent if the observations could not be matched with an expected pattern of change.

4.10.2 Integrated analysis of multiple biodiversity responses and multiple drivers including Glastir

Ecosystems are typified by interdependencies between their component parts. For example soil reflects geology, climate and above and below-ground species composition but these are also dependent on land management which also reflects the constraints imposed by climate which in turn can reflect feedbacks from vegetation. Estimating the amount of change in GMEP observations that might be attributable to Glastir intervention therefore requires careful framing of the question as well as methods that can account for these interdependencies in a statistically robust fashion. Part of our analytical approach will therefore be to develop and apply state of the art techniques for finding the best fitting causal/correlative model for a particular question. Ordination models have already been applied to quantify the patterns of covariation apparent among Wales-only indicators marking the start of our approach to High Nature Value farmland (See section 4.11.2) Further work will also develop and apply methods now being widely used to disentangle the causal pathways in survey and monitoring data (Sheppard *et al* in press; Van de berg *et al* 2011).

4.10.3 Analysing the legacy effects of previous scheme impacts

An analysis of legacy scheme effects is scheduled for winter 2013-14. This work will consist of an application to Tir Gofal and Tir Cynnal management data of the analytical approach used by Baker *et al*. (2012) to investigate the effects of the English Environmental Stewardship scheme on farmland birds (see Box 3.4.1). Baker *et al*. used BTO/JNCC/RSPB Breeding Bird Survey (BBS) data to provide the first evidence for landscape-scale impacts of agri-environment management on dispersed wildlife populations. The new analysis under GMEP will use the same data set (BBS covers Wales as well as England) and the same, recently developed technique for the efficient modelling of environmental influences on population growth rates (Freeman & Newson 2008). The results will indicate the extent to which the different individual management types in the legacy AESs, as well as the schemes as a whole, have driven changes in bird populations. The BTO will provide the BBS data for this analysis, but spatially referenced data on Tir Gofal and Tir Cynnal management (as well as any other historical management of interest to the Welsh Government) will be required, preferably in the form of GIS files with the finest spatial resolution possible, to complete the work.

This work will fit within a wider analytical strategy for applying past scheme data to test the hypothesis that equivalent habitat types in the same physiographic regions differ in species composition between parcels and features subject to past AES measures. This analysis will provide important evidence about the effectiveness of past AES management and, hence, lessons critical to the success of the implementation of Glastir. Analyses will as far as possible be carried out across species groups. Detecting convergent signals across for example soils, waters, plants, birds and invertebrates is a major goal. The unique power of the co-located biological recording carried out in the GMEP squares gives an unprecedented opportunity for testing the hypothesis that cross-taxon signals of past scheme effects are detectable and that these influence subsequent responses to Glastir. A complete test will only be possible after the end of the first 4 year rolling program. Year 2 will involve agreeing and testing the technical means necessary to execute these analyses which will in turn, be one component of a much broader integrated analytical strategy that seeks to quantify interdependencies among biota but also with other drivers and response variables being measured in other work packages.

4.10.4 Using remotely sensed data to estimate change and to upscale beyond the GMEP 1KM squares.

The potential contribution of remote sensing will be assessed for change detection and for extending the Broad Habitat mapping beyond the 1km x 1km survey squares. Initial maps will be cross-referenced with the Wales Fused Habitat Map which uses a novel approach of combining remote sensed data and expert ecological judgement. No change data is currently planned using this approach but it will provide a valuable cross-check with initial conditions used by GMEP when released publicly. The GMEP change detection work will test a novel method currently being developed under a JNCC project. The method uses a land cover classification to provide the land cover status at time 1, whilst a remote sensing image provides data on land cover at time 2. The change between land cover is assessed by calculating spectral distance between the core class spectral properties (the blue area in Figure 9) and the pixels corresponding to that class. Pixels that have not changed are expected to show standard spectral properties for their class and will fall in the blue area of Figure 4.10.4.1. Pixels that have changed are likely to show different spectral properties and will fall outside the core area and will be flagged as anomalous.

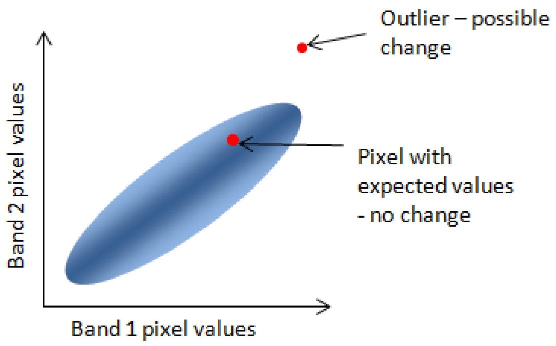


Figure 4.10.4.1 Illustration of the core spectral values of a class based on two spectral bands.

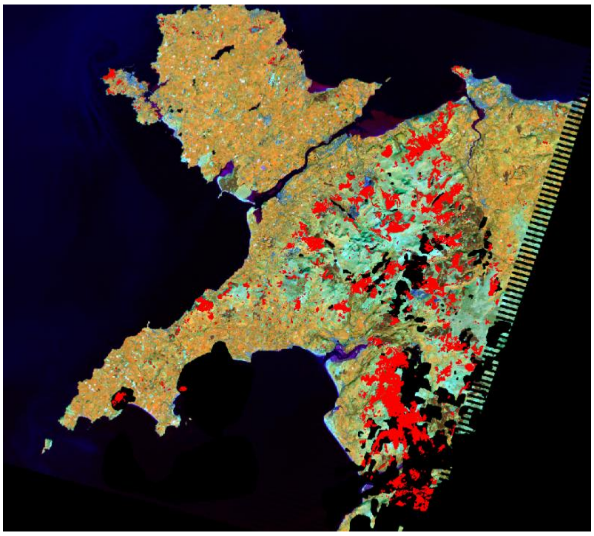


Figure 4.10.4.2: The two input data sets, with areas of Heathland (shown in red) from the Phase 1 Habitat Survey of Wales overlaid on a summer-winter composite satellite image.

Preliminary results are shown in Figure 4.10.4.3 to illustrate the method. The coverage of Heathland (defined as classes D1-D6) in the Phase 1 Survey (Figure 4.10.4.2) was used to identify heathland areas in the satellite image from which values were extracted and used to create 'core' Heathland spectral properties. The spectral distance (essentially a measure of the difference between the 'core' spectral values and the values of individual pixels) is then calculated. In future work the spectral distance will be thresholded to identify outliers that will be assessed for change. The method will only be able to detect land cover change that results in spectrally distinct change. One of the outputs produced by the work will be identification of classes that are likely to be spectrally distinct.

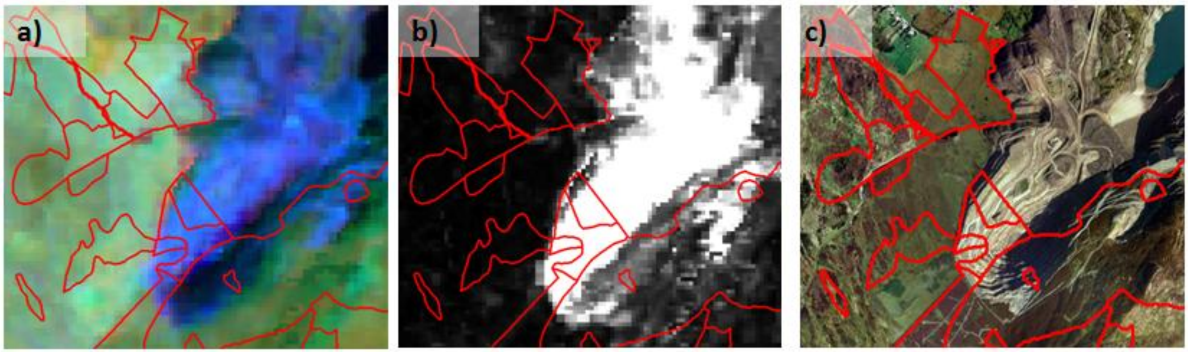


Figure 4.10.4.3 Land cover change due to the expansion of Penrhyn Quarry, Bethesda into areas mapped as Heathland in the Phase 1 Habitat Survey of Wales. A) shows satellite data overlain with Heathland areas (red polygons); b) shows spectral distance from core Heathland spectral values (white areas show large differences) and c) shows an aerial photo of the quarry, illustrating its expansion into the Heathland areas.

The second area of remote sensing, aims to extend the habitat monitoring beyond the field survey squares. The initial work will involve a scoping study looking at a small number of survey squares in upland and lowland areas. A range of remotely sensed data sources, from high spatial resolution aerial photography to low resolution satellite data will be assessed, in conjunction with the field survey data to determine the potential for using the field survey habitat mapping to classify the surrounding area. Some preliminary classification work has been conducted using Countryside survey Broad Habitat mapping data with only aerial photography data as input (Figure 4.10.4.4). Currently, there are some issues with the quality of the classification results, especially with water and deciduous woodland. Future work will assess how much the classifications can be improved given that aerial photographs have very limited spectral information to work with; only 3 visible bands compared to satellite data with 6 spectral bands, including key non-visible wavelengths. The classifications will then be extended beyond the 1km squares to the surrounding areas for the test areas.

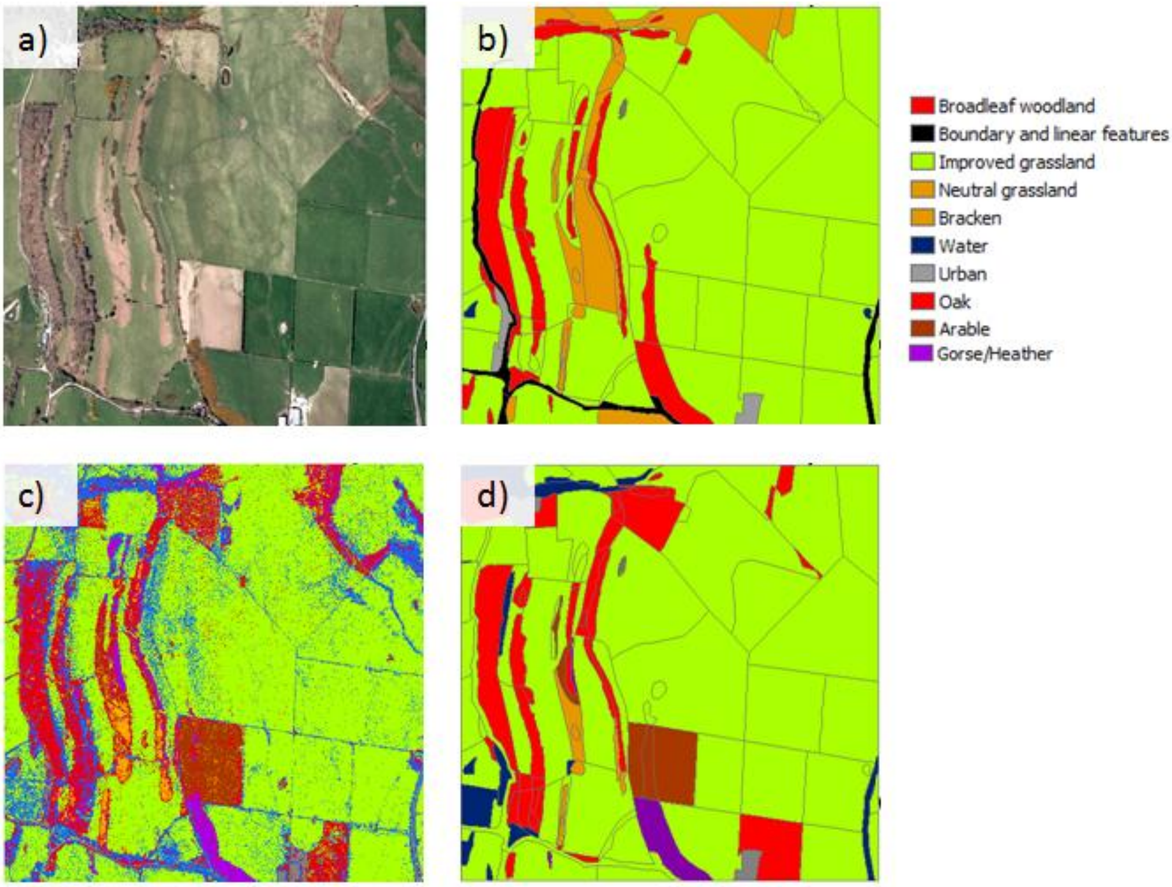


Figure 4.10.4.4 Preliminary classification results from applying a Random Forest Classifier to an aerial photograph, a) aerial photograph, b) Countryside survey (CS) Broad Habitat Mapping data for the square, c) per-pixel classification and d) classification summarised using CS-polygons.

4.10.5 Habitat connectivity

Habitat fragmentation is known to increase the risk of biodiversity loss. Provision for improving or maintaining connectivity between habitat fragments is supported by a number of Glastir options, for example woodland expansion (AWE 24) and the creation of planted streamside corridors (AWE 9b). High connectivity between patches of habitat provides pathways for wildlife to move across the landscape allowing organisms to move away from pressures on a particular area of habitat. Detailed data collected by the monitoring programme on the size and location of habitat fragments within monitoring squares will allow us to assess changes in habitat connectivity as a result of Glastir interventions.

Habitat connectivity is highest where there are large patches of habitat that are close together and lowest where there are small patches far apart. To assess changes in connectivity habitat data will be used to assess the location, size and distance between areas of habitat. A number of approaches can then be applied to quantify changes in connectivity over time. At present the LUCI modelling platform implements connectivity assessment using the BEETLE model. This is just one of a number of approaches. Further work is required to test other simple metrics and to explore ways in which existing datasets can be used to estimate dispersal distances for a wider range of target organisms. Here we report application of the Probability of Connectivity (PC) metric (Saura & Pascual-Hortal, 2007) used to measure changes in connectivity. The PC index works by calculating the probability that any two individuals dropped at random into the landscape both occur in areas of target habitat that are connected to each other. The degree to which two habitat fragments are connected is dependent on the dispersal capability of the focal species and on the composition of the surrounding habitat matrix. For example a broadleaved woodland species may be able to move further through coniferous woodland than arable land. The composition of the surrounding habitat matrix is therefore taken into account by calculating least cost distances between each habitat fragment.

To show the potential for this model to identify changes in habitat connectivity at a 1km scale a square was chosen from the Countryside Survey where woodland expansion had occurred between 1998 and 2007, in this case onto arable land (figure 4.10.5.1). Connectivity between broadleaved woodland habitats was assessed in 1998, prior to woodland expansion, and again in 2007 using the PC metric in the Conefor package (Saura & Torné, 2009). The resulting mosaic of tree saplings and neutral grassland present in 2007 was considered to be more permeable to the movement of woodland species than the previous arable habitat, and therefore the connectivity of broadleaved woodland in the square increased slightly. The potential future connectivity expected when the planted woodland matures was also calculated and a large increase in connectivity observed due to the increase in both habitat area and the creation of new connections.

Future work is planned to investigate integrating additional information from the monitoring squares such as vegetation data in improving the estimation and assessment of habitat connectivity. The detailed vegetation data should allow us to identify changes in biodiversity linked to habitat fragmentation and connectivity. The LUCI model described in section 2.3.3 also considers habitat connectivity using an incidence function model (Watts *et al.*, 2005) but it is not currently possible to extract a metric of connectivity from the GIS toolkit. Adding the functionality to assess connectivity at the 1km scale into the LUCI toolkit will increase comparability between small and large scale connectivity analyses.

A highly novel integration of the connectivity modelling and plant species MultiMOVE models is also underway. Application of MultiMOVE to four Glastir measures is described in section 2.5. The expected impact of these Glastir measures is to ameliorate abiotic conditions making habitat patches more favourable to target plants and therefore creating a more permeable landscape mosaic. A complete assessment of changing connectivity therefore requires quantifying the spatial dividend that arises from more, larger and better connected patches but also the favourability of the conditions likely to prevail across the newly created corridors and patches. MultiMOVE outputs (see section 2.5) can be used integrated into Conefor as weightings that result in a more unified and realistic expression of connectivity change since both spatial and abiotic changes are considered.

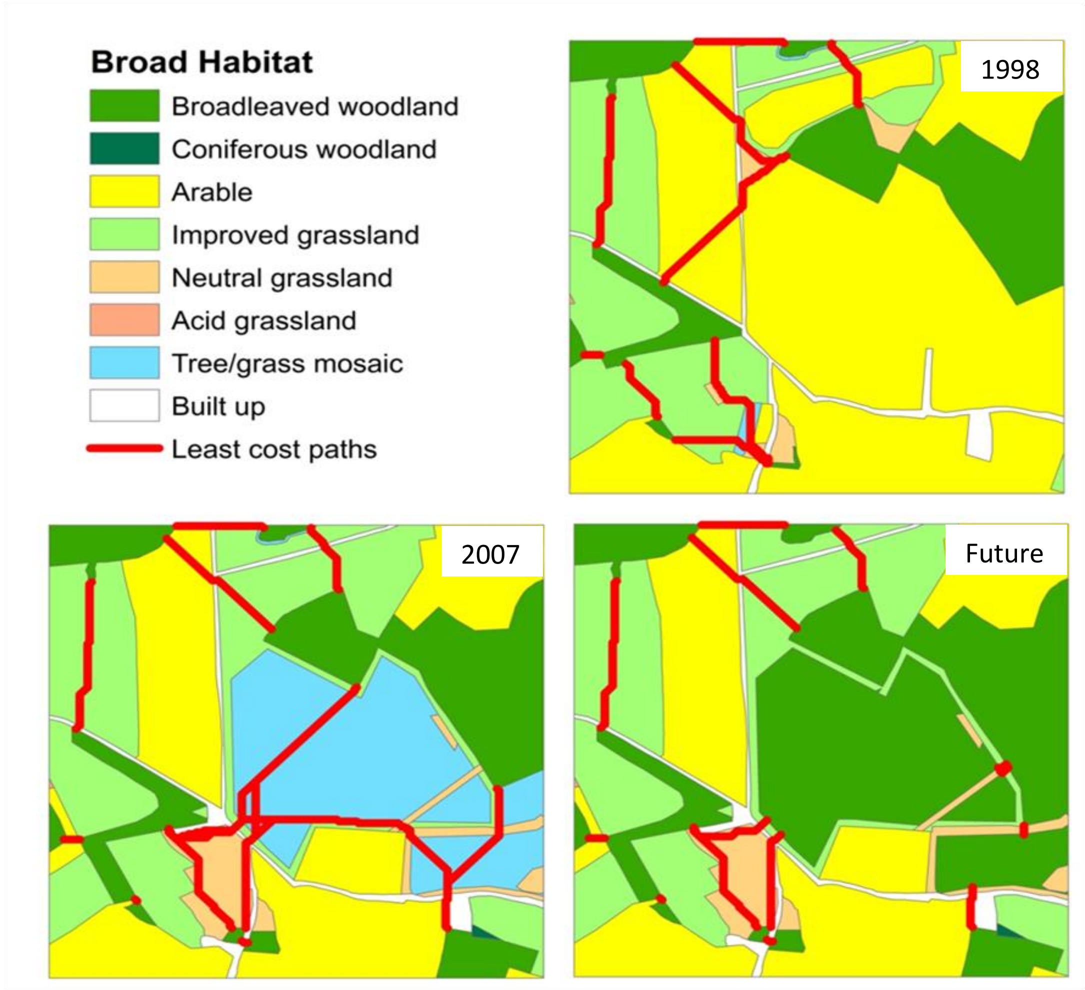


Figure 4.10.5.1 Changes in connectivity observed in a 1km square in 1998, 2007 and a future scenario of broadleaved woodland expansion. The Probability of Connectivity metric in each scenario was as follows: 1998, 0.0123; 2007, 0.0134; future, 0.0909.

4.11 New analytical results from year 1

4.11.1 Analysis of biological recording data from Wales

Here we report preliminary work testing and applying the best methods for quantifying species trends for a wide range of groups across Wales. A new prototype Priority Species indicator is also demonstrated. Ultimately the goal is to be able to express the average value of the trend indicator and how it varies from its average value with varying levels of uptake of Glastir having also taken account of other factors such as historic scheme legacy, habitat diversity and amount of semi-natural habitat. The goal is to be able to correlate Glastir uptake with changes in presence of rare or less often recorded taxa, many of which are not recorded in the GMEP field surveys. The first critical step is to develop and apply the best methods for taking account of variation in recording intensity. It is these results and a presentation of the first version of the priority species indicator that is presented below.

The impact of environmental change on biodiversity is well-known, with threats such as, habitat loss, climate change, invasive species and pollution, frequently related to biodiversity loss (Butchart *et al.,* 2010; Magurran & Dornelas, 2010; UK National Ecosystem Assessment, 2011). However, investigations into biodiversity loss in Britain have tended to be restricted to a core set of taxonomic groups, primarily birds, butterflies and plants, which all have a long history of structured recording.

The wide taxonomic scope, increased maturity and accessibility of species distribution data through the NBN Gateway (NBN, http://data.nbn.org.uk/) is now a key world-leading resource for quantifying the status and trends of a much wider proportion of the UK's biodiversity. With the increase in public participation in biological recording, the size and taxonomic breadth of species distribution datasets are expected to rise (Silvertown, 2009; Dickinson *et al.*, 2012; Miller-Rushing *et al.*, 2012), and in turn will open up new opportunities to address ecological research on poorly studied taxonomic groups. The use of such data has been limited by the lack of appropriate analytical methods for measuring trends across a range of species groups while accounting for variation in data collection protocol and/or spatial and temporal recorder effort. Recent advances in analytical methods provide a basis for overcoming the spatial and temporal biases inherent in much of the 90+ million records made available via the NBN Gateway and many other biological records databases.

In this study, we evaluate the potential of opportunistic biological recording data to estimate trends in the biodiversity of Wales. We examined trends across 18 taxonomic groups, many of which are poorly studied, and provide an example indicator of status for a subset of priority species. We test the performance of various analytical techniques to estimate trends from relatively unstructured biological recording data, and collate the best of these into an R package for estimating trends in species' status from opportunistic, presence-only data.

4.11.1.1 Methods

4.11.1.1.1 Data

We extracted 1 x 1km gridded (monad) distribution records from the Biological Records Centre (BRC) for 18 taxonomic groups (Table 4.11.1.2.1.1), covering 1,990 native species. Only distribution records that were recorded between 1970 and 2009 were included in the analysis, as data quantity is lower pre-1970. The use of this data for reliable trend analysis requires consultation with recording scheme experts to excluded species that are known to have taxonomic issue or specific patterns in recording bias that may confound trend estimates; we have initiated this review for the monitoring and evaluation programme.

4.11.1.1.2 Analysis

The use of unstructured gridded distribution data to determine change can be inhibited for a variety of reasons, including spatial and temporal variation in recorder behaviour, uneven recording effort and changes in species' detectability (Dennis & Thomas, 2000; Telfer *et al.,* 2002; Lips *et al.,* 2004; Rich, 2006; Tingley & Beissinger, 2009; Hill, 2012). Many techniques have been developed to account for such problems while estimating change trends, but currently we lack a coherent view of which technique is best. We have undertaken a quantitative test of the performance of available methods under a range of realistic recording scenarios (Isaac in prep and Appendix 4.2). We find that the well-sampled sites method (WSS) of Roy *et al*. (2012) performed well under a variety of recording scenarios where it produced accurate trend estimates. The robust nature of the WSS method made it the ideal choice for estimating trends across the wide variety of taxonomic groups included in this study. The WSS method uses data at the visit level, and in our analysis we defined visit as a unique date and monad (1km square) combination. The WSS method fits a separate generalised linear mixed effects model for each species using the series of presences and absences (taken from the visits) as the response variable with year included as a fixed effect and grid cell as a random effect. The slope of the relationship with year indicates the strength and direction of the temporal trend in the probability of observing the species in an average cell. Only well-sampled cells were included in the analysis and these were calculated separately for each taxonomic group (due to taxon specific patterns in recording). To be defined as well-sampled, the number of species recorded in the cell had to be equal, or greater than the median number of species recorded across all visits for the taxonomic group in question. Additionally, cells had to have at least three years of data, following the criteria of Roy *et al*. (2012). We developed an R package '*sparta*' (see Appendix 4.2 and https://github.com/BiologicalRecordsCentre/sparta, for further details) to run the analyses in this study, and to make the methods available more widely to other researchers.

To produce a clear, interpretable metric of the trend estimates, we used the WSS models to produce a decadal trend in the probability of observing a species in an average cell (referred to as the 10 year trend, from here on in). For each species, we extract the fitted trend value at 1990 and 2000, from the WSS model that was built using the full range of data for the species in question. We then identified the percentage change between these two fitted value, to determine the change in the probability of observing the species between 1990 and 2000. For each taxonomic group, we combined the fitted values for all species to identify the net 10 year trend for the group in question, and compared this to the median 10 year trend within each group.

4.11.1.1.3 Prototype priority species indicator

We used the trend estimates described above to develop a prototype priority species indicator for Wales. The indicator assessment was carried out on a select subset of priority species, listed under the Natural Environment & Rural Communities Act 2006: Section 42 – List of species of principle importance for conservation of biological diversity in Wales (http://wbp.wisshost.net/species-35.aspx). This list included species that were considered to be of international importance to conservation, *i.e.* listed as threatened on the IUCN Global Red List (IUCN 2013), on greater than 50% of the regional EU Red Lists or listed as threatened in other reliable sources. Species were included if Wales contained greater than 25% of its EU or Global population and that the population has declined by 25% or more in the last 25 years. In addition, species that have shown greater than 50% declines in Wales in the last 25 years were included. Finally, species were included if they had exceptional threat circumstances, such as a very restricted range size, as verified by taxonomic experts.

The output from the trend analysis described above was used to derive the index. We extracted the fitted value for each species each year, this value measures the probability of observing each priority species on an average visit to an average cell. The index for each year is the geometric mean of the fitted values, expressed as a proportion of the value in 1970 (set as 100).

4.11.1.2 Results

4.11.1.2.1 Species trends

We discovered widespread variation in the direction and significance of trend estimates within and between taxonomic groups (Figure 4.11.1.2.1.1). Species were categorised into one of three groups based on the direction and significance of their trend estimates; significantly increasing, significantly decreasing and non-significant trend (stable). We found that dragonflies & damselflies, moths and grasshoppers & crickets had the greatest proportion of significantly declining species, with approximately 30%, 20% and 20% of species significantly declining respectively. Dragonflies & damselflies and moths also had the highest proportion of significantly increasing species, with approximately 33% and 37% of species increasing. Additionally, fish showed a large proportion of significantly increasing species at about 25%. We found no evidence of a significant trend for any of the long-horn beetle, soldier beetle or millipede species. Interestingly, the proportion of significantly increasing species tended to mirror the proportion of significantly declining species within each taxonomic group. This suggests greater power for detecting trends within species groups with larger quantities of available data.

To gain a clear understanding of the species trend estimates, we grouped species based on their 10 year trend. Again, we found widespread variation in the 10 year trend within and between groups (Figure 4.11.1.2.1.2). We discovered that fish had the largest proportion of species with negative 10 year trends, however many of these are non-significant as can be seen from Figure 4.11.1.2.1.1, which showed that fish had a large proportion of significantly increasing species. Grasshoppers & crickets and ants also had a large proportion of species with negative 10 year trends, while ants, wasps and centipedes had the largest proportions species with severely declining (>80% decline in the 10 year trend) trends. Notably, millipedes had the greatest proportion, approximately 80%, of species with positive trend estimates, a trend that was reflected in the net trend across all millipedes (Table 4.11.1.2.1.1). When focussing on the groups with the largest proportion of dramatically increasing (>80% increase in the 10 year trend) species, we found millipedes were joined by soldier beetles, ladybirds and terrestrial isopods.

We found that 10 taxonomic groups had negative net change trends, with the remaining 8 taxonomic groups showing a positive net change trend. Millipedes, ground beetles and soldier beetles had the highest positive net change trends, suggesting they are performing well as a group, whereas grasshoppers and crickets, ants and isopods all had strongly negative net change trends. The comparison between net (total) change and median change across all species within a taxonomic group can give an insight into the relative performance of rare and common species. A positive net trend and negative median trend estimate suggests that common species are out-performing rare species in terms of the change in the probability of observing a species between 1990 and 2000. The reverse of this relationship suggests rare species have a greater increase in their probability of being observed between 1990 and 2000. Ladybirds and isopods had a negative net change trends but a positive median change trend, which suggests their rarer species are out-performing the common species. While in contrast to this hoverflies had a positive net change trend but a negative median trend, which suggests the common species are performing well but the rare species are in decline.

Taxon	**Source**	**Number species**	**Number visits**	**Net change**	**Median change**
Fish	Database & Atlas of Freshwater Fishes	20	924	-5.39	-63.03
Spiders	British Arachnological Society, Spider Recording Scheme	328	408	-5.29	-20.73
Moths	National Moth Recording Scheme	580	52909	10.44	6.03
Ants	Bees, Wasps and Ants Recording Society	15	53	-18.52	-27.46
Wasps	Bees, Wasps and Ants Recording Society	106	165	-9.86	-18.01
Bees	Bees, Wasps and Ants Recording Society	129	450	11.76	8.83
Ladybirds	Ladybird Recording Scheme	18	51	-14.64	0.78
Long-horn beetles	Cerambycidae Recording Scheme	12	23	3.83	9.75
Soldier beetles	Soldier Beetles, Jewel Beetles and Glow-worms Recording Scheme	30	65	30.75	24.83
Ground beetles	Ground Beetle Recording Scheme	183	453	52.46	24.15
Craneflies	Dipterists Forum, Cranefly Recording Scheme	46	105	12.85	0.55
Hoverflies	Dipterists Forum, Hoverfly Recording Scheme	165	2223	3.84	-2.74
Grasshoppers & Crickets	Orthoptera Recording Scheme	20	218	-17.22	-24.82
Dragonflies & Damselflies	British Dragonfly Society, Dragonfly Recording Network	31	5935	-2.62	-1.93
Millipedes	British Myriapod and Isopod Group, Millipede Recording Scheme	25	23	117.87	96.88
Centipedes	British Myriapod and Isopod Group, Centipede Recording Scheme	19	42	-6.23	-18.80
Isopods	British Myriapod and Isopod Group, Non-marine Isopoda Recording Scheme	23	116	-16.72	19.69
Bryophytes	British Bryological Society	240	706	-13.07	-3.36

Table 4.11.1.2.1.1 An overview of the taxonomic groups included in the study. The source column highlights the recording scheme that is responsible for the records. We illustrate the number of species for which trends were estimated and the number of visits that these estimates were based on. We also highlight the net (total) and median percentage change across all species records within each taxonomic group between 1990 and 2000.

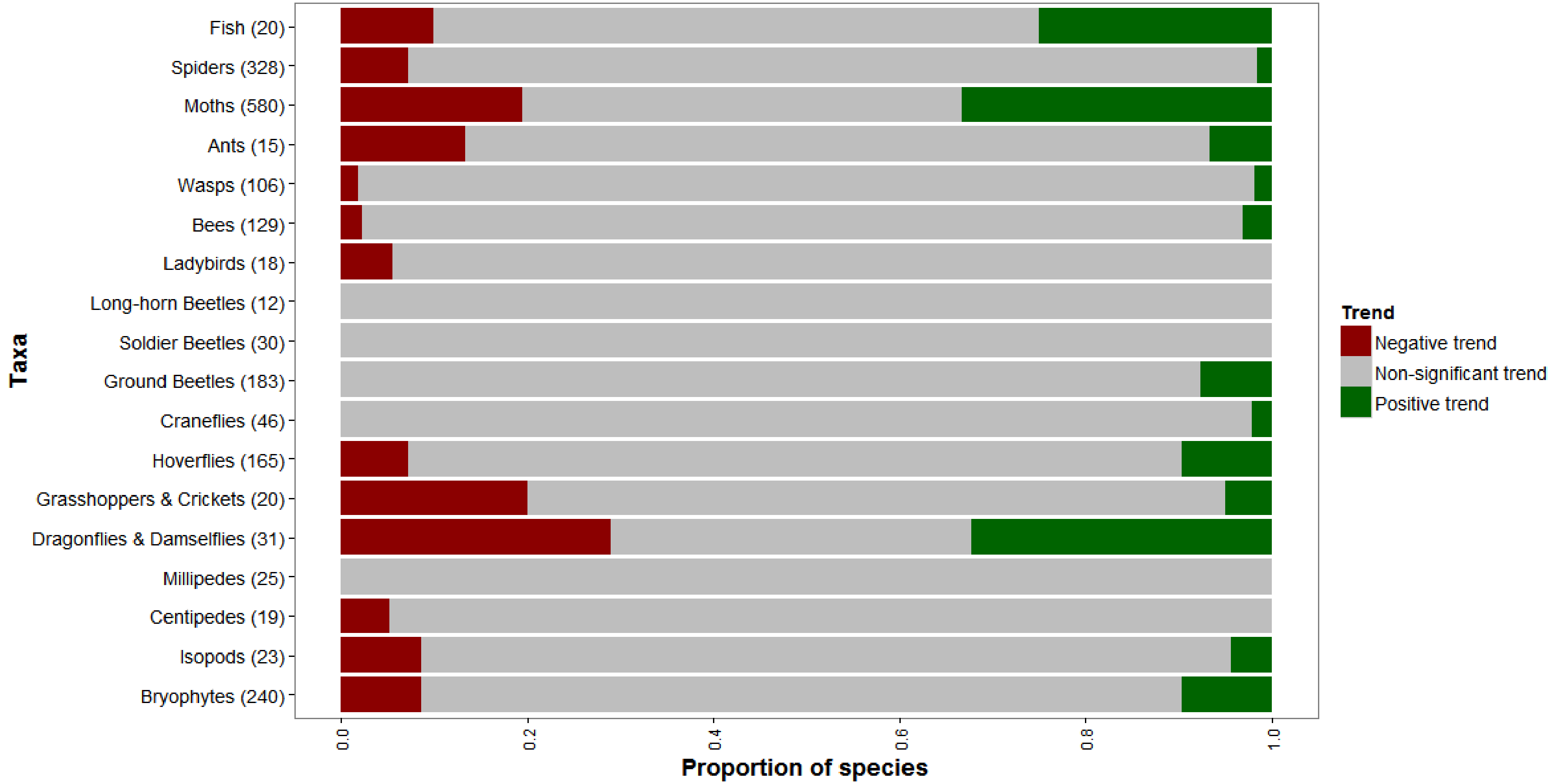


Figure 4.11.1.2.1.1 A bar plot showing the proportion of species in each taxonomic group that had a significantly increasing, a significantly decreasing or a non-significant slope in the relationship between probability of observation and year from the WSS model. The number of species for which trends were estimated is listed in brackets alongside the name of the taxonomic group.

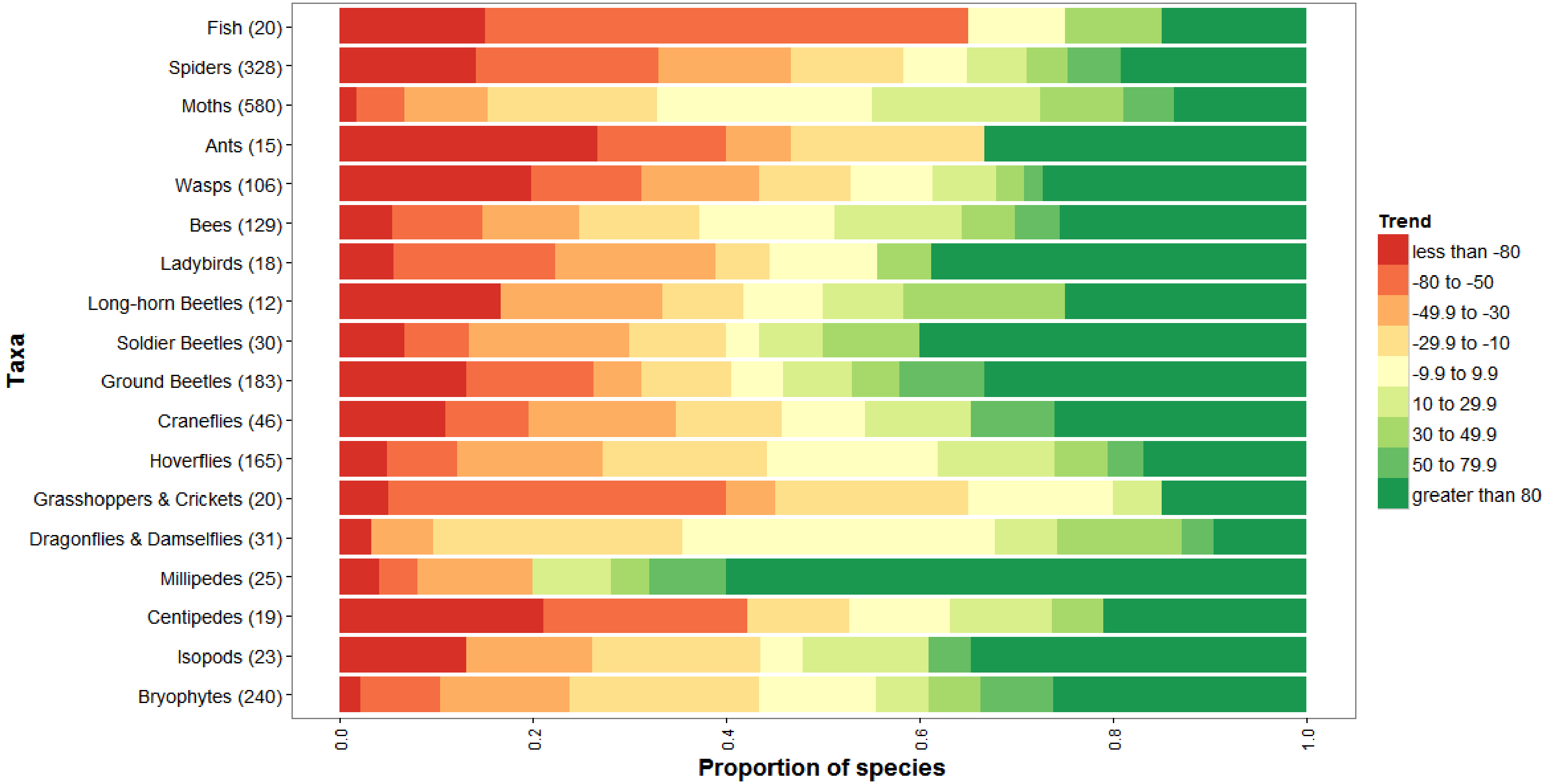


Figure 4.11.1.2.1.2 A bar plot showing the proportion of species that fall within each trend category based on the change in the probability of observation between 1990 and 2000. The number of species for which trends were estimated is listed in brackets alongside the name of the taxonomic group.

4.11.1.2.2 Priority species indicator

Following the various exclusion and inclusion criteria, the composite indicator consisted of 89 priority species. Moths made up the vast proportion of these priority species with 81 species, while six bees, one wasp and one odonate were also included. We discovered a consistent negative trend in the composite indicator (Figure 4.11.1.2.2.1), suggesting that priority species in Wales where data is available have declined over this period. In 2006, the species trend indicator was recorded at 45% of its original trend estimate in 1970. From this we can deduce that the probability of observing a priority species over the time period of this study declined by 45%.

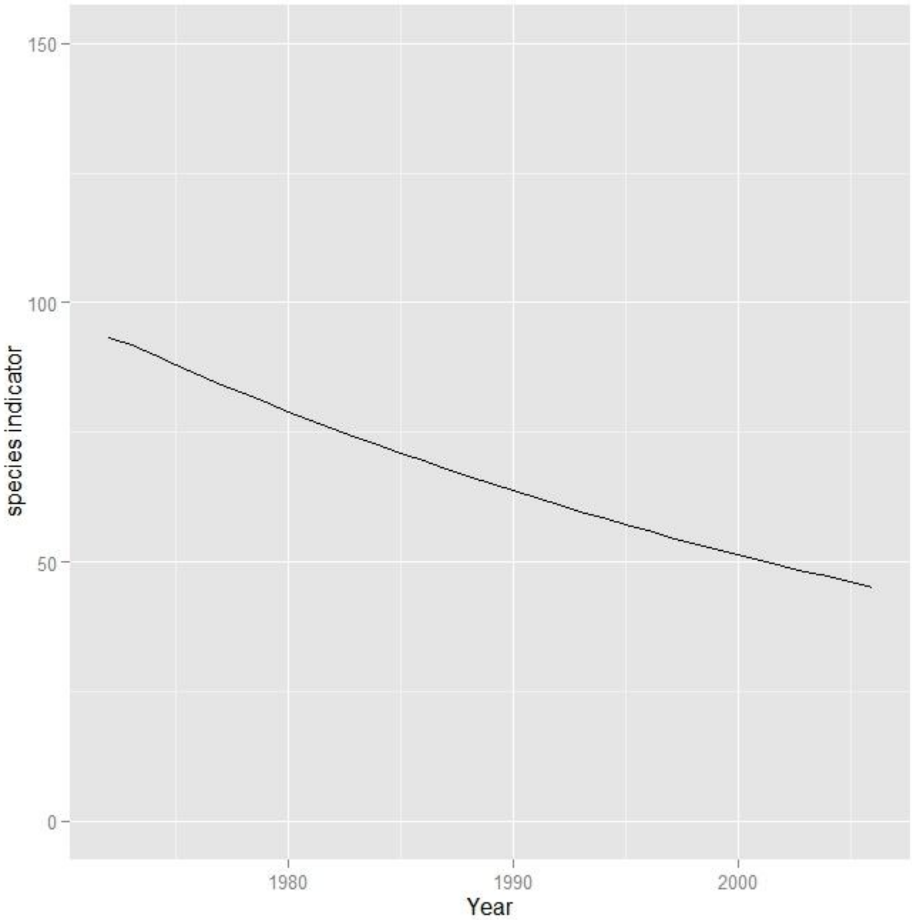


Figure 4.11.1.2.2.1: The temporal trend in the probability of observing a priority species on an average grid cell in Wales between 1972 and 2006 (we omitted years without the full complement of priority species). This figure highlights the steady decline in the trend indicator for priority species.

4.11.1.3 Discussion

4.11.1.3.1 Species trends

In this study, we estimated change in species trends across 18 taxonomic groups in Wales, finding variation in responses: 10 out of 18 taxonomic groups had a net negative trend from 1970 onwards. The loss of natural habitats is likely to be the key driver of declines, with climate change likely to ameliorate losses for some groups, *i.e.* thermophilous insects (UK National Ecosystem Assessment, 2011; Burns *et al*. 2013). We discovered widespread variation in species level trend estimates within, and between taxonomic groups. This variation highlights the variety in species responses to environmental change, *i.e.* some species may benefit from certain aspects of environmental change, whereas others may be driven to extinction. Dragonflies, damselflies, grasshoppers, crickets and moths had the greatest proportion of significantly negative trend estimates. However, further investigation of the factors underlying declines is required before using these results to target groups for conservation effort. The proportion of species with significant negative trends tended to mirror the proportion of species with significant positive trends within each taxonomic group. This may be due to certain taxonomic groups being inherently more unstable in terms of trend dynamics. Alternatively (and more likely), this is an artefact of the positive relationship between the power to detect a significant result and the number of visits from which trends were estimated.

4.11.1.3.2 Priority species indicator

The consistent downward trend in the probability of observing a priority species over the time periods of this study identifies the need for continued conservation effort for these species. Many of the species included were listed on the UK Biodiversity Action Plan List (UK BAP), so would likely have been targets for conservation effort in the past two decades. However, it should be noted that species on the BAP list that benefitted from conservation effort and are no longer be threatened may not be present in this current list of priority species. In addition, due to the various data exclusion criteria, the majority of species included in this indicator were moths. The work should be extended to cover more taxonomic groups, including some of the more well-studied groups such as other invertebrates and plants.

4.11.1.3.3 Caveats

We use opportunistic and relatively unstructured biological recording data for our analyses, much of which were collected by volunteers for documenting the distribution of species and not explicitly for measuring trends. The data were selected on the basis of availability and suitability for analysis, and therefore may not be representative of all species within the taxonomic group. For example, the stringent exclusion criteria for the analysis (*i.e.* exclusion of very rare species) may have restricted the majority of trends to the widespread generalist species. Additionally, restricting the analysis to 'well-sampled' sites could have led to trend estimates that were not representative of the whole of Wales, but were focussed on the trends in locally well-surveyed regions. This is more likely to be an issue for the taxonomic groups which have low numbers of visits included in the analysis (e.g. long-horn beetles, millipedes and centipedes). The data included in the analysis was restricted to those collated by national recording schemes and societies and published and peer reviewed within distribution atlases. Although it was not feasible to collate and review additional data that may be available from the network of Local Records Centres in Wales, these sources would be likely to provide valuable additional data for recent years. Finally, these trend estimates have not been peer reviewed by species experts, so subtle patterns in recording effort or behaviour that we are unaware of may have caused artefacts in the species trend estimates.

4.11.1.3.4 Conclusions

We have demonstrated the potential of opportunistic biological recording data collected by volunteers for measuring change in biodiversity within Wales. We provide a more taxonomically comprehensive assessment that has previously been available, offering the potential to assess the status of species providing key ecosystem functions (e.g. pollination, pest control, nutrient cycling). We found widespread variation in the trend estimates between species and taxonomic groups, and the ability to understand the drivers of this variation is vital for improving conservation effort. Identifying trends in the trait characteristics of declining species can help determine the key drivers of biodiversity change and can enable the prediction of high threat risk species. We recommend a trait-based study of species trend estimates as an ideal area for future work.

4.11.1.3.5 Future work; developing links to Glastir

In the next phase of work the application of Welsh species distributional data to GMEP objectives will be further progressed. Three main areas of work are envisaged, all of which seek to make more spatially explicit links between recorded grid cells, the GMEP 1km square sample and therefore to areas with known variation in uptake of Glastir measures over time.

- The highest priority is for downscaling species records to the 1km square resolution. This will allow species pools to be defined more precisely, albeit probabilistically, for the GMEP squares. By downscaling rare species records we will be able to estimate with greater precision the extent to which rare taxa, especially those that are the focus of Glastir measures, are likely to occur in any one square and therefore to be exposed to the potential benefits of related Glastir measures. These more precisely defined species pools will also allow MultiMOVE modelling of scheme impacts to be based on more realistic selections of rare plant species. This phase of work will also require collaborative working with the recording societies in Wales to ensure that the most accurate and contemporary data can be used.
- Having developed a priority species indicator a key question is what makes some species winners and some losers. Seeking to differentiate groups of changing taxa based on their traits is an established approach that can help define species at risk as well as estimate likely drivers of recent trends.
- Further statistical development work is also needed to explicitly model whether trends in the priority species indicator are correlated with differing levels of scheme uptake over time. This work involves major analytical and data-related challenges. Initial work will be carried out in parallel with WP3 addressing similar needs for the analysis of GMEP survey data over time. A sensible approach will be to trial statistical development on the legacy of past scheme uptake including ESA and Tir Gofal as they have applied to the GMEP. The aim will be to recalculate the priority species indicator in a way that allows spatial variation in uptake of Glastir and its impacts over time to be expressed as well as including the effects of other covariates such as climate regime and those factors linked to the definition of High Nature Value farmland such as total proportion of semi-natural habitat and habitat diversity. Hence using Fig 4.11.1.2.2.1 as the example, one would wish to additional lines estimating trends likely to coincide with differing proportional uptake of Glastir options. Expectations need to be carefully managed in light of the reductions in statistical power likely when drilling down to fewer sample squares, fewer taxa but involving a larger number of inter-correlated covariates.

4.11.2 High Nature Value farmland

Previous work (Parracchini *et al*., 2008) carried out at the European scale and within Wales looked at the concept of High Nature Value farmland and how it might be defined and applied. The GMEP team have been tasked by the Welsh Government to explore these concepts and propose new ideas, criteria and metrics that might be applied to define land of 'High Nature Value' and form an indicator to create a baseline extent and measure changes in extent and quality. We are conducting this work in consultation with a range of partners and stakeholders who are also interested in the potential value of this metric. Specifically this has included a small working group involving CEH, BTO, RSPB, NRW and the Welsh Government who met in April 2013; a RSPB workshop with a wide range of participants from across the farming and conservation section in May 2013; and a GMEP Steering Committee in June 2013 with representative from the farming community, the Welsh Government, NRW and NGOs. A wide range of views were expressed which range from this "is a metric of little value which could confuse rather than illuminate" to "a potentially useful metric to communicate overall trends in biodiversity".

Land which is of 'High Nature Value' is not easily defined; it may be a subjective and contentious exercise choosing which elements best represent 'high value'. It is important particularly for consistently measuring change to create a structure that uses objectively measured criteria.
It has been generally agreed that HNV (e.g. Andersen *et al* 2004) can be broken down into 3 types
Type 1: Farmland with a high proportion of semi-natural vegetation

Type 2: Farmland with a mosaic of habitats and/or land uses
Type 3: Farmland supporting rare species or a high proportion of European or world populations

Type 3 may overlap with types 1 and 2 but some rare species may be associated with biologically simplified agricultural areas with low habitat diversity.

The need for measures to prevent the loss of high nature value farmland is widely acknowledged (Parrachini *et al*. 2008) as part of the Habitats and Birds directives and rural Development Policy. The challenge is to identify such land based on consistently collected data, at a suitable resolution and then review if the information provides a useful addition to the reporting system for GMEP.

4.11.2.1 Progress during year 1

There have been a number of meetings with stakeholders to discuss the concept of HNV and how we might develop an indicator in the Glastir Monitoring and Evaluation Programme resulting in some decisions in scope and terminology and proposals for future work. A small working group involving CEH, BTO, RSPB and NRW was convened and agreed:

- The term HNV farmland would be used rather than HNV farming, farm type has been looked at in previous case studies (e.g. the Welsh Government, EN) but its usefulness has been questioned so the type of farming will not be included in a classification system.
- We should keep it simple – there is flexibility in the guidance we can exploit
- There were would be major benefits to objectively test out coincidence of HNV with range of Natural capital and Ecosystem Services maps within the Welsh Government and NRW. Is HNV coincident with delivery of high levels of both?
- It was important to consider extent and condition separately potentially as there may be areas which are potentially suitable for species but do not have viable populations due to size and or condition. Condition was likely to be more useful for ongoing monitoring.
- We asked stakeholders to propose criteria and datasets that might contribute to an indicator and have constructed a summary spreadsheet resulting from this consultation which links criteria to metrics and datasets (Table 4.11.2.1.1.).
- It was agreed that it would be useful to look at case study areas for HNV that the HNV topic group were familiar with e.g. East Carmarthenshire. This has not yet been done, in practical terms it is easiest to assemble relevant data, metrics and criteria nationally across Wales (including CS and GMEP 1km squares) which we have been doing and then 'cut-out' particular regions to discuss in a workshop. A follow-up workshop will be arranged in winter 2013-14

4.11.2.2 Proposal for an HNV indicator

1. BASELINE: How much and where is it at time 1?
   - We propose using existing datasets, expertise and results as proposed by topic group members to estimate the extent of HNV farmland across Wales. This will involve using external datasets additional to the GMEP monitoring such as NRW's Phase 1 and Land Cover Map as well as GMEP 1km square data to understand complex relationships between criteria.
2. IMPACT: How has HNV farmland changed?
   - Change in indicators of extent and condition across Wales by counterfactual and Glastir land where feasible (N.B. we will not use condition to define baseline as the danger is HNV could not get better but only deteriorate). GMEP data will be used to determine change as the rolling programme progresses, we will also explore the use of other techniques e.g. remote sensing combined with field survey (see above) to measure change.

Habitat criteria	Metric	Potential dataset
Mosaic of semi-natural habitats	Proportion of semi-natural habitat in 1km square	NRW Phase 1, CS 1km squares, GMEP 1km squares
Area of ancient woodland	Area of ancient woodland	NRW Priority Habitat
Area of priority habitat	Area of priority habitat	NRW phase 2 habitat layers, CS 1km squares, GMEP 1km squares
Habitat diversity/	Diversity indices (Shannon or Simpsons evenness)	NRW Phase 1, CS 1km squares, GMEP 1km squares
	Number of habitats	NRW Phase 1, CS 1km squares, GMEP 1km squares, LCM2007
	Patch size	NRW Phase 1, CS 1km squares, GMEP 1km squares, LCM2007
	Spatial configuration	NRW Phase 1, CS 1km squares, GMEP 1km squares, LCM2007
Habitat connectivity	Habitat connectivity for woodland plants	NRW Phase 1, CS 1km squares, GMEP 1km squares, NFI, LCM2007
	Habitat connectivity for wetland plants	NRW Phase 1, CS 1km squares, GMEP 1km squares, LCM2007
	habitat connectivity for butterfly e.g. Marsh fritillary	data on nectar plants from Cs and GMEP, data on nectar plants from BRC
	Habitat connectivity for honey bee health	data on nectar plants from Cs and GMEP, data on nectar plants from BRC
	habitat connectivity for red squirrel	NFI, protected zones map for red squirrel, LCM2007
	habitat connectivity for great crested newt	CS 1km squares, GMEP 1km squares
Presence of water: running	Length of streams	CS 1km squares, GMEP 1km squares
Presence of water: still	Area of standing water	CS and GMEP 1km squares,
Length of vegetated boundary	Length of vegetated boundary	CEH Linear product using LCM, LIDAR and CS data, Fused habitat map, GMEP 1km squares,
Designated areas	SSSI's	Spatial layer
Topographic diversity		5m DTM, NextMap
Species criteria		
Species data	Species richness in sample plots	Vascular plants, Bryophytes, pollinators, soil invertebrates
Species data: e.g. database of scarce/rare/declining species; breeding bird data; areas important plant / fungi areas	Species richness in 10km squares	BRC data, BTO Bird Atlas - presence-absence data,
Presence or abundance of key bird species/Presence of key bird assemblages		BTO Bird Atlas - presence-absence data and some abundance data from 2007-11; BTO/JNCC/RSPB Breeding Bird Survey - annual abundance data; GMEP Bird survey data - abundance/density
Species richness maps		
Richness map of functional diversity		
Species complementarity map		
Optimise gamma and beta plant diversity.		CS and GMEP plots

Habitat criteria	Metric	Potential dataset
Ecosystem service indicators	growth form cover (trees and shrubs, Sphagnum, grass:forb ratio),	CS and GMEP plots
	pollinator plants and sugar reward	BRC 10km data, CS and GMEP plots
	pollinator plants and sugar reward	CS and GMEP plots
	CSM indicator richness.	CS and GMEP plots
Freshwater macroinvertebrate data and associated metrics from survey in sample squares	CCI and O/E total taxa	CS and GMEP data
Other		
Management intensity	Various measures	IACS/Edina Agcensus
Area identified in Advanced Element of Glastir for enhanced habitat or species payments	Points	Welsh Government Glastir Advanced maps

Table 4.11.2.1.1 Proposed criteria for analyses of HNV farmland

4.11.2.3 Achievements in Year 1

4.11.2.3.1 Analysis of habitat diversity metrics for 1km squares

At the stakeholder meeting in July, NRW presented the work that they have already done using the phase 1 habitat data to calculate the cover of semi-natural habitat and the diversity of semi-natural habitats in a 1km square. These are two measures which may be useful to identify HNV farmland of types 1 and 2. The advantage of the phase 1 data set is that it provides a continuous cover of every 1km square in Wales, however the disadvantage is that it was last updated in 1997 and cannot be used to measure change.

The GMEP habitat data should be compatible with the phase 1 habitat data. We have used Countryside Survey data which is collected using similar methods to GMEP to test this and using the method applied by NRW re-calculated diversity and the proportion of semi-natural habitat within a 1km square for overlapping squares.

To calculate percentage cover of semi-natural habitat, each habitat class was labelled as either modified or semi-natural using criteria provided by NRW.

The diversity of semi-natural habitat per 1km square was calculated using the Shannon diversity index (H´) using the same method as NRW substituting habitats for species and 1km squares for habitats.

% semi-natural habitat [illegible]m square	Count of squares in NRW	Percentage of squares in NRW	Count of squares in CS	Percentage of squares in CS
60 - 100	4409	20	40	37
24 - 60	4550	21	39	36
12 - 24	4364	20	19	18
6 - 12	3788	17	5	16
0 - 6	4643	21	4	4

T-Value = 4.8 P-Value = 0.000

Diversity of semi-natural habitat/1km square (H´)	Count of squares in NRW dataset	% of squares in NRW dataset	Count of squares in CS dataset	% of squares in CS dataset
1.13 - 2.23	4458	20	45	42
0.75 – 1.13	4375	20	35	33
0.47 – 0.75	4066	19	14	13
0.24 – 0.47	4338	20	9	8
0-0.24	4517	21	4	4

T-Value = 5.9 P-Value = 0.000

Table 4.11.2.3.1.1

There do appear to be significant differences between the metrics depending upon which dataset is used. The CS dataset appeared to have a higher proportion of semi-natural habitat and habitat diversity. T tests comparing the samples suggested that they were significantly different. There needs to be more work on the compatibility of the methods for describing habitats. The graphs below compare the relationship between the proportion of semi-natural habitat in a 1km square and habitat diversity (Figure 4.11.2.3.1.1). A similar relationship can be seen in both datasets.

a.) *CS* *b.) NRW*

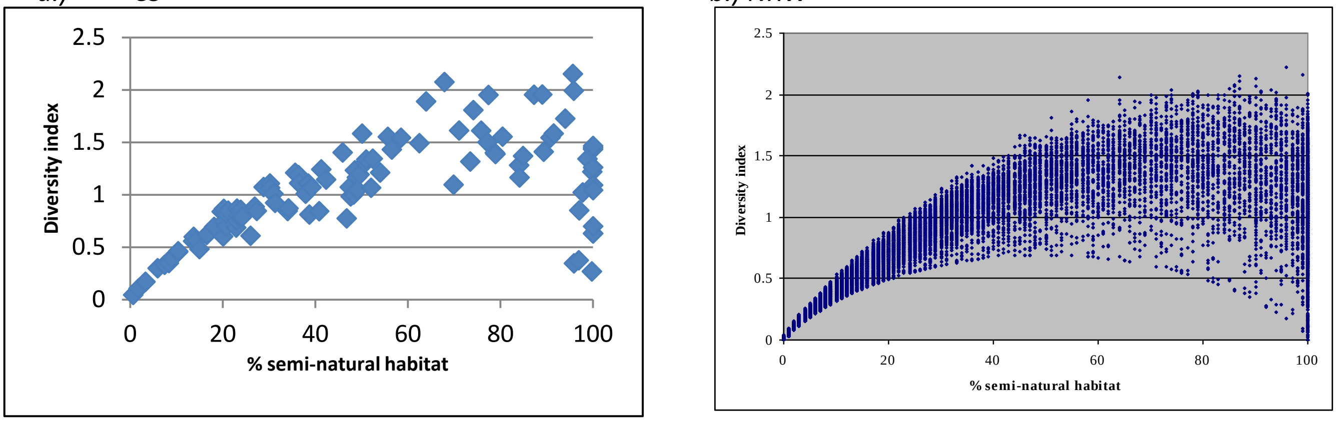


Figure 4.11.2.3.1.1 Shannon diversity index plotted against % of semi-natural habitat for a) Countryside Survey 1km squares in Wales, b) All 1km squares in Wales (NRW Phase 1 Habitat Survey)

4.11.2.4 Exploring the coincidence of HNV and Ecosystem Service Indicators

Previous work (Maskell *et al* 2013) used large scale yet fine grained monitoring data from Countryside Survey to identify a series of ecosystem service indicators and to explore interactions between them. These included; soil carbon, a cover-weighted plant trait (Specific Leaf Area (cSLA)) as a surrogate for Net Primary productivity (NPP), plant diversity, freshwater quality and diversity, bee and butterfly nectar plants as a surrogate for pollination and habitat diversity. The original analysis was carried out for GB. We have repeated that analysis for Wales only, again using Countryside Survey data but also including two additional measures; the proportion of semi-natural habitat within a square (as described above) and the length of hedgerows within a square.

Figure 4.11.2.4.1 shows the results of this analysis. Soil Carbon and cSLA *i.e.* annual net productivity occupied opposing ends of the unconstrained first ordination axis supporting the hypothesis as for GB that the principal axis along which the indicators co-vary is strongly correlated with primary productivity. This was supported by an analysis constrained by the proportion of intensive land within a square (Figure 4.11.2.4.2). This result is very interesting, some of the indicators (e.g. diversity based) are less significant, the relationships shown are the divergence of soil carbon and the NPP surrogate, with an increased length of hedgerows associated with high productivity and the proportion of semi-natural land and habitat diversity associated with low productivity and higher soil carbon (although both of these are unimodal relationships).

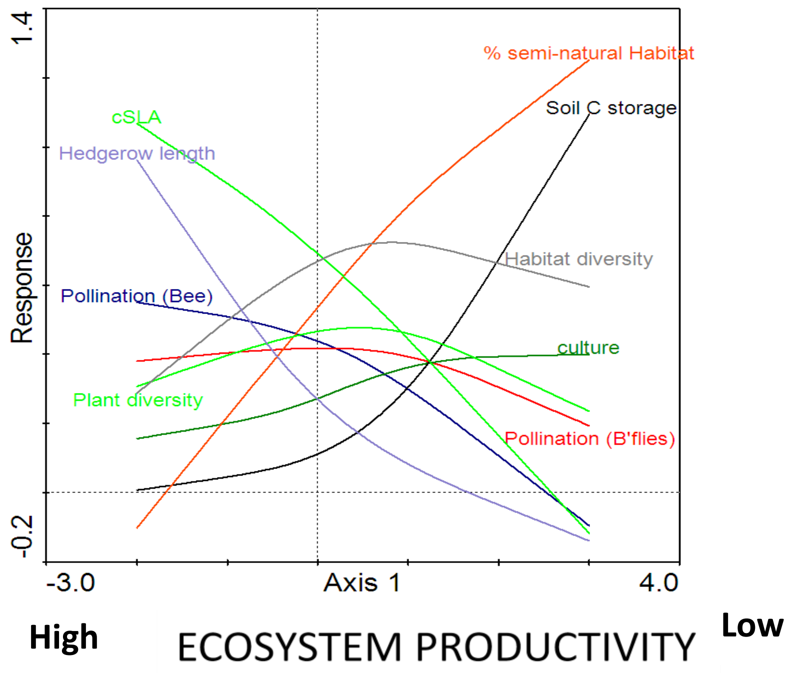


Figure 4.11.2.4.1 Projection of ecosystem service indicator response curves for Wales only derived from existing Countryside Survey data. Response curves of ecosystem service indicators are projected along the first ordination axis (fitted using Generalised Additive Models). Indicators are as follows: plant diversity (richness in a 200m^2 plot), Pollination (Bee) and Pollination (Butterflies) (richness of Bee and Butterfly nectar plants in a 200m^2 plot), soil diversity (total taxon richness of soil invertebrates from 15cm soil cores co-located with each 200m^2 vegetation plot), Soil carbon storage (Loss-On-Ignition), Freshwater diversity (freshwater macro-invertebrate diversity-CCI index), Water quality (biological measurement), cSLA (mean cover-weighted Specific Leaf Area; trait-based indicator of ANPP), Habitat diversity (Simpson's index, added as a passive variable)

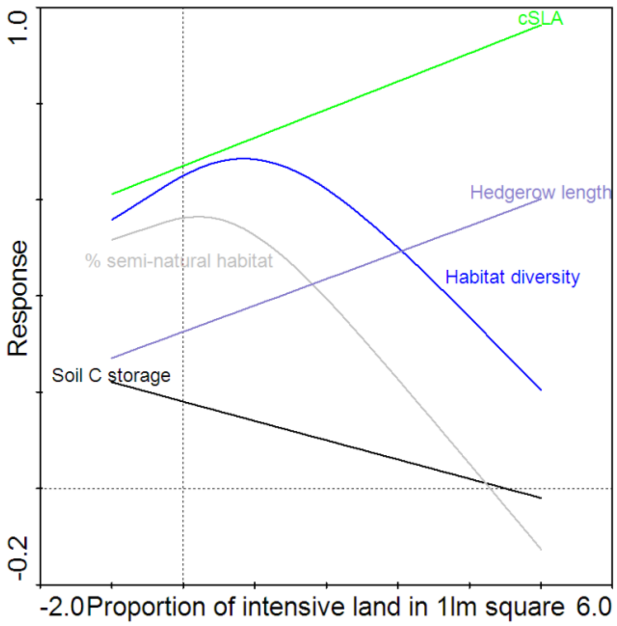


Figure 4.11.2.4.2 Response curves of mean ecosystem service indicators per 1km^2 across Wales, fitted using Generalised Additive Models to ordination axes constrained by; a.) proportion of intensive land (Arable and Improved grassland habitats) within each 1km square from CS field survey data

Figure 4.11.2.4.3 shows the CS Wales squares set in the context of the ordination space for GB. The Welsh squares appear to be distributed across the x-axis indicating that equivalent ecological variation and all parts of the underlying GB-wide productivity gradient are also to be found across Wales.

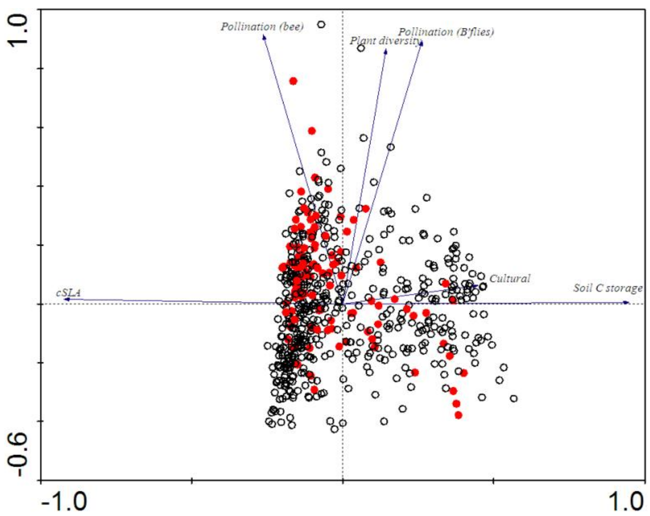


Figure 4.11.2.4.3 Multi-variate analysis (PCA) of ecosystem service indicators across 1km CS squares for GB with Welsh squares highlighted in red.

4.11.3 Biodiversity modelling: Forecasting possible benefits of Glastir on plant species occurrence in response to four management interventions

A small ensemble of statistical plant species niche models were used to simulate the impact of four Glastir prescriptions on habitat suitability for target species in two test catchments in Wales; the Conwy and Plynlimon. The objective was to test the modelling approach and its conceptual basis and to build and apply the technical apparatus needed to implement the projections. In brief the MultiMOVE model has been derived from large national datasets and defines the probability of occurrence of 1,342 higher and lower plants in Britain along seven environmental gradients namely: soil pH, % carbon, %nitrogen, soil moisture, vegetation height and three climate variables.

The MultiMOVE models (Smart *et al* 2010) were applied to scenarios of changing abiotic conditions and vegetation height based on starting values defined to be as ecologically close as possible to conditions found in the two test catchments where there is a wide range of research activities ongoing (Figure4.11.3.1) (see also Chapter 2).

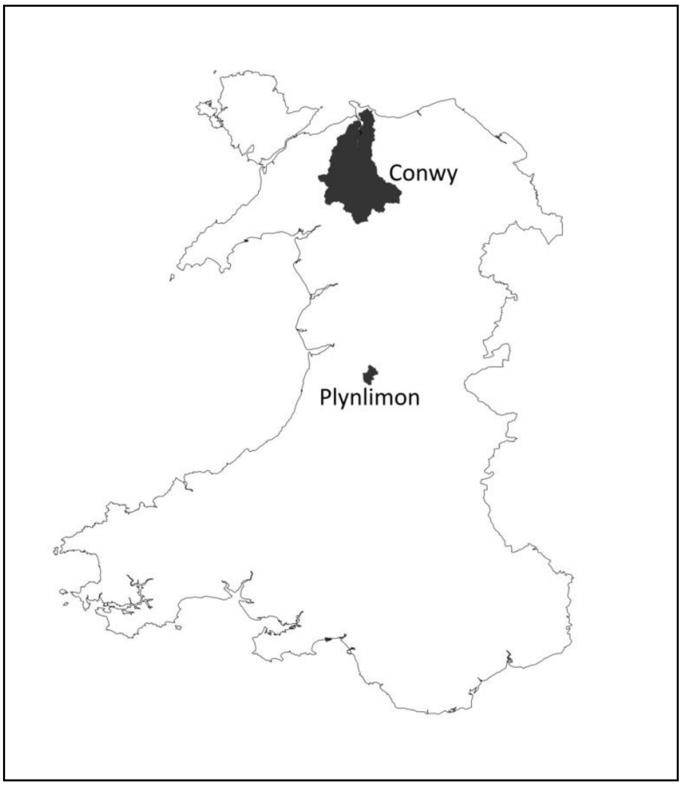


Figure 4.11.3.1 Map of Wales with Conwy and Plynlimon catchment areas shown.

A total of 21 common and rare species were selected for modelling under four different Glastir prescriptions:

- Low input grassland applied to improved grassland
- Bracken control on acid grassland and lowland heath
- Woodland expansion on improved land
- Streamside wooded buffer strips on improved land

Our original aim was also to model changes in habitat suitability in response to the Grazing Management of Open Country prescription (AWE 41A) and then to interpret modelled change in vegetation height in response to stock reduction in terms of impact on priority bird species. A literature search and discussion with BTO confirmed the complexity and species specific nature of the dynamic linkages between stocking reduction, vegetation height, plant species composition and bird populations. Consequently, whilst a model analysis is feasible, a more careful treatment of the evidence is required before applying scenarios of modelled change to different habitat starting points. A discussion of the evidence is presented in Appendix 4.4. No further results are presented here for the impact of this measure on biodiversity.

Species were selected for modelling the impact of the other four Glastir measures based on the following criteria:

1. Dominant species typical of either the baseline starting assemblage or the target assemblage.
2. Indicator species characteristic of the baseline or target assemblage: Species that are desirable components of the target vegetation would be expected to increase in habitat suitability. Less desirable species more typical of the baseline vegetation were expected to decline in habitat suitability assuming the management intervention resulted in a planned reduction in the favourability of abiotic conditions.

Simulation of the ecological impact of each measure required quantifying the likely magnitude of change expected in soil conditions and vegetation height (the model input data for MultiMOVE) as a result of applying the measure to baseline conditions. We adopted an evidence-based approach. Literature searches were used to locate experimental and survey-based evidence of changes in MultiMOVE input variables. To contribute to the evidence required to build a scenario of change in conditions, three criteria had to be satisfied; a) changes in conditions had been measured in terms of variables that were inputs to MultiMOVE, b) change had been driven by treatments that corresponded with the Glastir measure, c) change had been driven from a soil and vegetation starting point comparable to the soil and vegetation starting points modelled in each test catchment. These conditions were strict but ensured that changing soil conditions were modelled with maximum realism with respect to each test catchment. A comprehensive literature search resulted in selection of a number of key studies from which scenarios were built.

4.11.3.1 Results and conclusions

Full results and a summary tabulation of modelled change in habitat suitability scores for each species and measure are presented in full in Chapter 2 and Appendix 2.3. Two examples outputs are shown in Figure 4.11.3.1.1

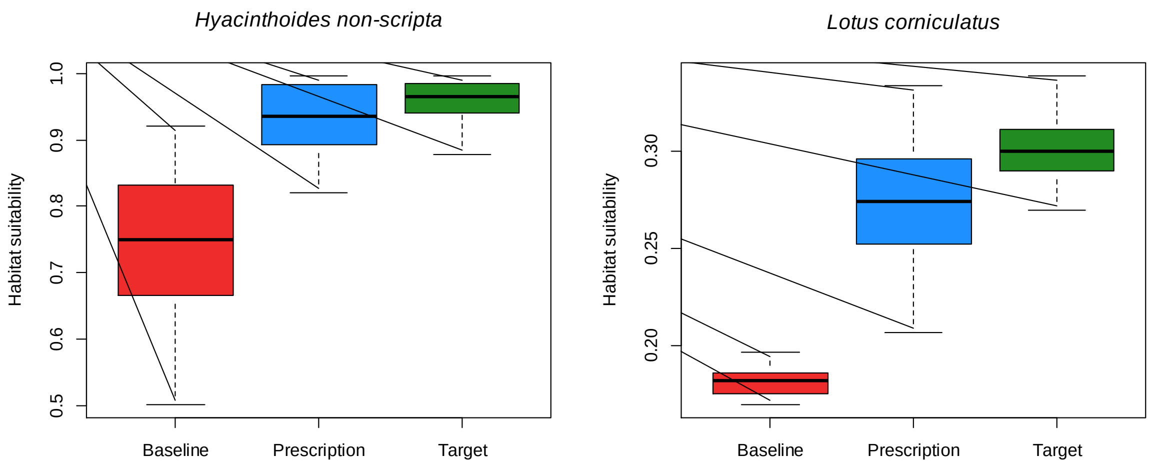


Figure 4.11.3.1.1: Modelled habitat suitability scores (bigger number equals more suitable habitat) for two indicator species; a) H.non-scripta (Bluebell) in response to broadleaved woodland expansion into improved grassland in the Conwy Valley over 23 years and Lotus corniculatus (Bird's-foot Trefoil) in response to zero nitrogen inputs on Improved grassland in the Conwy Valley over 12 years, this

being the length of time for which robust evidence of abiotic change could be drawn from literature sources. The red box show the range (median plus inter quartile range) in habitat suitability for each species as a function of conditions associated with improved grassland typical of the region while the green boxes represent a target vegetation type against which projected change can be evaluated; established broad leaved woodland and unimproved neutral grassland respectively where each was based on conditions typical of the region. The plots show substantial projected increases in habitat suitability for both species in response to condition changes associated with each Glastir measure.

Of the total number of species and measure-specific projections run for common species, 30 (75%) were consistent with the expected impact of Glastir however these changes were projected over relatively long periods. Thus after ten years of simulated Bracken control, fine-leaved forage grasses increased in habitat suitability but *Viola rivinana*, the food plant for Fritillary butterflies declined. After 12 years the projected impact of the low input grassland measure was to increase habitat suitability for a range of neutral unimproved meadow indicators whilst after 23 years of succession in response to Woodland expansion and Streamside planted buffer strips, native trees, Bramble and Bluebell all increased substantially in terms of habitat suitability reaching the target habitat suitability defined from applying the models to reference woodlands in the same land classes as those in the test catchments . Common sense suggests that less change is likely over shorter periods. These projections, driven by an evidence-based literature review, provide useful guidance on how much change in ecological conditions might be expected in the observed GMEP monitoring data over time. Driving the models by evidence-based scenarios of changing soil condition and vegetation height offers a usefully transparent and robust link back to the experimental literature. Increasing and extending the power of the approach simply requires inclusion and analysis of more studies.

The application of MultiMOVE involved developing and testing the generic steps required to apply the models to a much wider range of Glastir measures. Workflows can now be easily repeated for additional measures in other test catchments and to derive projections for the GMEP sample squares. We believe that the principle of defining local target conditions by which to judge projected change is a sensible and helpful step. Additional work is now needed to explore options for more precise definition of target conditions tailored to each focal species.

The most important conclusion from this analysis is that given a long term commitment to management intervention, sought after changes in the suitability of ecological conditions for local target species appear to be achievable at least for the measures explored here.

5. Climate Change and Diffuse Pollution Mitigation

Chadwick, D.[1], Anthony, S.[2]., Taylor, R.[1], Cross, P.[1], Abdalla[3], M., Smith, P[3], Malcolm, H[4]. and Moxley, J[4].
Bangor University[1], ADAS[2], Aberdeen Unisersity[3], CEH Edinburgh[4]

Agriculture is a significant source of diffuse water pollution and greenhouse gas emissions in Wales; whilst some agricultural practices are also responsible for losses and gains of soil carbon. The Welsh Government has set national targets to improve water quality and reduce greenhouse gas emissions, and the agricultural sector is expected to contribute to the meeting of these targets. In consequence, the Glastir scheme has been developed with sufficient flexibility to target priority themes (such as soil carbon) in a spatial context, and introduce measures on farms to e.g. enhance carbon sequestration, reduce greenhouse gas emissions and diffuse water pollution from the agricultural sector. Welsh Government has prioritised funding for interventions focussed on climate change mitigation and diffuse water pollution for Years 1 and 2 of the scheme.

As a first step to determine the potential impacts of Glastir on diffuse water pollution, greenhouse gas emissions and carbon sequestration, Welsh Government have tasked the Glastir Monitoring and Evaluation Programme to assess the potential impact of Glastir interventions on these priority areas through modelling, a Farmer Practice Survey to identify actual changes on the ground, and additional work to identify the wider benefits of the Glastir Efficiency Grants.

5.1 Overall achievements in Year 1

- Assessment of the greenhouse gas sources and carbon sequestration, which each of the modelling tools has the capacity to estimate (e.g. soil methane, enteric methane, embedded emissions)
- Mapping of four modelling approaches to Glastir intervention measures, by the Expert Panel
- Application of the Bangor footprinting life cycle approach on 16 model farms for four Glastir intervention measures to quantify changes in greenhouse gas emissions from on-farm sources, as well as embedded emissions associated with feed and fertiliser production. Estimates of the potential outcome of 4 intervention measures were a 0-24% decrease in carbon footprint.
- Population of the ADAS modelling tool at the national scale for five Glastir interventions to assess potential changes in gaseous emissions (nitrous oxide, methane) and diffuse water pollution (nitrogen, phosphorus and sediment) (see Chapter 2)
- Acquisition of datasets for future spatial modelling using the ECOSSE model
- Developed a draft protocol for the repeat Wales Farm Practice Survey, including the proposed stratification strategy, for discussion with funders and the wider programme project team
- Planned the approach for assessing the impact of Glastir Efficiency grants on i) the carbon footprint of farms which have made use of them, and ii) the wider (off-farm) benefits to the rural economy

5.2 Greenhouse gas emissions from Agricultural Land Use in Wales

In 2010, Agriculture contributed 12% of CO_2e emissions in Wales, with CH_4 and N_2O representing 63.5% and 88.2% of total Welsh emissions of these two gases, respectively. In total, 5,665kt CO_2e were emitted by agriculture in Wales in 2010; comprising 44% as CH_4 (2,469kt CO_2e), 48% as N_2O (2,644kt CO_2e), and the remainder associated with transport (AEA, 2012).

Enteric fermentation contributed 90% (2,219 ktCO_2e) of total agricultural CH_4 in Wales, manure management representing the remaining 10%. Dairy and beef cattle were responsible for 63%, and sheep 35% of these CH_4 emissions. Agriculture is the dominant source of N_2O in Wales, with >95% (2,502 ktCO_2e) of this arising from agricultural soils. The key sources of N_2O from agricultural soils are: fertiliser nitrogen, grazing returns and manure applications. Table 5.2.1 illustrates the significance of indirect N_2O emissions, especially those associated with nitrate leaching.

N_2O (kt CO_2e)	**Direct**	**Indirect**	
		Leaching	N deposition
Fertiliser	419	279	37
Grazing returns	880	329	87
Manure application	189	143	37
Crop residues	34		
Biological fixation	-		
Improved grassland	28		
Histosols	12		
Sewage sludge	16	12	3.1
Total	1578	763	164.1

Table 5.2.1 Sources of N_2O from agricultural soils in Wales (2010)

5.2.1 National trends

Agricultural greenhouse gas emissions

Emissions from agriculture have declined by 15% from 1990-2010 (Figure 5.2.1.1) in line with the decrease in sheep and cattle numbers, although CH_4 emissions increased by almost 2% between 2009 and 2010, due to an increase in total cattle numbers.

Nitrous oxide emissions are largely driven by fertiliser nitrogen use, manure applications and grazing returns to soils. Between 1990 and 2010, N_2O emissions have decreased by 25% due to a general decline in fertiliser use and livestock numbers. Between 2009 and 2010, emissions of N_2O also increased (by 5.3%) due to a small increase in fertiliser nitrogen use following many years of decline.

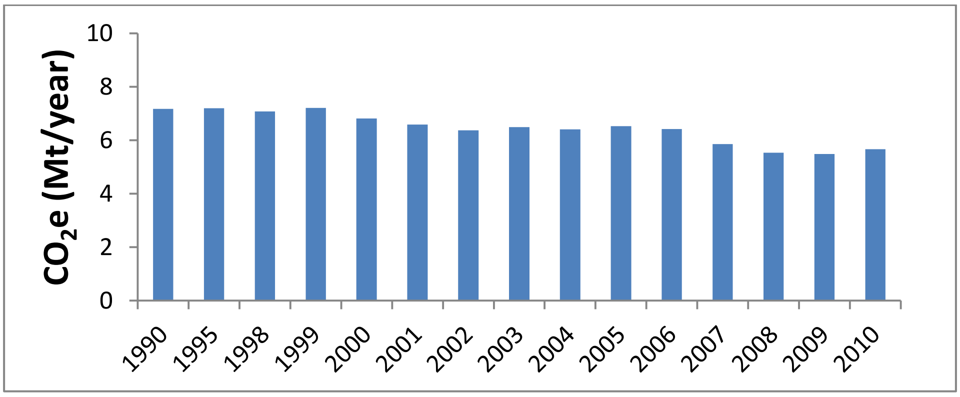


Figure 5.2.1.1 Trends in GHG emissions from agriculture in Wales

5.2.2 Land Use, Land Use Change and Forestry

Whilst Wales is a small net sink of greenhouse gases from LULUCF activities, Figure 5.2.2.1 shows that between 1995 and 2000 Wales was a small source (using the 2010 inventory). There are small differences in net emissions between the 2010 and 2011 inventory, due to the inclusion of new activity data and other minor revisions. 2011 data suggest that Wales is a small net source of emissions from the LULUCF sector again. Croplands are the major net contributor to the LULUCF sector in Wales, as the size of the Forest Land sink has diminished in recent years.

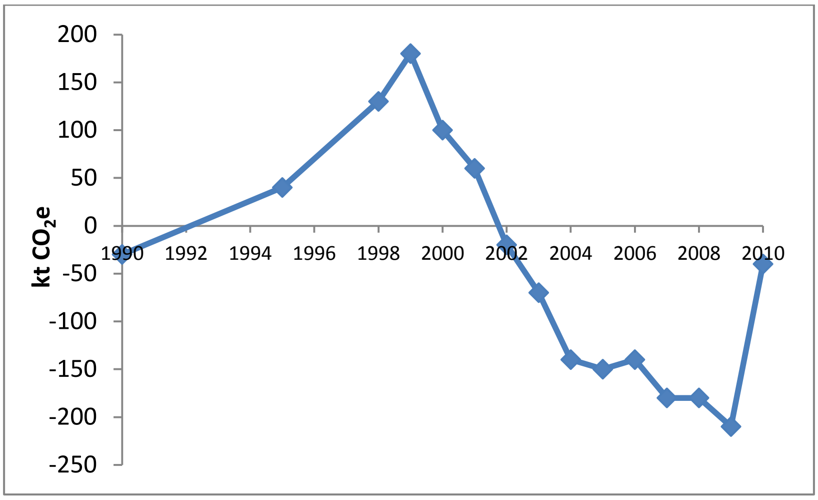


Figure 5.2.2.1 Changes in net CO2 emissions/removals 1990-2010 in Wales.

5.3 Assessment of Glastir Measures on GHG emissions

5.3.1 Greenhouse gas and soil carbon models

We have taken an 'ensemble' approach to the assessment of GHG emissions and soil carbon stocks, whilst the ADAS modelling is the only approach used to assess the impacts of Glastir measures on diffuse water pollutants and greenhouse gas emissions. What will become clear from the following discussion is that no one model can describe the entire GHG/soil C balance associated with changes in farming practices resulting from adopting Glastir measures: a number of models may be required to adequately account for changes in GHG balances/soil C at the field, farm and landscape scales. The Bangor Carbon Footprinting Tool also assesses impacts of management changes on upstream 'embedded' greenhouse gas emissions associated with e.g. feed and fertiliser production.

5.3.1.1 Modelling approaches

In this work package, four modelling approaches are being evaluated for their ability to account for changes in GHG emissions and soil C stocks as the result of introduction of potential Glastir measures. These approaches span the spectrum from highly mechanistic modelling to the simple Tier 1 (IPCC) approach. The four models/tools are; ECOSSE (Smith *et al*., 2010), ADAS modelling tool (Anthony *et al*., 2012), LULUCF (Heath *et al*., 2013) and the Bangor Carbon Footprinting Tool (Taylor *et al*., 2010), which are described briefly below.

5.3.1.1.1 ECOSSE

The ECOSSE (Estimating Carbon in Organic Soils - Sequestration and Emissions) model was developed to simulate SOC in highly organic soils from concepts originally derived for mineral soils in the RothC and SUNDIAL models. ECOSSE contains additional descriptions of a number of biogeochemical processes in mineral soils, including simulation of anaerobic processes in organic soils (Smith *et al*. 2007, 2010). It uses a pool type approach, and all of the major processes of C and N turnover in the soil are included and described using simple equations driven by readily available input variables. It can be used to carry out site-specific simulations with detailed input data, or national-scale simulations using the limited data typically available at larger scales. Data describing SOC, soil water, plant inputs, nutrient applications and timing of management operations are used to drive the model. In the case of missing information, it can still provide accurate simulations of GHGs (N_2O associated with nitrification and denitrification, CO_2 corresponds to heterotrophic respiration and CH_4 through a balance between methanogenesis and methanotrophy) and changes in soil organic carbon stock. It can be used for both organic and mineral soils, providing accurate values of net change to soil C and N in response to changes in land use and climate. This model calculates outputs for each soil layer for each time step. Thus, it may be used to inform GHG inventories at the field and national scale and assess mitigation options and provide information for policy decisions.

ECOSSE model outputs include: soil methane, soil CO_2 (heterotrophic respiration), soil N_2O (direct), soil carbon stocks, above ground carbon stocks

Recent publications on use of ECOSSE include:

- Bell *et al*., 2012. Simulation of soil nitrogen, nitrous oxide emissions and mitigation scenarios at 3 European cropland sites using the ECOSSE model.
- Abdalla *et al*., 2013. Simulation of ecosystem respiration (Reco) and attribution analysis on European peatland sites using the ECOSSE model.

5.3.1.1.2 ADAS model

In the ADAS model, mitigation impact is quantified using the Wales Diffuse Pollutant Emissions Modelling Framework developed under the previous project, 'Eco Systems Lot 3' (Anthony *et al*., 2012). In this framework present-day pollutant emissions are first calculated by application of a range of empirical and process based models including PSYCHIC (Davison *et al*., 2008) for phosphorus and sediment, and N-CYCLE, NITCAT and MANNER (Scholefield *et al*., 1991; Lord, 1992; Chambers *et al*., 1999) for nitrate, and IPCC tier one and two for nitrous oxide and methane (Baggott *et al*., 2006). Each model is modified to provide an explicit source apportionment of emissions by source, area and pathway for representative farm system types across Wales. The impact of a mitigation method is then calculated as a percentage reduction against emissions from targeted coordinates. The reductions may be trivially calculated if the mitigation option maps directly to a modelled pollutant source (e.g. a reduction in fertiliser nitrogen) or are based on a synthesis of experimental literature and further computer modelling for representative scenarios. The impact of a mitigation method depends on the relative contribution of the targeted coordinates to total pollutant emissions, and the extent to which a mitigation method is already widely practiced.

ADAS Model outputs include: ***gases*** - enteric methane, manure methane, direct soil N_2O, N_2O associated with nitrate leaching (indirect N_2O), CO_2 from energy use; ***diffuse water pollution*** – nitrogen, phosphorus, sediment

The ADAS Modelling framework was used in a previous Welsh Government funded project to assess the contribution of previous Welsh agri-environment schemes to the maintenance and improvement of soil and water quality, and to the mitigation of climate change (Anthony *et al*., 2012)

5.3.1.1.3 LULUCF

The IPCC LULUCF reporting model can use three Tiers of reporting of varying complexity to assess emission from the Land Use, Land Use Change and Forestry sector. Emissions of soil- CO_2, CH_4 and N_2O from this sector are included, but it does not include emissions allocated to the Agriculture sector. It includes emissions due to changes in above and below ground biomass, soil and dead organic matter. Tier 1 and 2 reporting are used for most activities. Tier 1 reporting uses national (UK) level activity data from censuses and surveys and default emission factors given in the IPCC Guidance. Tier 2 reporting uses higher resolution activity data (devolved administration or regional level) and UK-specific emissions factors where available. Tier 3 reporting uses modelling to assess emissions and is only currently used for the emissions from LULUCF activity related to Forestry. To date the CEH C-Flow model has been used for this, but Forest Research's CARBINE model will be used in the future. While LULUCF reporting captures land use change and has the potential to capture emissions from land management activity, the UK has currently only a elected to report on a limited number of land management interventions, namely liming of grassland and cropland, emissions from wildfires and emissions from peat extraction. A Defra funded project, SP1113, is currently working on capturing emissions from land management activities on grassland and cropland.

LULUCF outputs include: soil CO_2, soil N_2O (direct) and soil CH_4 – all from land use change and forestry. Above- and below-ground carbon stocks

LULUCF is used to quantify greenhouse gas emissions and carbon stocks from the LULUCF and the Forestry sector for UNFCCC submissions.

5.3.1.1.4 Bangor University Carbon Footprinting tool

The Bangor CF takes real farm data on all inputs, land management practices (and history for Land Use Change) and monthly stock diary data to generate annual C footprints that are PAS 2050 compliant (unless soil and biomass C sequestration effects are included). It adopts Tier 1 emission factors for most N_2O and CH_4 emissions (enteric fermentation based on animal category numbers x average EFs; soil emission factors; manure storage by type *etc*…). But it includes a simplified Tier 2 estimate of soil C accumulation under grassland, and accounts for on-going C sequestration in tree biomass. Monthly stocking diary enables more accurate estimation of annual enteric fermentation (x animal numbers) and manure management (N excretion and CH_4 EFs). It has a Life Cycle Analysis approach to it, and boundaries can include embedded GHG emissions associated with feed and fertiliser production and transportation to the farm.

The Bangor Carbon Footprinting Tool outputs include: soil direct N_2O, indirect N_2O associated with nitrate leaching and N deposition, enteric CH_4, manure CH_4, CO_2 associated with electricity and energy use, embedded greenhouse gas emissions associated with feed and fertiliser production, agricultural productivity. Above and below ground carbon stocks are also included but were not implemented in this GMEP application.

The Bangor Carbon Footprinting Tool has been used previously in e.g. Taylor *et al*. (2010).

Table 5.3.1.1.1.4 summarises the sources of nitrous oxide and methane emissions (as well as soil C stocks) which each model/tool is able to predict. Clearly, some tools are capable of modelling different sources of greenhouse gases and carbon stocks. For example, of the four models/tool, only ECOSSE models CH_4 fluxes from agricultural soil, although it does not include ruminant or manure CH_4 emissions; whilst the LULUCF model quantifies soil CH_4 losses due to land use change and from forest soils; and the Bangor Carbon Footprinting Tool is the only model which includes upstream 'embedded' GHG emissions, e.g. GHG emissions associated with fertilizer and feed production. The latter may be important, should WG wish to demonstrate the wider benefits of Glastir options (*i.e.* beyond Wales) following reductions in e.g. fertiliser use (and hence production requirements). Also, its LCA approach can account for potential knock-on effects should a knock-on effect of a Glastir measure (current or future) result in farmers reducing production of home grown forages and feeds for livestock but retain current stocking through importing of feedstuffs (*i.e.* displaced greenhouse gas emissions from more feed production).

IPCC Tier level	Methane	Nitrous oxide	Carbon Dioxide	Carbon stocks
Tier 1 (some Tier 2)	**Bangor Carbon Footprinting Tool**			
	Ruminant and manure	Direct and indirect + embedded	CO_2 energy, incl. embedded losses	Soil and vegetation[1]
Tier 1 (some Tier 2)	**ADAS Tool**			
	Ruminant and manure	Direct and indirect	CO_2 energy	
Tier 1	**LULUCF and Forestry**			
	Soil	Direct	Soil respiration	Soil and vegetation
Tier2/Tier 3	**ECOSSE**			
	Soil	Direct and indirect	Soil respiration	Soil and vegetation

Table 5.3.1.1.1.4 Sources of GHG emissions and soil Carbon stocks predicted by the different modelling tools. [1] Note Bangor Carbon Footprinting Tool soil and vegetation stocks were not implemented in this GMEP application.

5.3.2 Applicability of the models for Glastir measures

The results of scenarios applications regarding the potential impacts of Glastir interventions for diffuse water pollution and greenhouse gas modelling with the ADAS model is reported in Chapter 2 to facilitate evaluation with modelling work for biodiversity using the MultiMOVE model and water flow and quality using the LUCI model. This section of the report deals solely with the three models focussed exclusively on greenhouse gas emissions and carbon stocks.

Glastir measures are being introduced to increase biodiversity, increase woodland area, control livestock numbers (stocking rates), and reduce nutrient inputs (Welsh Government, 2012). With the focus of this work package on greenhouse gas emissions and carbon stocks, an initial activity was a simple assessment of which models are capable of reflecting the effects of Glastir measures on these parameters. The expert model users populated a model-measures matrix, where the applicability of each model to estimate impacts was mapped to each Glastir measure. The list of 105 Glastir measures included 45 of those listed in the Glastir Advanced Target Checker for 'Carbon Soils'.

Whilst this 'mapping' exercise is still being completed, it has demonstrated that, depending on interpretation of the changes in on-farm management practices, there are groups of Glastir measures which are can be modelled by all of the tools (albeit delivering information on different sources of emissions and carbon stores – as discussed earlier). But there also appear to be groups of Glastir measures which cannot be modelled by any of the tools. Further exploration of the reasons why this is the case is required. Some of this uncertainty is due to the current lack of information on the prescriptive management practices associated with the measures, that all the tools require as inputs.

5.3.2.1 Initial assessments of Glastir measures on greenhouse gas emissions and carbon stocks

Initial assessments of Glastir measures on greenhouse gas emissions and carbon stocks are limited to the national ADAS modelling, reported in Chapter 2, and the farm-scale based assessment with the Bangor Carbon Footprinting Tool. (ECOSSE modelling is planned for Year 2 – a summary of the approach is provided in section 5.6); whilst the CEH LULUCF assessments await detailed land area data for the degree of uptake of individual Glastir measures, which will also be reported in Year 2).

5.4 Bangor Carbon Footprinting

5.4.1 Farms

To explore baseline greenhouse gas emissions and carbon storage from Welsh farms, we selected a subset of farms from a database of Welsh farms used in previous carbon footprinting studies at Bangor University. Farms were selected to represent a number of farming typologies representative of those found in Wales (in terms of size, altitude, stocking rates *etc*). Some of these farms had been in previous Welsh agri-environment schemes. Table 5.4.1.1 summarises the characteristics of these farms.

Modelling of Glastir measures was conducted on a subset of the farms in Table 5.4.1.1.

					Farm level use (kg)				Sheep numbers		Beef numbers		Dairy numbers	
Farm Type[1]	Previous Scheme[2]	area (ha)	peat (ha)	Altitude (m asl)	N	P	K	Lime	Summer	Winter	Summer	Winter	Summer	Winter
Beef														
7	OR	96	10	290	0	0	0	8000	0	0	151	152	0	0
32	TC	140	0	220	10682	2350	1270	10836	678	410	266	232	0	0
38	TG	90	0	70	5520	1104	1380	92000	329	328	78	36	0	0
53	TC	279	64	240	31140	7110	9810	210000	961	848	465	461	0	0
62	TG	460	168	350	11575	10050	3150	200000	3630	1928	153	153	0	0
Dairy														
20	TC	182	1	100	34354	0	3229	50177	0	0	0	0	371	336
23	TG	188	0	125	13296	840	840	25000	0	0	0	0	528	582
30	TC	70	42	266	5098	85	284	7800	500	274	0	0	123	126
56	NS	340	0	50	33037	9952	11988	94680	0	0	0	0	413	472
Mixed														
19	TC	214	0	175	18500	1500	14000	100000			248	246	286	311
34	NS	108	0	60	8599	2824	3183	1489	390	226	46	51	64	70
51	TG	158	0	215	0	0	0	60000	1025	410	0	0	213	177
Sheep														
43	NS	39	10	300	0	0	0	0	230	0	0	0	0	0
54	TG	143	68	100	2764	1053	1448	0	1401	804	0	0	0	0
61	TG	69	0	60	0	0	0	0	424	483	0	0	0	0
64	TG	117	40	310	500	250	250	0	254	123	0	0	0	0

[1] Farm type definition based on percentage of farm income from livestock categories. [2]TC = Tir Cynnal, TG = Tir Gofal, NS = no scheme, OR = organic.

Table 5.4.1.1 Key characteristics of the farms used in the Bangor Carbon Footprint Modelling

5.4.2 Glastir measures and assumptions

The Glastir measures which were assessed were the same as those used agreed by the steering group to be used in the ADAS modelling, *i.e.* Retain winter stubbles (AWE Option No. 28), Woodland margin extension (AWE Option No. 24), Grazing Management of Open Country (AWE Option No. 41A), Grazed Permanent Pasture – No Inputs (AWE Option No. 15), Create New Streamside Corridor – Both Sides / Tree Planting (AWE Option 9B). The assumptions used in developing the model runs were the same as those adopted for the ADAS model runs (see section 2.2). Change in soil and vegetation carbon stocks were not implemented in this application. A brief description of each measure is summarised below:

Grazed Permanent Pasture – No Inputs, requires that no manufactured or organic fertiliser nitrogen is applied to permanent grazed grassland. Grassland is maintained using grazing stock to remove the entire year's grass growth (with no supplementary feeding of livestock). This requires a reduction in nitrogen fertiliser application to permanent grass, and a reduction in cattle and sheep stocking rate in proportion to reduction in effective forage production. Thus, CH_4 and N_2O emissions would be expected to be reduced accordingly.

The modelling assumed a reduction of N inputs to zero for selected areas (marginal land parcels) adding up to 1/3 of grassland or 18ha of improved /semi-improved grassland, according to Welsh Government farm entry statistics. N inputs were adjusted relative to the proportion of the farm impacted, and stock numbers (% across all year) reduced relative to the proportion of farm impacted. The assumption that fertiliser reductions occurred on only one-third of the permanent grass area is different to that used by the ADAS model, and is a little closer to reality. These stock changes were based on previous data on farms with/without fertiliser use, e.g. for beef this modification would be from a stocking rate of 1.4 LU on fertilised grass to 1.1 LU on non-fertilised grass. This impacts on direct, indirect and manure emissions. Feed, feed delivery, bedding, bedding delivery, pharmaceuticals, plastics *etc.* were also adjusted according to reductions in stock numbers.

Grazing Management of Open Country aims at reducing stock numbers on farms stocked to their forage carrying capacity (based on forage production) to levels conducive with maintenance and restoration of habitat quality, and would reduce livestock numbers (and hence reduce CH_4 emissions from ruminant and manure sources, as well as N_2O associated with N in excreta and less fertiliser N production and use).

Specific modelling reduced stock levels to 'sustainable' levels defined by the Welsh Government. This meant reducing N use of zero for improved grassland and adjusting stocking rates accordingly (using approach outlined above). This effects direct, indirect and manure emissions – with reduced requirements for feed, bedding, pharmaceuticals, plastics *etc*.

Woodland extension is aimed at existing grassland and arable land, with often the existing fence between agricultural land and woodland being replaced 6m into the field. This results in reduced nutrient (N and P) input to the field (and should result in reduced soil N_2O emissions, and greenhouse gas emissions associated with feed and fertiliser manufacturing), and an assumed proportional reduction in the number of stock that can be carried (reduced enteric and manure CH_4 emissions). In terms of sources of greenhouse gas emissions, less fertiliser nitrogen would be required and fewer stock carried.

This measure requires farms with woodland bordering grassland or arable land. This was not the case for many of the farms selected for this modelling assessment. For those that did, affected areas were calculated, and reductions in stock numbers and associated fertiliser, feed, bedding, pharmaceuticals, plastics calculated.

Create New Streamside Corridor requires the fencing of an average area of 7 square metres per 1 metre length of watercourse (shared between both sides of the water course, hence an average buffer strip width of 3.5 m). The area must be fenced and native trees planted. The primary aim of this measure is to intercept particulates and enhance infiltration of pollutants in surface runoff. But the reduction in the agricultural land area will results in reduced cattle and sheep stocking rates (in proportion to reduction in effective forage production), and a reduction in the quantity of manufactured fertiliser nitrogen applied. Hence CH_4 and N_2O emissions would be expected to be reduced accordingly. There would also be prevention of direct excretion by animals using the watercourse for drinking water or cooling, and a reduction in bank-side erosion. This measure requires farms with streams bordering grassland or arable land. This was not the case for many of the farms selected for this modelling assessment. For those that did, affected areas were calculated, and reductions in stock numbers and associated fertiliser, feed, bedding, pharmaceuticals, plastics *etc.* calculated.

Retention of winter stubbles is primarily aimed at reducing the mobilisation of particulate pollutants due to protection of soil from raindrop impact, and some reduction in nitrate leaching associated with reduced mineralisation from later soil disturbance (ploughing) and uptake of N by weed species/volunteer grasses. However, after consideration of the modification in land, livestock and input management changes involved with this measure, it was clear that there was insufficient management change which the Bangor Carbon Footprinting Tool could model.

5.5 Results

5.5.1 Baseline emissions

Baseline greenhouse gas emissions from the different sources, and carbon sequestration for the modelled farms are summarised in Table 5.5.1.1 The data show that enteric methane emissions are the main source of emissions, representing up 10-67% of the total farm footprint. Methane emissions from manure stores contribute up to 10% of the total carbon footprint. Of the direct soil emissions, fertiliser N applications and manure applications contribute *ca.* 5-15% of the total farm footprint, with managed livestock manure and excreta contributing a similar proportion of the farm footprint. As has been noted previously (Anthony *et al*., 2012), embedded ‘upstream’ greenhouse gas emissions associated with fertiliser and feed production, up to 10% and 20%, of the total farm footprint, respectively – although these contributions are highly variable depending on the level of intensity of production. Embedded emissions associated with bought in bedding material was typically low, <1% of the total farm footprint. Emissions associated with bought-in stock were typically <5% of the total footprint, but in one beef farm (No 62), represented *ca.* 40% of the total farm footprint.

			Embedded GHG emissions (upstream)											
Farm ID		Total Farm C footprint (emission)	fertiliser manuf.	Feed Concent.	Bedding	Bought in stock	Livestock manure and excreta	Direct N_2O – N fert.	Direct N_2O crop resid	Indirect soils N_2O	Enteric methane	Manure methane	LUC	Total C seq
Beef														
7	OR	418983	0	6320	1368	0	61001	0	0	23724	281037	9190	0	80589
32	TC	992016	73397	51583	1163	19999	163800	50681	1232	67470	494809	17520	0	412123
38	TG	1810291	35888	17443	1259	1337323	65659	25676	341	27428	156669	4751	1915	140780
53	TC	2345931	203925	192022	5434	5258	251981	144845	7683	145726	1055708	33222	0	204105
62	TG	2658992	89666	317	0	1132134	236037	53840	7397	127477	650526	18072	114848	434125
Dairy														
20	TC	2332422	221285	523429	3255	47903	204967	159794	0	104522	728574	138005	0	437043
23	TG	2188313	86633	201418	5654	0	278217	61845	826	101741	1097842	206120	0	192830
30	TC	805478	32588	182841	922	0	96512	23711	0	48212	313835	50489	0	124846
56	NS	2327227	239950	309086	4707	18925	167269	153668	20410	115921	879758	167342	0	225106
Mixed														
19	TC	2261067	125020	202240	0	0	267486	86051	1392	99570	1072042	126598	0	136381
34	NS	634268	62872	9067	4543	31518	80416	39999	2167	37309	289321	31995	0	118630
51	TG	1272893	0	228784	7466	14294	170132	0	2746	64902	539976	80867	0	152699
Sheep														
43	NS	61543	0	17867	0	711	7294	0	0	4205	28509	417	0	40834
54	TG	335975	21104	16634	472	10964	58935	12855	0	37792	155701	3567	0	146528
61	TG	130080	0	6320	1368	0	35285	0	0	15622	62867	1601	0	69500
64	TG	66049	3865	1896	137	0	11009	2326	0	10996	22440	533	0	165042

*TC = Tir Cynnal, TG = Tir Gofal, NS = no scheme, OR = organic

Table 5.5.1.1Total carbon footprints (kg CO_2e / farm) – emissions and sequestration from key sources.

For comparative purposes, and as a sanity check against the national modelling using the ADAS tool, we calculated the on-farm total N2O (direct+indirect soil emissions + manure management) and total CH4 emissions (enteric + manure) per hectare for each of the farming systems (Table 5.5.1.2). The range in emissions encompass the values estimated by Anthony *et al* (Table 2.5.3.2.1) of 5.8 kg N2O/ha and 82.7 kg CH4/ha.

			area (ha)	Total N_2O (kg/ha)	Total CH_4 (kg/ha)
Beef					
7	CS LFA	OR	96	2.9	121.0
32	0	TC	140	6.8	146.1
38	0	TG	90	4.4	71.7
53	0	TC	279	6.7	156.1
62	0	TG	460	3.1	58.1
Dairy					
20	DAIRY	TC	182	8.6	190.1
23	DAIRY	TG	188	7.9	277.3
30	CS LOW	TC	70	8.1	208.2
56	DAIRY	NS	340	4.5	123.1
Mixed					
19	DAIRY	TC	214	7.2	223.5
34	DAIRY	NS	108	5.0	119.0
51	0	TG	158	5.1	157.6
Sheep					
43	CS LFA	NS	39	1.0	29.7
54	0	TG	143	2.6	44.6
61	CS LFA	TG	69	2.5	37.4
64	CS LOW	TG	117	0.7	7.8

Table 5.5.1.2 Baseline GHG emissions.

5.5.2 Results of modelling Glastir measures with the Bangor Carbon Footprinting Tool

5.5.2.1 Grazed Permanent Pasture – No Inputs

The reduction in N inputs to grazed permanent grassland on the modelled farms resulted in marked reductions in the carbon footprint (Table 5.5.2.1) as a result of reduced fertiliser N use (and manufacturing) and carried stock.

		Embedded							
Farm ID	**Reduction in farm C footprint***	Fertiliser + agrochemical	Feed Concent.	Bedding	Bought-in stock	Livestock manure and excreta	Direct soil N_2O from fertiliser N applications	Indirect soils N_2O	Total methane from livestock
Beef									
53	**-8**	-8	-8	-8	-8	-8	-8	-8	-9
62	**-10**	-33	-8	0	-8	-6	-33	-10	-7
Dairy									
20	**-7**	-8	0	-8	-8	-10	-8	-9	-10
30	**-8**	-8	-8	-8	0	-8	-8	-8	-9
Mixed									
34	**-8**	-8	-8	-8	-8	-8	-8	-8	-9
51	**-8**	-8	-8	-8	-8	-8	0	-8	-9
Sheep									
54	**-6**	-6	-6	-6	-6	-6	-6	-6	-6
64	**-8**	-33	-8	-8	0	-6	-33	-8	-6

*column 2 provides the % change in total farm C footprint, whilst the remaining columns provide % changes in C emissions associated with key sources within the total footprint. Not all sources have been included; hence the rows are not additive.

Table 5.5.2.1 Percentage reductions in the total farm carbon footprints and some greenhouse gas sources as a result of Glastir measure for Grazed Permanent Pasture with No Inputs (AWE No. 15)

5.5.2.2 Grazing Management of Open Country

Management of grazing land in this scenario resulted in reduction of stocking rates across significant amounts for farmland. This was especially so for one of the sheep farms, resulting in a marked reduction in the farm carbon footprint (Table 5.5.2.2). Reductions in the carbon footprint of other farms were mode modest, 0-5%.

Farm ID	**Reduction in C footprint***	**Fertiliser + agrochemical manufacturing**	**Feed Concentrates**	**Bedding**	**Bought-in stock**	**Livestock manure and excreta**	**Direct N_2O from fertiliser N application**	**Indirect soils N_2O**	**Total methane from livestock**
Beef									
53	-1	0	0	-1	-4	-2	0	-2	-1
62	-3	0	0	0	0	-9	0	-8	-7
Dairy									
20	0	0	0	0	0	0	0	0	0
30	-5	0	-2	-1	0	-10	0	-8	-5
Mixed									
34	0	0	0	0	0	0	0	0	0
51	0	0	0	0	0	0	0	0	0
Sheep									
54	-24	0	-25	-25	-25	-30	0	-27	-30
64	0	0	0	0	0	0	0	0	0

*column 2 provides the % change in total farm C footprint, whilst the remaining columns provide % changes in C emissions associated with key sources within the total footprint. Not all sources have been included; hence the rows are not additive.

Table 5.5.2.2 Percentage reductions in the total farm carbon footprints and greenhouse gas sources as a result of Glastir measure for Grazing Management of Open Country (AWE No. 41A)

5.5.2.3 Woodland margin extension

This measure was only applicable to a few of the farms selected from our database. The measure resulted in small reductions in the carbon emissions footprint (Table 5.5.2.3).

Farm ID	Reduction in C footprint*	Fertiliser and agrochemical manufacturing	Feed Concent	Bedding	Bought-in stock	Livestock manure and excreta	Direct N2O from fertiliser N applications	Indirect soils N2O	Total methane from livestock
Beef									
53	0	0	0	0	0	0	0	0	0
62	-1	-1	0	0	-1	-1	-1	-1	-1
Dairy									
20	-4	-4	-4	-4	-4	-4	-4	-4	-4
Sheep									
61	-2	-2	-2	-2	n/a	-2	n/a	-2	-2

*column 2 provides the % change in total farm C footprint, whilst the remaining columns provide % changes in C emissions associated with key sources within the total footprint. Not all sources have been included; hence the rows are not additive.

Table 5.5.2.3 Percentage reductions in the total farm carbon footprints and greenhouse gas sources as a result of Glastir measure for Allowing Woodland Edge to Develop Out into Adjoining Field (AWE No. 28)

5.5.2.4 Create New Streamside Corridor – Both Sides / Tree Planting

This measure resulted in no net impact on the farm carbon emissions footprint (data not shown).

5.5.3 Summary of the ECOSSE modelling approach

The suitability of ECOSSE model for estimating C and nitrous oxide emissions at spatial level will be tested. The model will be run spatially (1km^2) for the whole of Wales using baseline climatic data (1961 to 1990), national soil data (2005), and the land cover map for 2007. Maps of estimated greenhouse gas emissions and carbon storage for different management and land use (arable, grass and forest) will be produced and compared.

In addition, a sensitivity analysis will be carried out by running the ECOSSE model for different soil C, soil nitrate and N fertilizer scenarios (baseline ± 20%).

Finally, the model will be applied to estimate the effects of climate change on GHG emissions by comparing baseline and projections, and maps will be produced.

5.5.4 Wales Farm Practice Survey

A repeat Wales Farm Practice Survey is required to provide accurate information on modifications in farming practices as a response to uptake of different Glastir measures by different farmer cohorts, and provide indicators of the degree of implementation. This is particularly important for the modelling of Glastir impacts. The survey needs to read back to previous surveys to provide longitudinal information on adoption (or not) of farming practices. Importantly, there is opportunity to revise current questions and introduce a limited number of new questions to obtain information for wider use within the GMEP.

The main aims of the survey will be to: (i) determine changes in livestock numbers, fertiliser application rates, area of new woodland, area of land receiving reduced inputs *etc.* as a result of entering Glastir, (ii) assess differences in the uptake of mitigation methods due to belonging to previous agri-environment schemes by comparison of data aggregated across the Tir Gofal, Tir

Cynnal schemes with the data for non-scheme farms and new Glastir entrants, and (iii) provide baseline farm practice information for trend analysis both backward and forwards in time.

We have developed the following draft sampling protocol for this Farm Practice Survey. This a telephone survey of all Glastir new entrants and a number of other types of farmer. All survey respondents will be contacted by phone. This work is to be contracted to the Hill/Taylor Partnership who previously undertook the same survey on behalf of ADAS.

5.5.4.1 Survey stratification

Farmer respondents will be characterised under the following broad headings:-

1. New to Glastir cohort
2. No previous stewardship experience and not joining Glastir
3. In Tir Gofal, but not intending to join Glastir
4. Tir Gofal to Glastir
    a. Entry level
    b. Higher level

We will further stratify by farm type

a. LFA
b. Lowland cattle and sheep
c. Dairy
d. Sheep only

				Farm sector			
		We have records	Sample size	LFA	Lowland cattle and sheep	Dairy	Sheep
No steward/ no Glastir		No	200	50	50	50	50
Tir Gofal / not Glastir		Yes	100	25	25	25	25
New Glastir		Yes	140	35	35	35	35
Tir Gofal to Glastir	Entry	Yes	80	20	20	20	20
	Higher	Yes	80	20	20	20	20
Total numbers			**600**	**150**	**150**	**150**	**150**

Table 5.5.4.1.1. Proposed sampling stratification for the Wales Farm Practice Survey

We require sufficient respondents in each category from which robust statistical analyses can be conducted and meaningful results be obtained about modifications in farm practice. Table 5.5.4.1.1 below summarises the proposed number of respondents by farmer scheme cohort and farm typology.

For those farmers never entering a scheme, addresses will be obtained from their county parish holding, as all farmers are expected to have entered the single payment.

5.5.5 Glastir Efficiency grants – impacts on farm-scale Carbon Footprints and wider benefits Modelling

Welsh Government is investing in Glastir Efficiency grants to provide farmers with an All-Wales Element Glastir contract the opportunity to apply for a capital grant for improvement in energy use efficiency, heat generation, water efficiency and manure/slurry efficiency. With this additional funding, we aim to assess the impact that the scheme is having on carbon footprints of farms which have already capitalised on this opportunity. This additional activity is planned for year two (2013-2014) of the programme.

A socio-economic component will consider the direct economic impact to farm businesses and also the wider rural community (beyond the farmer) impact via capital work contracts. The results will help inform the policy object of the grant scheme, climate change mitigation and also the reporting requirements of the scheme in line with the funding mechanism, economic growth and competitiveness.
The approach being planned is to:

- Develop a stratified sampling protocol for the interviews. There is probably resource to allow up to 50-60 carbon footprints in total. Welsh Government have been contacted to obtain data on uptake of the Glastir Efficiency grant scheme, and we envisage the stratification to be via factors such as farm typology, use of the capital grant (*i.e.* what has it been used for), size of grant *etc.*
- Undertake interviews for the C footprint work and economic component together to maximise efficiency of resources. Interviews will assess how efficiency grants have modified farming practices, whether farmers would have undertaken the work anyway (*i.e.* without the grant), where grant funds were spent *etc*. Assessments will be made on baseline (prior to grant use) farm practice data, and also following use of grant funds.
- We envisage this work being spread over an eleven month period (September 2013-August 2014).
    - Data to populate the footprint model will be collected from September to December 2013. This stage of the work will involve arranging meetings with farmers to complete the footprint survey. We already have the survey questionnaire in place. We have also earmarked staff to undertake the work (data collection and data analysis).
    - Footprint modelling will be undertaken between January and August 2014 Summary of Plans for Year 2

5.6 Summary of Plans for Year 2

- The Expert group will build upon the mapping of individual Glastir measures to models, and review groups of measures to explicitly assess if (and how) each model can represent them. Grouping of Glastir measures will be directed using current uptake statistics, in advance of the Wales Farm Practice Survey, to establish which measures/groups to prioritise and how they have been implemented.
- The Expert group will also assess (via modelling) whether novel measures, *i.e.* measures not currently included in the Glastir scheme, could deliver greater benefits
- An important complementary activity for the Expert Group is to define what each of the prioritised measures involve in terms of on-farm practice and the wider knock on effects. This is not a trivial task, based on the effort required to generate these definitions for the five individual Glastir measures modelled in Year 1.

  The three bullet points (above) will make best use of the Expert Group, rather than conducting a critique of the models and assumptions used per se. These are generally well documented already. However, the tasks above will, by their approach, explore model function, and the Expert Group will ensure transparency of model operation continues to be communicated, and that where applicable, notes of caution are highlighted.

- The level of uptake of Glastir measures to date is a key deliverable in assessing the potential impact of Glastir measures on diffuse water pollution, greenhouse gas emissions and carbon sequestration. We will undertake an assessment of measure uptake in Year 2, linking June Census for individual holdings to scheme records.

- ECOSSE data sets will continue to be collated, and where appropriate, proxy data will be used – prior to testing the suitability of the model for estimating spatially explicit carbon sequestration and greenhouse gas emissions across Wales. Following a sensitivity analysis, the model will be used to assess impacts of selected Glastir measures on national emissions.
- The assessment of the impact of Glastir Efficiency Grants on carbon footprints and wider (off-farm) benefits to the rural economy will be conducted in Year 2, once farm-level data on grant use is made available.
- The Expert Group will provide a list of the key assumptions and justification of the emission factors used in the models, for comparison with current literature and best practice for inventory and carbon footprinting. This information will be used to decide if models need to be updated, and help to explain any differences in model outputs for a given change in farming practice. The Expert Group will ensure transparency of model operation contributes to be communicated, and that where applicable, notes of caution are highlighted.

6. Landscape and Historic

Swetnam, R.[1], Harrison, S.[1], Korenko, J.[1], Scott, L.[2] and White, J[1].
[1] Staffordshire University, [2]Ecorys

Wales is typified by some of the finest mountain and coastal scenery in Europe, as well as small-grained farmed landscapes and heritage landscapes of national and international significance (WLP, 2009). Landscapes provide the framework for our natural capital and the individual components which create this wealth –habitats, species, culture, geology, and the human economic activity which takes place within them, all contribute to their development. As such, landscapes are not just "snap-shots" rather they provide direct and visible evidence of centuries of human activity. The rich and distinctive nature of Wales's historic environment is revealed through its historic landscape character (fields, moors, lanes, settlements *etc*.) and is further manifested in its unique endowment of archaeological sites, field monuments and other material remains.

Landscape quality is an inherently subjective concept, the measurement of which is dependent on a variety of factors, including where the assessment is made, when it is made (time/season/weather) and, critically, on who is making the judgement. The key challenge in landscape studies is therefore to define a method which can measure components of quality in quantifiable and repeatable ways and this is a key output of the first phase of the landscape component of the monitoring programme.

Landscape and Historic Environment as part of the Ecosystem Services Framework
Cultural ecosystem services include those non-material aspects of the natural environment which support societal needs for recreation and access to green space, alongside spiritual and religious enrichment (MEA, 2007). Indeed, the UK National Ecosystem Assessment of cultural ecosystem services outlines a myriad of contributions that natural landscapes make to our physical and mental well-being (Church *et al*., 2011).The need to both preserve our shared cultural heritage and have access to aesthetically pleasing natural environments is central to this concept and plays an important role in the shaping of the Glastir monitoring programme. In Wales, there is a strong sense of "place-based identity" and the connections between the Welsh language, history, culture and physical environment have been enshrined in a number of policy documents, including the Welsh Assembly Government's position statement on the historic environment (WAG, 2007) and the Wales Landscape Partnership agenda for the protected landscapes of Wales (WLP, 2009).

6.1 Major achievements in Year 1

The Glastir Monitoring and Evaluation Programme includes a range of activities to ensure the impact of Glastir interventions on the Welsh landscape and the historic environment can be reported. Achievements in our first year include:

- The construction of detailed 3D datasets for all 60 1km^2 study sites which take into account both landscape topography and small-scale landscape features which constrain the visibility of the landscape (e.g. significant trees, boundaries such as hedgerows, buildings, woodlands).
- The construction of 3D datasets at 5m resolution for a 3 x 3km area surrounding each of the 60 study sites.
- The extraction of a complete Public Rights of Way (PROW) network for different classes of user (walker, cyclist, horse-rider, small vehicle, large vehicle) for all 60 sites.
- The collation of a visual record of all 60 sites from both fixed point photography completed during the field survey (16 per site), and from the collation of nearly 200 publically contributed photographs of these 60 sites to the geograph website

(http://www.geograph.org.uk/), with typically 4 additional photographs provided per site (Figure 6.1.1).

- The construction of detailed 3D viewsheds based on the PROW for all 60 1km^2 study sites. In addition, we have also coded the methods to calculate the viewsheds from each 1km study site looking out to the surrounding 3 x 3km, as well as the contribution that the 1km study site makes to the landscape view looking in from the surrounding 3 x 3km area. This is a quantifiable measure of how "visually accessible" this landscape is to the general public.
- The extraction of all historic environment features for the 60 sites.
- An assessment of historic feature condition has been successfully incorporated into the field survey, building on field notes provided by the archaeological trusts. This will yield a timely and significant new set of survey data about historic sites' condition.
- The development of a unique Visual Quality Index (VQI) to quantify the landscape value of each 1km study site. This includes five key components: topography (how rugged / varied the landform is); "blue-space" (water features in the landscape); "green-space" (habitat diversity, vegetation complexity); anthropogenic (built components); historic / cultural (including presence of Scheduled Ancient Monuments *etc*).

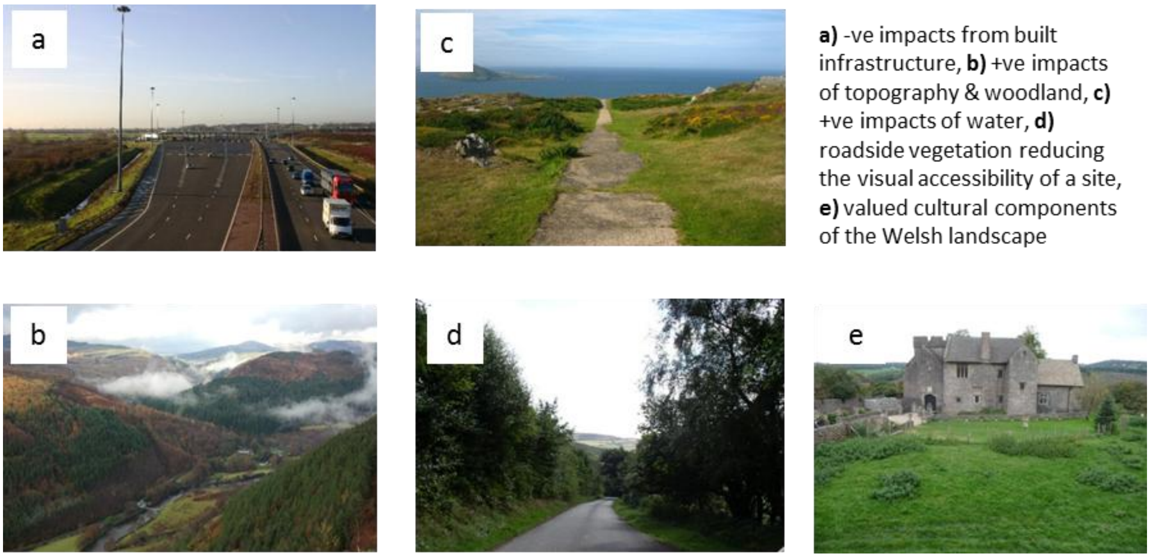


Figure 6.1.1 Part of the photographic archive of the Year 1 study sites illustrating some key components of the landscape methodology. Photographs used under a Creative Commons license and are attributed as follows: (a) = Ian Macaulay, 2005; (b) = Gwilym James, 2005; (c) = Natasa, 2009; (d) = Eirian Evans, 2006; (e) = Jeremy Bolwell, 2012.

6.2 Current Status and Trends

Overall, when averaged across the whole of the country, the habitats which define the Welsh landscape did not change significantly between 1998 and 2007 (Countryside Survey, 2007). This might imply that the landscape has been static; however in the UK such stability is rare and detailed analysis of the Welsh squares within the survey revealed that there were some important changes in specific components of the landscape. These included an increase in the overall area of built land, which increased by 14,500ha (a rise of 12.5%) and an increase in the area of broad-leaved woodland across lowland Wales (rising by 12%). Certainly, there are new landscape challenges emerging from the growth of the energy sector which has been thrown into sharp relief by the impact of wind farms on Anglesey and out in the Irish Sea. These significant installations can impose landscape costs, although their installation is strictly controlled in the designated landscapes of the National Parks and Nature Reserves. Woody linear features are important in landscape quality assessments and they make up over half of all boundaries in Wales. Within these boundaries there has been a reduction in the length of managed hedgerow as previously stock-proof hedges have deteriorated into lines of trees. The recently published State of Nature report 2013 and analysis of the species data for Wales in Countryside Survey indicates a decline in overall species diversity. These declines may have cultural significance when considering specific aspects of landscape quality, for example, in Wales 57% of flowering plant species are in decline and this may negatively impact on visitors' enjoyment of certain landscapes in spring and early summer (State of Nature: Wales 2013).

There is no doubt that high quality landscapes and heritage features are a valued resource in Wales, attracting visitors to the country and generating income across many different sectors. There is clear recognition of the significant contribution of the historic environment to quality of life in Wales. The recent Historic Environment Strategy for Wales (Welsh Government, 2013) is focused on actions to enable the protection of Wales's heritage while also encouraging public access, enjoyment and participation. The historic environment comprises a diverse set of assets ranging from formally designated sites to locally important landmarks and features. Across Wales there are 3 World Heritage Sites, 428 registered historic landscapes, parks and gardens, 519 conservation areas, 4,000 scheduled ancient monuments and 30,000 listed buildings.

There is evidence that such assets contribute to a range of benefits spanning job creation, tourism, place-making, identity, education and community involvement. Research to assess the value of the historic environment in Wales (ECOTEC, 2010) estimated that the sector supports over 30,000 jobs and contributes around £840 million to national gross value added (GVA). Some of the most popular visitor attractions in Wales are heritage sites, including Conwy Castle which attracted over 160,000 visitors in 2012. The historic environment is widely used in the promotion of Wales as a destination and is one of most popular reasons cited by visitors in Visit Wales research of visitor motivations. However, the strategy identifies a need for action to increase accessibility, understanding and engage under-represented groups. The cost of maintaining and restoring assets is also a significant challenge. The Programme for Government, set out in 2011 for the current Assembly term, includes an aspiration to enrich the lives of individuals and communities through culture and heritage with a longer-term goal to increase the percentage of historic environment assets in a stable or improved condition. The 2013 update reports that public engagement with heritage is growing and there has been some success in strengthening the place of the Welsh language in everyday life and the percentage of historic environment assets in a stable or improved condition is estimated at just over 78%[11].

6.3 Benefits of past schemes

In Wales, Glastir has replaced a number of agri-environment schemes including Tir Gofal, the entry-level scheme of Tir Cynnal and the Tir Mynydd scheme which provided specific support payments to hill-farmers in the Less Favoured Areas. Tir Gofal was launched in 1999 with an objective to protect characteristic rural landscapes and to promote the management and restoration of significant landscape features. The scheme aimed to protect and improve the Welsh landscape by making payments to farmers who committed to sustaining the environmental features on their land, this included options designed to protect and restore historic and archaeological features. Tir Cynnal was introduced in 2006 and provided support to farmers to protect wildlife habitats and landscape features. It objectives included protection of important landscape features on farmland, including

[11] This figure is based on an assessment of listed buildings and scheduled ancient monuments. The corresponding figure in 2008 was 75% which suggests that progress has been made; however, it is noted that prior to 2012 the percentage of listed buildings deemed to be not at risk was used to represent those in a stable or improved condition but in 2012 a more accurate assessment of those in a stable or improved condition has been used. Cadw is now looking at ways to extent this evaluation to a wider group of historic environment assets.

traditional field boundaries and safeguarding the historic environment by protecting archaeological and historic sites and features from damage.

Under Tir Gofal many of the land management options were designed to protect and enhance components of the natural and cultural heritage of Wales whilst increasing permissive access. In addition, there were capital grants to support specific activities. A review found that 93% of Tir Gofal applicants in 2003 received a capital grant from a total budget of £7.15 million. Of these payments, a significant proportion was spent on activities which have a direct impact on the quality of the landscape and the maintenance of its historic context including: dry stone walling (15.3%), repair of the unique Welsh slate fencing (0.2%), hedgerow management (9.2%) and traditional farm building repair (7.4%). With respect to the creation of new ponds (1.3%) and the planting of new trees (0.5%) overall capital spend was much lower. A further 5.6% of the capital grants budget was spent on improving access through the creation of new permissive paths and improvements to existing access infrastructure (Agra, 2005: Table 3.8).

The mid-term evaluation of the Wales Rural Development Plan for the period 2007-13 (ADAS, 2010) found that in general terms, the area under agri-environment measures was likely to at least maintain landscapes and features; and, in particular, Tir Gofal has resulted in a number of specific actions which will have contributed to maintaining and improving landscapes and features.

It was also noted that the schemes have also played a role in decisions to remain in farming, usually as one of a number of factors, which will contributed to maintaining the structure of farming in Wales and, in turn, may have helped to maintain existing farm sizes and boundary features.

A survey of participants in Tir Gofal, undertaken by the evaluators, asked whether beneficiaries had maintained or improved a range of landscape features since joining the scheme. The most frequently cited response was hedgerows (85%), followed by management of individual trees or orchards (50%) and public rights of way (44%). In terms of historic features, it was reported that work had been done to maintain or improve traditional buildings (37%), other historic features (including mines, ponds, cairns, ruined buildings and features associated with farming or mining) (28%) and scheduled ancient monuments (14%). Programme monitoring data provides an indication of the progress that has been made in respect of historic features (Table 6.3.1).

	Indicator	**Cumulative to end of 2011**
Outputs	No. of historic of archaeological features covered by agri-environment agreements	18,985
	Public access covered by agri-environment agreements	9,927km public rights of way
	No. of traditional farm buildings within agri-environment agreements	1,180 farm buildings
Results	No. of historic features within agri-environment schemes with positive management prescriptions	20,338 features
	Quality of historic or archaeological features covered by agri-environment agreements	0 decline in quality

Table 6.3.1 Additional Indicators Measures for class 214 which related to Tir Cynnal, Tir Gofal and the Organic Farming Scheme and class 216 which concerns Tir Gofal support for non-productive investments. These figures present Wales programme-specific indicators. Source: Annual Implementation Report 2011, Welsh Government.

A more recent review of the impact of agri-environment schemes undertaken for the UK Government found that the entry level schemes that had operated in England and Wales since 2000 had positive impacts on maintaining landscape character and quality. There was significant uptake of landscape / historic options including the management of archaeological features under grassland; buffer strips in open landscapes; the maintenance of a pastoral character through the support of low input grazing and mixed stocking, as well as through hedgerow management (FERA, 2013). These landscape impacts were most highly rated by those land managers in the Less Favoured Areas which in the Welsh context is significant as over 80% of the agricultural land in the country falls into an LFA, with 56% of it in severely disadvantaged areas.

Although there have been significant benefits accrued with respect to landscape quality under pre-existing agri-environment schemes, a note of caution must be sounded with respect to the historic and archaeological components of landscapes. A review undertaken by ADAS of the conservation of the historic environment in the English uplands highlighted that there was still a lack of information about this important resource and that this has been exacerbated by a focus on individual sites and features in existing agri-environment schemes rather than considering the historic landscape as a whole (ADAS, 2011).

6.4 Aims of Glastir with respect to landscape & historic environment

One of the five key aims of Glastir is to manage and protect the Welsh landscape and historic environment whilst retaining and promoting opportunities for access. There are four specific landscape targets in Glastir namely: ditch landscapes; historic features and landscapes; pond landscapes and protected landscapes. An additional five targets also have strong links to landscape: orchards; parkland and wood pasture; parks and gardens; permissive access and woodlands.

6.4.1 Measures to deliver landscape & historic goods in Glastir

Many of the measures embedded in both the Glastir Entry and Glastir Advanced scheme have impacts on both the visual quality of the rural landscape and the historic features it contains. The VQI outlined in section 6.3 quantifies a number of indicators of relevance to these Glastir Objectives (Table 6.4.1)

	TARGET OBJECTIVES: GLASTIR								
VQI Measure	Ditch landscapes	Historic features & landscapes	Orchards	Parkland & Wood Pasture	Parks & Gardens	Permissive Access	Pond Landscapes	Protected Landscapes	Woodland
Presence of water	1	*					1		
Standing water area	1	*					1		
Flowing water total length	1	*							
Number of BH types present	*			*				1	
Number of species recorded (diversity)	*			*				1	
Colour contrast			*		1			1	1
Area of deciduous / mixed woodland	1		1	1	1			1	1
Length of hedgerows	1				1			1	1
Area of intensive arable / conifer forestry	1	1	1	1	1	1	1	1	1
Number of spot facilities (pylons, turbines *etc.*)	1	1	1	1	1	1	1	1	1
Area of built infrastructure (houses, industry)	1	1	1	1	1	1	1	1	1
Roads - total length	1	1	1	1	1	1	1	1	1
SAM - presence / absence		1						*	
Parks and gardens		1			1				
Listed buildings		1						*	
Landscape of outstanding hist. beauty.		1			1			1	
Condition assessment of SAMs		1						*	
PROW length / type		*				1			
Access		*				1			
Listed buildings	1	*					1		

*Table 6.4.1: Measured landscape / historic indicators mapped to Glastir objectives. 1 = measure of relevance, green cells = positive impacts, orange = negative impacts, * of possible relevance.*

These management measures include:

- Options relating to hedgerow management and creation (1, 1b, 2, 2b, 6, 6b, 42a,42b,43a, 43b)
- Options relating to streamside vegetation (7a, 7b, 8, 173, 175)
- Options relating to new tree planting, both of orchards (11,12, 172) and native trees, as well as the expansion of existing woodland edges (13,104,. In addition, there are provisions made for payment for the removal of conifers where appropriate.
- Options relating to the creation of new water features in the landscape, as well as the maintenance of existing farm ponds (35, 35b, 36, 146, 147).
- Options relating to the management of flower rich meadows and other botanically diverse habitats which add colour, variety and structure to a farmed landscape whilst also fostering biodiversity (22, 26, 26b, 27, 28, 33, 34, 34b).
- Options relating to historic components of the landscape, including maintenance of traditional buildings, historic parklands and preservation of archaeological sites (10, 39)

A full listing of management options of relevance to landscape quality are mapped against the landscape and historic target objectives in Appendix 6.5.

The latest 'Programme for Government' update for culture and heritage indicators notes that during 2012, Cadw wrote 110 management plans for Scheduled Ancient Monuments that are being delivered through Glastir and that effective implementation of these plans by landowners should mean that the condition of these assets will either remain stable or improve (Welsh Government, 2013[12]).

[12] http://wales.gov.uk/about/programmeforgov/culture/performance?code=OU095&lang=en

6.5 Methods

Landscape is a cross-cutting theme, with links to both the socio-economic and biophysical parts of the monitoring programme, wherein the analysis can be split into two main components: functional and visual. Functional landscape analysis focuses on the ecological structure of the landscape as related to its connectivity (e.g. habitat areas, permeability, diversity) and is generally approached from two angles: the areal measures, *i.e.* sizes and shapes, and the linear features such as boundary lengths and types *etc*. These measures are being collected for the $1km^2$ survey sites and subsequently processed under the biodiversity activities. Landscape and historic takes these data as input but focuses on the visual aspects of the survey sites in their landscape setting, including their aesthetic quality, their visual accessibility to the general public and their physical, cultural and historic context.

Quantifying landscape quality in a rigorous and repeatable way is a challenge. Our aim in this work package is not to make a subjective judgement; rather we are deriving evidence from specific indicators which we believe can be supported by evidence from research in this field. After reviewing the current literature, some components of landscape structure emerge as having strong associations with valued landscapes and are consistently rated highly by a diverse cohort of the public (Fry *et al*., 2009). Our approach in GMEP is to derive a Visual Quality Index for each site based on these components and derived from the detailed field survey data collected by the surveyors (Figure 6.5.1).

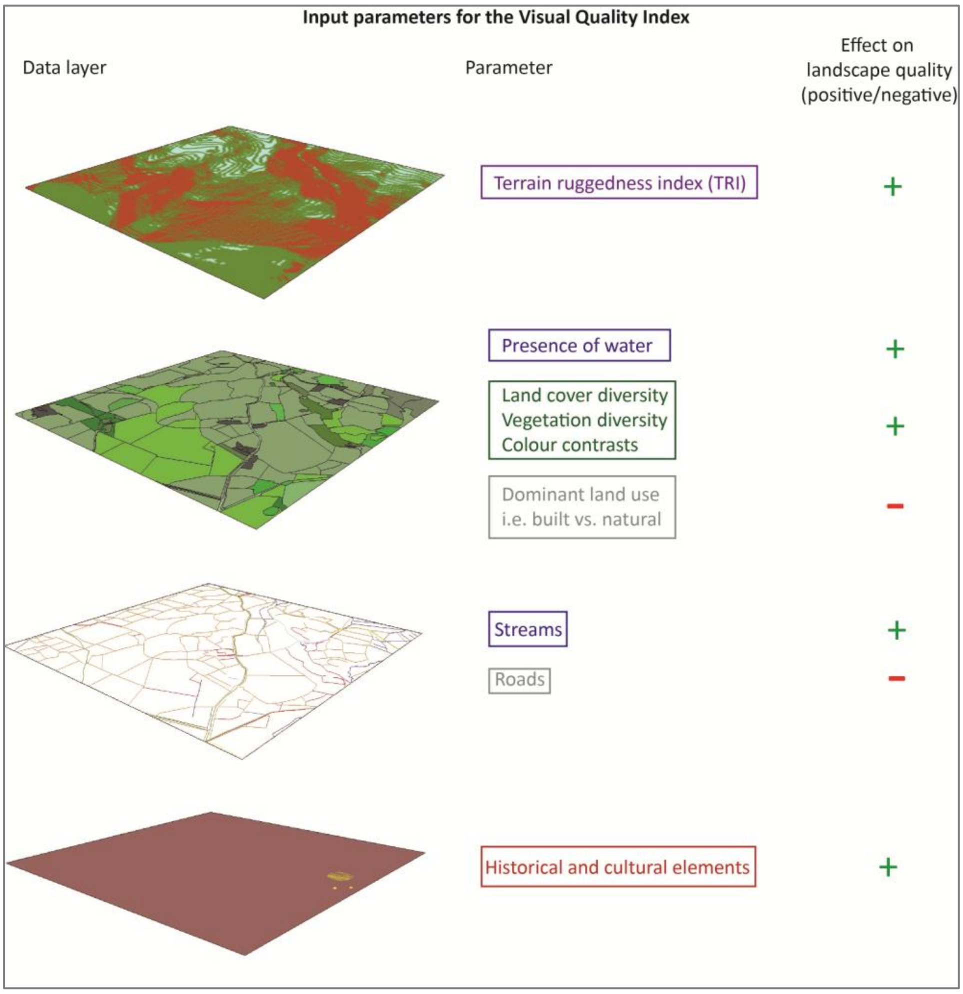


Figure 6.5.1 Input data used to evaluate the visual landscape quality. This shows one of the wider Wales sites from the year 1 survey with example layers extracted for each indicator and the relative impact of that indicator on the overall value.

6.5.1 The Visual Quality Index

Our literature review helped us to crystallise some common landscape themes, from which we have identified a range of key landscape indicators that can be measured. Together these indicators capture the elements of places which tend to be rated highly when people are asked to examine images of landscapes (Herzog & Bosley, 1992). We have grouped these into five areas:

1) *terrain* - which measures the physical ruggedness of the landscape (Riley *et al*., 1999) – see Appendix 6.1;
2) *blue space* - indicators which measure the amount of water in the landscape including rivers, lakes, sea (White *et al*., 2010);
3) *green space* – the amount and diversity of natural and semi-natural vegetation (Arriaza *et al*., 2004; Ode & Miller, 2011);
4) *built* - the presence of roads, buildings or industry usually acts as a negative factor in the quality assessments of landscape; however, some rural architecture is often rated in a positive light for the contribution it makes to the cultural landscape. The most striking examples perhaps being churches or vernacular buildings of note such as manor houses, mills, farmhouses (Howley *et al*., 2012);
5) *Historical-cultural* - the presence of historical or archaeological infrastructure is often valued highly by visitors. This can include cultural components, e.g. significant farm buildings, archaeological remains, e.g. standing stones, traditionally managed hedges or walls and even the presence of native breeds of livestock. These factors may all contribute positively to the historical and cultural setting of a particular landscape (Church *et al*., 2011).

Each of these groups contains a number of individual measures which are quantified from the GMEP field survey and ancillary datasets (Appendix 6.3, 6.4). These are calculated for each individual site and a summary value derived for comparison (Figure 6.5.1.1).

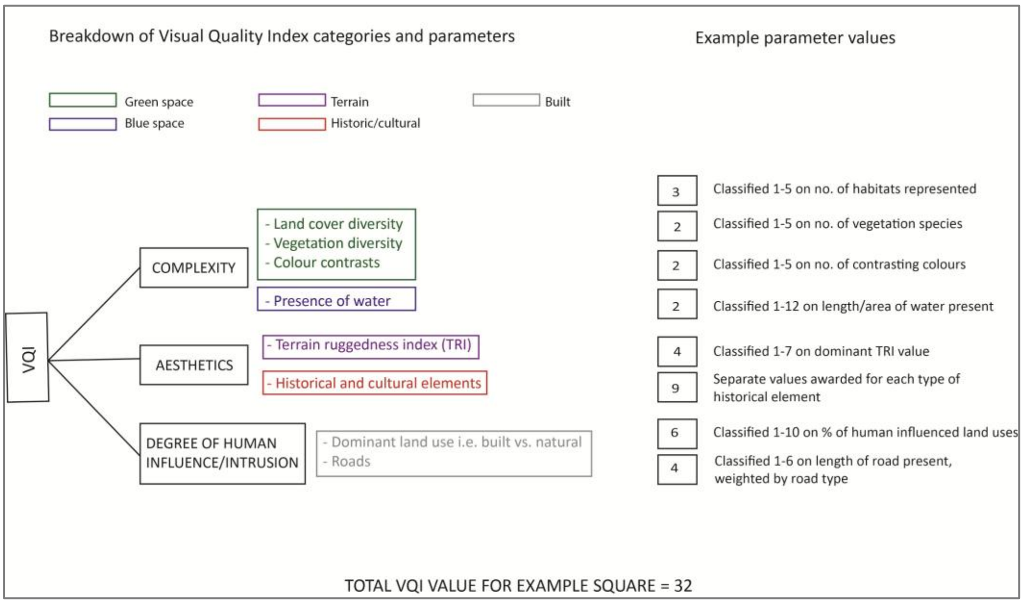


Figure 6.5.1.1 An example Visual Quality Index calculation for a 1km survey square, the output is a comparable measure which gives an indication of the landscape components.

6.5.2 Visual accessibility

For visitors to a rural environment, access to the landscape is a critical factor and can determine the type of experience they receive when walking, cycling or driving through an area (Brush *et al*., 2000). Physical access is largely determined through the public rights of way network (PROW) and it is this which ultimately controls which parts of the landscape can actually be seen by the visitor. A landscape does have its own existence value - so a good quality landscape does not stop being a good landscape just because it is non-accessible to the general public, but it only delivers some types of public goods (*i.e.* cultural ecosystem services) when it can be seen by the public.

Our visual accessibility measure captures this aspect of the Glastir sites. Through computer processing of the landscape we can quantify which part of the site can be seen and enjoyed by the wider public. This is determined by a number of factors including: topography (the shape and height of the land itself) and the existing vertical structures (the buildings, hedges, trees) and the viewing height of the participant (pedestrian versus the view from a coach window for example). Calculating visibility from known locations is called *viewshed analysis* and such methods are well established for the siting of large infrastructure projects such as windfarms, power stations or major retail ventures. They have rarely been applied to smaller scale landscapes due to a lack of detailed information but within our monitoring programme we have the opportunity to work at a fine-scale in order to construct detailed viewsheds for our study sites. By combining a fine-scale 3D dataset (5m) with the detailed vegetation information collected in the field by the surveyors (Figure 6.5.2.1), we have been able to construct realistic visual landscapes which incorporate the boundary information and the wooded vegetation of the sites (Appendix 6.2). Some of these components also contribute to the overall landscape quality, particularly the presence of native woodland, but these same high quality components can also restrict the wider, landscape views. A densely wooded landscape might rate highly on the VQI but would have a very restricted viewshed as it may well hide many of the historic and fine grained aspects of the rest of the site.

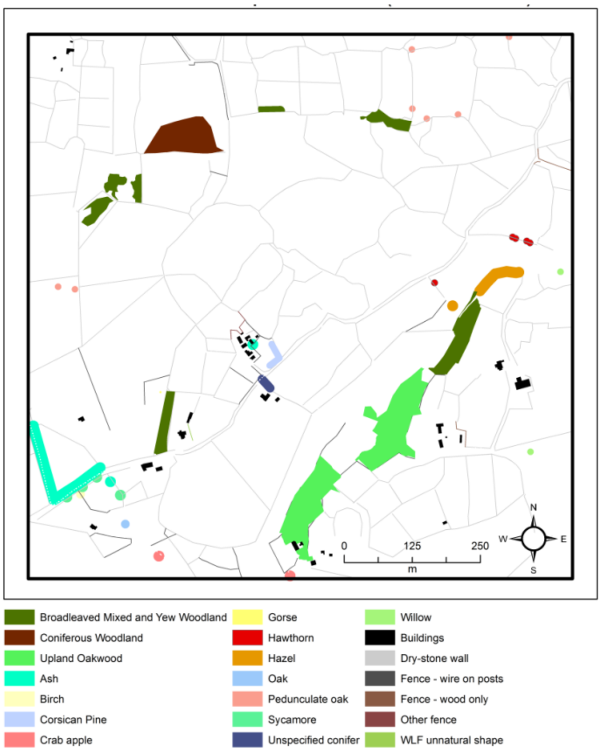


Figure 6.5.2.1 An example wider Wales site (1km^2); showing the field survey data included in the elevation modification of the height surface to feed in to the detailed viewshed calculation (Appendix 6.2).

With respect to historic landscape features, vegetation can both indicate the presence of features such as a clump of trees defining a tumulus for example, but conversely can damage and/or obscure archaeological sites or vernacular architecture of value. As a consequence, some of these features may only be visible at certain times of the year when the trees are without leaves or only by their owners. For each site we are constructing three different viewsheds (Figure 6.5.2.2):

1. a within-site viewshed for each 1km study site, *i.e.* what can be seen from the PROW when within the site.
2. a viewshed from the PROW of the 1km study site looking outwards to the surrounding 3 x 3km landscape, *i.e.* the contribution that the wider landscape makes to the quality of the landscape of the 1km study site.
3. a viewshed from the PROW of the surrounding 3 x 3km landscape looking in to the 1km study site, *i.e.* the contribution that each square makes to the wider view.

Such an approach recognises that each Glastir site sits within a wider landscape and these "longer" views can play a significant role in our experience of the site. In addition, we may have a 1km study site which has no PROW within in it (so it is visually inaccessible in itself) but which is highly visible from surrounding ridges or higher land. The contribution of a site to the landscape quality of an area is therefore happening at three different levels, all of which are captured by our multi-pronged approach. This is particularly important when considering some of the larger, expansive, unenclosed mountain scenery of upland Wales. In addition, this approach counters the criticisms raised about previous agri-environment schemes that fail to take account of the historic landscape as a whole.

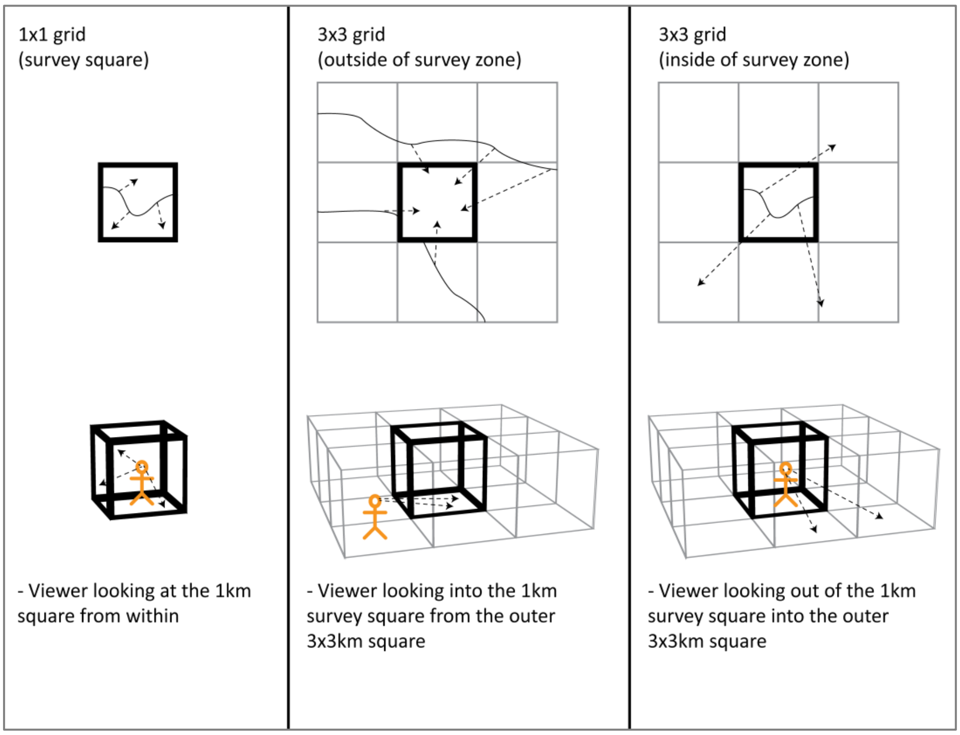


Figure 6.5.2.2 The three different levels of landscape view accounted for by the landscape methodology.

6.5.3 Combining the Viewsheds with the Visual Quality Index

We therefore have two key outputs for each site: a spatial calculation of the components of the study site that can be seen by the public from the PROW and secondly, an overall quality index. The first is a detailed map whilst the second is a single index value which allows rapid comparison across sites. The final stage of the analysis is to bring these two components together by overlaying the viewshed with the VQI map which shows how the quality indicators are actually dispersed across each site. This process is illustrated schematically in Figure 6.5.3.1 and will give us a second measure of the landscape quality of a site which takes into account the public experience of these visually accessible components of the site.

Figure 6.5.3.1 Combining the viewshed analysis with the VQI. The overall index would be calculated for the site as a whole to yield one value for comparison across the Welsh sites (a). Using the PROW, the viewshed is calculated (b) using the terrain data as input to calculate those areas which are visible (green) and those which are hidden (red). The high positive and negative components of the landscape are location specific, the VQI is spatially disaggregated to show which specific parts of the landscape contain the high value and low value components (d). This is then combined with the viewshed from (b) to derive a refined value for the site (e) which in this example shows that a valued historic aspect is visible, whilst an attractive native woodland is not, the factory which is rated negatively in the landscape does not have such a visual impact due to its location and the terrain and access.

6.6 Outputs and their contribution to the Glastir evaluation

The landscape analysis will provide answers to the following questions:

- How do the landscapes of Wales compare at the 1km scale?
- How accessible are these landscapes to the wider public? This is both in terms of their physical accessibility (how well covered are they by the PROW network) but critically in terms of their visual accessibility.
- In particular, we will be able to identify at a detailed scale those sites which potentially require improvement from an aesthetic / functional standpoint.
- Are there currently high quality landscapes which are poorly accessible? By splitting the analysis based on the type of access (whether over rough terrain, accessible by bike or only accessible from a car) we may also be able to comment on these measures with respect to different categories of user.
- Are there sites of high landscape quality which are currently failing to provide cultural ecosystem services to the general public, because they are essentially "off-limits" and privately owned, which could potentially provide more through targeted intervention under Glastir, specifically with regards to the establishment of permissive access where appropriate?

6.7 Workplan for Year 2

The quality index is currently being derived for all 60 of the Year 1 sites; this work is dependent on the incoming field survey data which provides the detailed vegetation information required to apply appropriate heights to vertical structure in the site. All the processing methods are now coded and tested. It is our intention to compare our outputs against the cultural and historic layers of the Welsh LANDMAP dataset (Scott, 2002). Although this spatial dataset has been collated using very different methods and is intended to evaluate the landscape over much larger units, it will provide a useful validation of our approach. In addition, the detailed sample approach taken by GMEP can be used to evaluate the results given in the LANDMAP dataset.

Having derived a working, repeatable and quantifiable metric of landscape quality for each 1km study site, the next challenge will be the spatial disaggregation of this metric. Since the high quality landscape components of a site may well be confined to just one area of the study site, the next development phase of the work will see the individual indicators identified within the 1km site. This is important as we can then compare the area that is visually accessible, as calculated by the viewshed analysis, with the specific characteristics that people value in the landscape. For example, a site may contain lakes, woodland or historic buildings that contribute to the overall index for the 1km square but these features may not actually be visible. In addition, negative aspects of the landscape such as a working quarry, or a major road may dominate the view for the general public resulting in a low value being assigned in terms of the public experience of these places.

The incoming field survey data will also be reviewed in respect of historic features, particularly the assessment of condition and management issues which will provide an insight into the potential for deterioration of these features. We will also explore the potential for undertaking a number of case studies and stakeholder discussions to illustrate specific examples of work which have been supported by Glastir to protect and manage the historic environment and landscape with the outcomes this will achieve in the future.

In order to assess the response of the Welsh public to landscape interventions funded through the Glastir programme, a range of social science surveys activities will be undertaken. These include:
a photographic preference survey (PPS) to evaluate the landscape preferences of different types of countryside user. This bilingual survey will be delivered online and targeted at key internet forums, educational establishments, outdoor websites, and stakeholders amongst others yet to be identified. Key stakeholders will be agreed with the Welsh Government to ensure that target groups of particular interest are included (children, urban youth, socially disadvantaged groups, ethnic minorities *etc.*). In addition, we intend to run two roadshow events in Wales where we will take the survey out to the public and gather responses in person to ensure that groups that do not engage with web-based surveys are included. The following questions will be addressed:

1. Does the Visual Quality Index calculated in the Landscape Work Package match the value assigned by the public to different landscape types?
2. Do different societal groups (youth, middle-aged, elderly; urban/rural; landowners / recreational users) value the landscape in similar ways?
3. What components of the landscape are liked or disliked?
4. Do changes implemented under Glastir invoke a positive / negative response in terms of landscape quality perception of the public in Wales?

A key development during spring 2014 will be the development of landscape visualisations to illustrate future landscape changes on the target sites instigated and paid for through Glastir. These will address question 4 above; preference surveys will again be used to evaluate the public response. The most significant visual impact is often caused by the management of individual trees, boundaries and woodlands. Where new native woodland is planted, for example, the full visual impact of that intervention will not become apparent for 15 or 20 years. Other interventions such as the installation of new hedgerows or the creation of new water features (farm ponds *etc.*) will be apparent in much shorter timescales. Indeed, the removal of a conifer shelter belt to reveal a fine historical façade could make an almost overnight difference. In order to show the public how these landscapes may realistically look we need to model these changes.

As part of the landscape component, we will be making use of cutting-edge, computer-gaming visualisations to produce ecologically correct future landscapes (Figure 6.7.1). Staffordshire University has particular expertise in this field, with industry-standard researchers able to create exceptionally high-quality landscapes. These visualisations will be grounded in reality, with all of the vegetation based on the survey information collected in the field by the ecologists and changes in these wooded structures will follow ecologically realistic growth patterns for Wales. The user will be able to "walk through" the landscape on the PROW network and their perception of the value of the intervention ascertained. These final landscapes will be made available online and will not only gather the views of Welsh citizens, but also of potential visitors to Wales from across the globe. Far from being a gimmick, these visualisations are now of such a quality that they can be used to engage the view of young people and those members of the Welsh public (perhaps in more urban locales / potentially socially disadvantaged areas) with regards to the shared landscape assets of Wales which they are all paying to help protect. We believe that this will be the first time, such high quality and ecologically correct landscape visualisations will be created and used for such public engagement purposes.

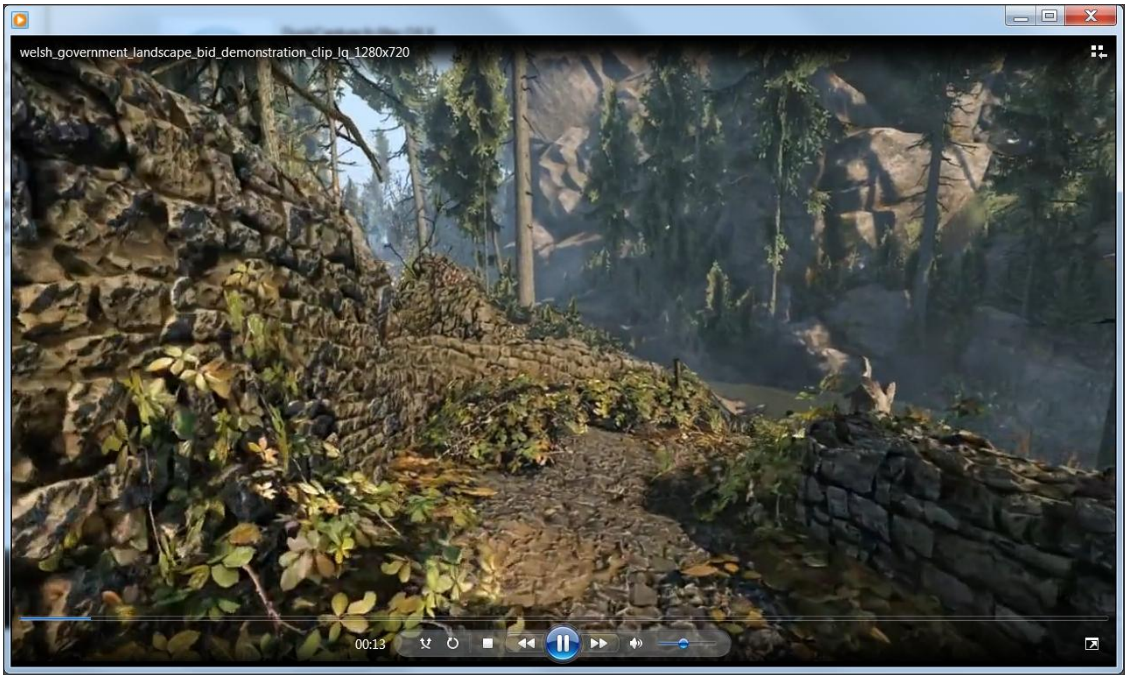


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Figure 6.7.1 Screen still from an example landscape visualisation to illustrate the quality of the image that will be created. This is a highly detailed and stylised landscape, the proposed visualisations will include data from the field survey and will be ecologically correct. The video which shows this imagined landscape can be viewed at https://vimeo.com/72492997 *using the password "WGP"*

7. Woodlands

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Why woodlands? Woodlands are important for the provision of multiple Ecosystem Services, goods and benefits including timber, soil protection, flood prevention, recreation, climate regulation and wild species diversity (for both generalists and woodland specialists). Many of these services are additive and there are synergies between services rather than trade-offs, woodlands are multi-functional habitats. The environmental benefits of woodlands in Wales have been valued at £34 million (Read *et al*. 2009). A recent survey[13] demonstrated that nearly 65% of people in Wales visit Welsh woodlands regularly and 94% believe they provide a definite benefit to the local community.

There are two main woodland Broad Habitats; Broadleaved and yew mixed woodland and Coniferous woodland. In Wales, only broadleaf-dominated woodland is native, and this type is the main focus of nature conservation interest. It includes seven Priority Habitat types recognised in the UK Biodiversity Action Plan (Wet Woodland, Lowland Mixed deciduous woodland, Lowland Beech and yew woodland (confined to South Wales), Upland mixed ash woodland, Upland Oak woodland accounting for approx 50% of semi-natural woodland (Russell *et al*. 2011), Wood pasture and parkland and traditional orchards) and Broadleaved, Mixed & Yew Woodland is recognised as a feature of interest on many SSSIs. Woodlands in Wales vary in size and distribution; areas of semi-natural and Ancient woodland tend to be small and fragmented. There are also areas of coniferous woodland particularly located on poorer soils in upland Wales. The ecosystem services provided by Broadleaved woodland and Priority Habitats tend to be more focused upon cultural services, aesthetic qualities and wildlife conservation and less on timber production, although there is activity in Wales to encourage sustainable management of Broadleaved woodlands for environmental, social and economic outcomes[14]. Modified habitats and plantations, although less valuable for biodiversity, can still provide education and recreational opportunities as well as timber production, soil protection and flood prevention. Woodland services and species are represented in area Broad Habitats but also in woody linear features (hedgerows and lines of trees) and smaller point features (individual trees including veterans and small clumps of trees and scrub). These features are extremely important in connecting woodland habitats within a landscape and used for shelter, dispersal, habitat by many species. An analysis of potential expansion of existing woodland and establish streamside corridors under low, medium and high uptake scenarios estimated a potential 10,000 additional hectares of woodland from these interventions alone (see Chapter 2). Veteran trees are also important for species diversity, they are often more likely to be found in non-woodland situations (Read 2000) in open parks and wood pastures but may still be found within woodland. The UK has a relatively high density of veteran trees and it is a conservation priority to protect them.

Of the UK countries, Wales has the highest percentage cover of Broadleaved, Mixed & Yew Woodland (as a proportion of all land cover types) although this is low by European standards, only Scotland has a higher total woodland cover however this is a consequence of the much higher percentage cover of Coniferous Woodland there than elsewhere (Smart *et al*. 2009). About 210 (39%) of the Section 42 species of principal importance for conservation of biological diversity in Wales either rely on woodland habitats, or could potentially be affected by silvicultural operations (Russell *et al* 2011).

[13] http://wales.gov.uk/newsroom/environmentandcountryside/2013/130910woodlands/?lang=en
[14] Coed Cymru http://www.coedcymru.org.uk/

7.1 Achievements of GMEP in Year 1

The Glastir Monitoring and Evaluation Programme is using a combined survey and modelling approach to identify the benefits of Glastir interventions at the national scale. Progress to date:

- Field protocols agreed and implemented for recording of woodland habitats and species in GMEP survey squares which includes mapping of woodland habitat, dominant species, management information, land use, vegetation plots in small and large woodland patches and along woody linear features and bird and pollinator recording.
- Assembly of explanatory data to analyse changes in woodland extent and condition and impacts on other environmental and biodiversity response variables.
- Mapping of Glastir interventions to GMEP measurements and Woodland Plan for Wales
- Application of the MultiMOVE niche plant species model ensemble to explore forecasting of the effects of 2 woodland Glastir prescriptions (AWE 9b) Create streamside corridor on improved land with tree planting, (AWE 24) Allow woodland edge to develop out into adjoining fields (see Chapter 2).
- Application of the LUCI landscape ecosystem model to explore forecasting of the effects of 2 woodland Glastir prescriptions and their synergies or trade-offs with other services (see Chapter 2).
- Application of the WDP-EMF model to explore forecasting of the effects of 2 woodland Glastir prescriptions (see Chapter 2).
- Explored habitat connectivity metrics to develop methods for assessing impacts of Glastir measures on connectivity of woodland habitats (see Chapter 4).

7.2 Policy context

Woodland expanded significantly in Wales following the First World War (Quine *et al*, 2011) primarily as a result of increasing conifer plantations. This continued after the Second World War. Concern over the loss and degradation of ancient and native woodland led to formation of protected areas such as NNRs and SSSIs (Russell *et al.* 2011, Latham 2005). More recently there has been a shift for new planting to be Broadleaved rather than coniferous. There is also a move away from felling in even aged stands towards maintenance of forest cover (Mason 2007). The key threats/drivers identified to semi-natural woodland (JNCC 2007, Quine 2011) are overgrazing, habitat fragmentation and isolation, invasion by non-native species, unsympathetic or lack of management, air pollution, landuse change, climate change and new pests and diseases. Climate change is both a threat affecting species composition and woodland condition and a driver of policy change e.g. pressure to increase carbon sequestration or increasing costs of fossil fuels and searches for alternatives may result in increased woodland planting. Although the tree species themselves being long-lived and relatively adaptable may not respond quickly to climate change species using woodlands or those shifting niche in response to rises in temperature or changes in weather patterns (e.g. increased frequency and severity of storms) may change. There may be interactions between threats e.g. tree diseases are likely to have a more severe effect were trees are also suffering from climatic stress.

The Land Use Climate Change report[15] recommended an expansion of woodland over 20 years by about 100 000ha (mainly deciduous but with a proportion of conifer) with tree provenance adapted to the projected climate. This initiative would create a GHG sink and a fuel wood potential. They also recommended management to ensure that woodlands do not become an annual GHG source and that Welsh woods are managed to optimize long term GHG abatement.

[15] Land use Climate Change report to Welsh Assembly Government 2010. http://wales.gov.uk/topics/environmentcountryside/farmingandcountryside/farming/landuseclimatechangegroup/?lang=en

Tree disease and tree health has risen sharply up the political agenda recently with the spread of diseases e.g. *Chalara fraxinea*, *Phytophthora ramorum*, sudden oak death, Dothistroma needle blight and the high number of potential threats that could adversely affect a number of species. *Phytophthora ramorum* was first found in larch trees in Wales in May 2010, since then the disease has spread across much of south Wales and to a few sites in north Wales. A survey in May 2013 identified many new sites. Many larch trees have been felled and more areas are showing signs of infection and will require management (e.g. Cwmcarn forest, Bwlch Nant-yr-Arian near Aberystwyth). Welsh Government has drawn up a disease management strategy for *Phytopthora ramorum* [16]. *Chalara* is also an issue and has been found in newly planted sites in Wales and more recently in the wider environment[17].

There is an increasing interest in the extent to which woodlands are functionally connected (Quine *et al* 2011) and policy for new planting tends to be focused on increasing connectivity within a landscape. Glastir has a series of measures specifically designed to address connectivity which have multiple aims and benefits; to allow the spread of native trees connecting woodland components in the landscape, to enhance the character of the landscape, to encourage habitat diversity and so species diversity, to sequester carbon, to act as a buffer for fields and to increase the extent of woodland.

The Welsh Government strategy ‘Woodlands for Wales’ was published in 2001 and revised in 2012. It promotes the design and management of woodlands to provide a wide and balanced range of ecosystem services. A set of 23 indicators have been developed to measure progress towards achieving the 20 high level outcomes outlined in the Woodlands for Wales’s strategy[18]. These include measures on extent, area of woodland of different types (urban, farm *etc*.) and how that is changing, habitat diversity and species, sustainability of woodland management, carbon balance, tree health, local benefits of woodland, accessibility, value of wood and water management; spanning the range of social, economic and environmental benefits.

Other policy drivers which may affect woodland include the water framework Directive, and strategic environmental impact assessments and the Rural Development Program. In Wales, the Glastir scheme is a significant component of the Rural Development Program and therefore contributes to fulfilling a number of statutory obligations and targets relevant to biodiversity derived from agreements at global (Aichi targets), European (European Union Biodiversity Strategy (EUBS) plus Habitats and Birds Directives) and UK levels (Wildlife and Countryside Act and Natural Environment and Rural Communities Act) which will apply to woodland habitats. Glastir has a specific woodlands element which includes options on creating and managing woodland (see 7.7.3)[19].

[16] http://naturalresourceswales.gov.uk/our-work/policy-advice-guidance/phytophthora-ramorum/?lang=en
[17] http://naturalresourceswales.gov.uk/our-work/news/chalara/?lang=en
[18] http://wales.gov.uk/topics/environmentcountryside/forestry/woodlandsforwales/?lang=en
[19] http://wales.gov.uk/topics/environmentcountryside/farmingandcountryside/farming/schemes/glastir/glastirwoodland/?lang=en

7.3 Current status and trends of woodland stock and condition

7.3.1 Extent

- NFI estimate the total area of all woodland in Wales in 2010 to be 3035000 ha, 14% of Wales[20]
- NFI estimated that between 2001-2010 the area of broadleaved woodland increased by 16000ha and the area of conifers decreased by 13,000ha
- NFI estimated new planting in Wales to be 9300ha between the two periods 1989-90 and 2009-2010.
- NFI estimated that there had been a loss of 133ha of woodland to other land uses between 1997-98 and 2009-10 so overall there is estimated to be a net increase in woodland area.

Other data sources are broadly comparable:

- CS data shows that Broadleaved, Mixed & Yew Woodland covered 8.6% (173,600 ha) of the total area of Wales in 2007 (Smart *et al.* 2009) with 5.0% (105,900 ha) of Coniferous Woodland *i.e.* a total of 13.6%
- CS data showed no significant net change in area of woodland was estimated to have occurred across Wales between 1998 and 2007 however it did demonstrate that there was a significant increase of 12% (8,900 ha) of Broadleaved woodland in the Welsh lowlands between 1998 and 2007 (Smart *et al.* 2009).
- The total area of woodland in Wales is consistent between CS and NFI although Countryside Survey allocates a much larger proportion of woodland to Broadleaved, Mixed & Yew Woodland relative to Coniferous Woodland and this is reflected in inconsistency in changes in woodland area with CS not showing a significant loss of Coniferous woodland.
- There are differences in the way that CS and NFI record woodlands; NFI has 9 forest types (including broadleaved, Coniferous, mixed, Coppice, Shrub land *etc.*). The minimum mappable unit in CS is 20m x 20m, whereas the smallest woodland recorded by the NFI is >0.5ha (either under stands of trees or with the potential to achieve tree crown cover of more than 20% of the ground). There are also differences in definition, CS records the land cover in a parcel whereas NFI records a parcel of land within the woodland cycle as woodland even if there are no trees and another habitat (e.g. heathland) is present, as woodland, so NFI surveys land use rather than land cover.
- In parallel with the rest of Britain, there has been a reduction in the length of managed hedgerow in Wales between 1984 and 2007. Although hedgerow removal was common between 1984 and 1990, there has been no significant loss of length of hedgerows between 1998 and 2007; the loss of managed hedgerows appears due to reduction in management resulting in relict hedges and lines of trees.

Table 7.3.1.1 shows the results of an analysis published earlier this year as a result of discussions between JNCC, the Forestry Commission and CEH in response to concerns about ash dieback and how to estimate the current extent and distribution of ash. The analysis was extended to include the top ten tree species in GB. The figures for Countryside Survey solely represent areas of woodland <0.5 ha, the FC and private estimates are for areas > 0.5ha so the figures are complementary rather than comparative. Oak appears to be the most abundant tree species in Wales. Ash, Birch and Hazel are also quite abundant although beech which is a significant component in GB is at relatively low levels.

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[20] http://www.forestry.gov.uk/pdf/NFI_Wales_woodland_area_stats_2010_FINAL.pdf/$FILE/NFI_Wales_woodland_area_stats_2010_FINAL.pdf

Principal species	Countryside Survey '000 ha	FC '000 ha	Private sector '000 ha	Total estimate '000 ha
Great Britain				
Ash	38.51	3.5	138.1	180.11
Birch	35.23	14.8	212.5	262.53
Oak	48.41	20.4	209.6	278.41
Beech	8.89	14.8	87.8	111.49
Sycamore	21.70	1.5	108.2	131.3
Hazel	8.79	0.6	87.3	96.69
Hawthorn	26.89	0	60.8	87.69
Willow	9.24	0	50.5	59.74
Alder	4.84	1.1	51.9	57.94
Sweet Chestnut	1.36	0.8	27.4	29.56
Wales				
Ash	1.99	0.4	17.2	19.59
Birch	2.43	1.1	10.3	13.83
Oak	5.50	2.4	22.5	30.4
Beech	1.00	1.7	6.1	8.8
Sycamore	1.31	0.1	9.9	11.21
Hazel	1.56	0	12.8	14.36
Hawthorn	1.69	0	5.4	7.09
Willow	1.05	0	8.9	9.95
Alder	1.12	0.1	9.0	10.22
Sweet Chestnut	0.02	0.0	0.4	0.42

Table 7.3.1.1 A real extent of individual tree species in Wales and Great Britain. Data from CEH Countryside Survey and NFI.

7.3.2 Condition

- Coed Cymru state that 'Following a century of neglect and plunder the majority of Welsh broadleaf woodlands had been left in a state of serious decline. 85% showed no significant recruitment of young trees'[21]
- Countryside Survey (CS) showed a significant reduction in species richness in Broadleaved, Mixed & Yew Woodland between the 1990 and 2007 surveys (Smart *et al* 2009). This is consistent with a general trend seen elsewhere in Wales for a reduction in abundance of species associated with canopy gaps, disturbance and an increase in more nutrient-demanding taller plants.
- There was a significant increase in the Grime Competitor Score for plant species in the upland zone in Main Plots between 1990 and 2007 in CS.
- There was a decrease in butterfly larval food plant richness in the lowland zone in Main Plots in CS between 1990 and 2007 reflecting a reduction of an average 3 species per plot over the 17 year period.
- There was no statistically significant change in mean number of Ancient Woodland Indicators in either Main or Targeted Plots either at the country level or within each Environmental Zone in CS.
- The Woodlands for Wales indicators[22] (2012) showed that the population trends of the majority of species of conservation concern are still unknown, however, the population

[21] Coed Cymru http://www.coedcymru.org.uk/

declines of red squirrels and floating water plantain had been stabilised, declines of the pearl bordered fritillary, the great crested newt and Juniper were slowing and the population increase of black grouse had stabilised. There was no significant trend in the woodland bird index between 1994 and 2009.

- There are suggestions that forest holdings although currently a carbon sink[23,24] could become a source for emissions within a decade unless changes in management are implemented.
- Since 2010, there has been an outbreak of one quarantine disease affecting tree species in Wales (*Ramorum* disease) and major efforts are being made to control this. There are also four non-quarantine diseases known to be affecting tree species in Wales[21].

7.4 Aims of Glastir and measures to deliver in the Glastir woodland element

Glastir has a woodlands element which has been designed to support land managers to create new woodlands and manage existing woodland to promote ecosystem services; Biodiversity, Water, carbon, landscape, historic features and access. The woodland element provides area and capital grants for

- Thinning-allowing more light to enter the woodland top improve ground flora and natural regeneration
- Restocking- improving species diversity
- Infrastructure- managing previously inaccessible woodlands
- Boundary work- to stock proof woodlands or improve stock management
- Protected and priority species- grants to conserve important species
- Vegetation management- to control invasive and exotic plants
- Pest control- including grey squirrels and deer
- Public access- to improve woodland access and provide visitor information

7.5 Benefits from interventions / past schemes.

In Wales, funding from agri-environment schemes (AES) that could be related to woodland management has been available since the early 90s including ESAs, the Habitat Scheme, Woodland Grant scheme, Farm and Conservation grant scheme, Tir Cymen, Tir Cynnal, Tir Gofal, Better woods for Wales and now Glastir. A few key results include

- Tir Gofal has been largely successful in maintaining the condition of woodlands and parklands. In woodland light grazing produces the most positive change[25].
- The area of farm woodland within a grant scheme doubled between 2000 and 2012, principally due to a large area of woodland within the Tir Gofal agri-environment scheme[26].

Spatially explicit analysis of the legacy effects of previous scheme impacts on species and habitats forms a core part of the GMEP analytical strategy for quantifying the future impacts of Glastir. This is because lack of change or relatively rapid change could reflect an ecological starting point that has already benefited from a history of agri-environment funding. Detecting these legacy effects of

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[22] http://wales.gov.uk/docs/drah/publications/130514woodlandforwalesindicators2012en.pdf

[23] Emissions and Removals of Greenhouse Gases from Land Use, Land Use Change and Forestry (LULUCF) for England, Scotland, Wales and Northern Ireland: 1990-2011 http://uk-air.defra.gov.uk/reports/cat07/1304150833_DA_LULUCF_GHG__Inventory_report_2013_final_version.pdf

[24] Land use Climate Change report to Welsh Assembly Government 2010. http://wales.gov.uk/topics/environmentcountryside/farmingandcountryside/farming/landuseclimatechangegroup/?lang=en

[25] http://wales.gov.uk/docs/drah/publications/130917report1habitatsen.pdf

[26] http://wales.gov.uk/docs/drah/publications/130514woodlandforwalesindicators2012en.pdf

scheme history will be highly dependent on the quality and quantity of the data available. A more precise assessment of legacy effects comes from having information about the exact duration and detail of the measures applied and where the information is resolved at the level of individual fields and features. High quality data from the previous Tir Gofal scheme has been made available to the GMEP team, and a next step is to develop the analytical strategy that incorporates these data into the detection and attribution of scheme impacts resulting from specific measures to affect woodlands.

7.6 Approach

7.6.1 Woodland recording methods

7.6.1.1 Habitat mapping

In the GMEP field survey every habitat within the 1km square is mapped, this includes areas above 20m x 20m in size, as well as linear features such as hedgerows, smaller patches are not mapped but vegetation plots may be placed in these or some may be described as point features. Each area parcel is assigned to a Broad Habitat, for woodland this is either; Broadleaved, Mixed & Yew Woodland or Coniferous Woodland. Each woodland parcel is also given a structure code as to whether it is Woodland/Forest, a belt of scrub, a Belt of trees, a clump of trees, Dead lying trees, Dead standing tree(s), a Patch of scrub, Ride/firebreak, Scattered scrub or trees (2-5, >6).

As with mapping of the other habitats 2-4 dominant or characteristic species are chosen to represent the parcel and presence and cover recorded. There are additional attributes which may be added by the surveyor to describe the woodland environment. These include;

- Deer fences
- Felling/Stumps
- Fenced (single trees)
- Grazing (stock)
- Grazing/browsing (non-stock)
- Grey squirrel damage
- Natural regeneration
- Open glade and rides
- Pheasants and pheasant pens
- Planted
- Pollarded/Shredded
- Regrowth - cut stump
- Signs of recent management
- Staked trees
- Tree protectors
- Underplanting
- Windblow

They will also be given a use code as to whether the use is Landscape, Nature conservation, Public recreation, Sporting, Shelterbelt or Timber production.

Surveyors also record linear features that pertain to forestry e.g. hedgerows, lines of trees. A lot of additional detailed information is captured on these important landscape features including the base height, most common (modal) diameter at breast height, historic management, staked trees, presence of tree protectors, whether there is a margin on each side and the species and proportion.

Individual trees, scrub, clump of trees, scattered trees, scattered scrub, patch of scrub, dead standing trees and dead lying trees may be recorded as point features, additional information added to this survey asks for evidence of habitat boxes and signs of disease. When recording veteran trees surveyors are asked to identify the species, the modal DbH, the type (standard, pollard or lay), whether epiphytic species are present, the % of the canopy that is live, whether there are dead or missing limbs, tears, scars, lightening strikes, hollow trunk or rot.

7.6.1.2 Vegetation plots

Surveyors would have to set up new vegetation plots in the 1km square. Some of these would be randomly located and according to strict protocols and would likely sample different woodland features including area plots from 2m x 2m in size to large area plots of 400m^2 which could be placed within woodland and Hedgerow plots and Boundary plots 1 x 10m that sample woody linear features. Other plots (Y plots) could be selected according to the requirement to capture information on potential Glastir prescriptions. The surveyors did not have the information on management of the land within a square but suggested locations for vegetation plot placement applicable to woodland included; Broadleaved woodland> 0.5ha, Traditional and newly planted orchards, Broadleaved woodland where natural edge regeneration might be encouraged, newly planted or fenced Woody linear features, Coppice, Clearfelled conifer, Broadleaved wood pasture and areas of woodland priority habitat.

7.6.1.3 Animal, soil and freshwater sampling

Bird and Pollinator surveys took place within and outside of woodlands as did soil sampling, streams and pond surveys. This provides a population from which woodland change can be followed within the context of its surrounding landscape.

7.7 Reporting

7.7.1 Initial assessment of Tir Gofal coverage within GMEP

Figure 7.7.1.1 shows the uptake of woodland measures within Tir Gofal across Wales. Figure 7.7.1.2 shows the proportion of GMEP wider Wales squares with uptake of Tir Gofal woodland measures which is a similar proportion to that across all of Wales. The projected coverage with the GMEP survey of land previously within Tir Gofal is around 5% of all squares in Wales in the wider Wales sample and approx 5% in the targeted over four years. Current targeted squares are based on the Welsh government priorities of carbon and water, the amount of woodland sampled could be higher if priorities changes towards woodland. The next phase of work will be to intersect the GMEP field survey results with each Tir Gofal woodland option at polygon and feature level preparing the ground for a spatially explicit assessment of the contribution of scheme legacy from woodland measures to observed and modelled changes in habitats and biodiversity.

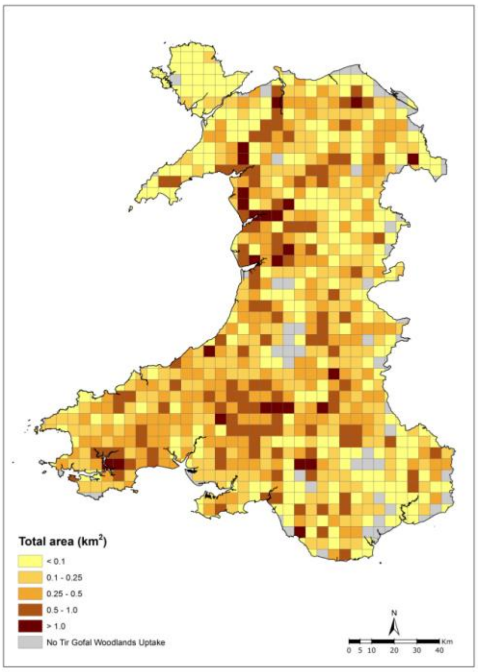

Figure 7.7.1.1 Uptake of Tir Gofal woodland measures across Wales.

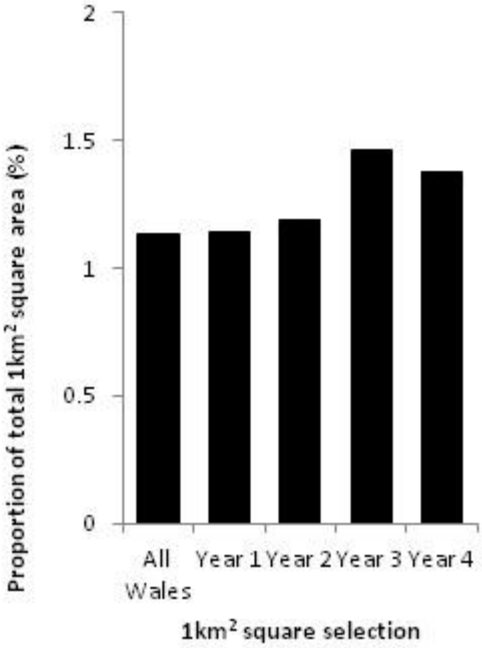

Figure 7.7.1.2 Proportion of total Wider Wales 1km square area with previous and current Tir Gofal uptake for woodland management compared to all squares in Wales.

7.7.2 Coverage of Woodland section 42 habitats in the GMEP sample

Broadleaved woodland was represented in 60% of squares in the first year of survey and Coniferous woodland in 30%, across Wales Broadleaved woodland is found in 70% of all 1km squares and Coniferous in 48% (NRW Phase 1 data). In the wider Wales squares already selected for the next 4 years 65% should contain broadleaved woodland and 50% Coniferous. Figure 7.7.2.1 shows the results from an analysis that overlays GMEP sample squares with woodland Section 42 (Priority) habitats. The GMEP sample is the Wider Wales 1km squares for 4 years (2013-2016) and the targeted squares for 2013 only as the Targeted squares for 2014-2016 have not yet been chosen. An analysis of the Section 42 (Priority) habitats that are covered demonstrates a surprisingly high coverage of traditional orchards but many may be in private gardens which will not be covered in GEMP. Other woodland priority habitats are less well represented however this may change according to priorities assigned to choosing targeted squares. It was agreed with the Welsh government that other approaches may be needed for rarer habitats and work is ongoing to find other datasets which can be used to complement these data.

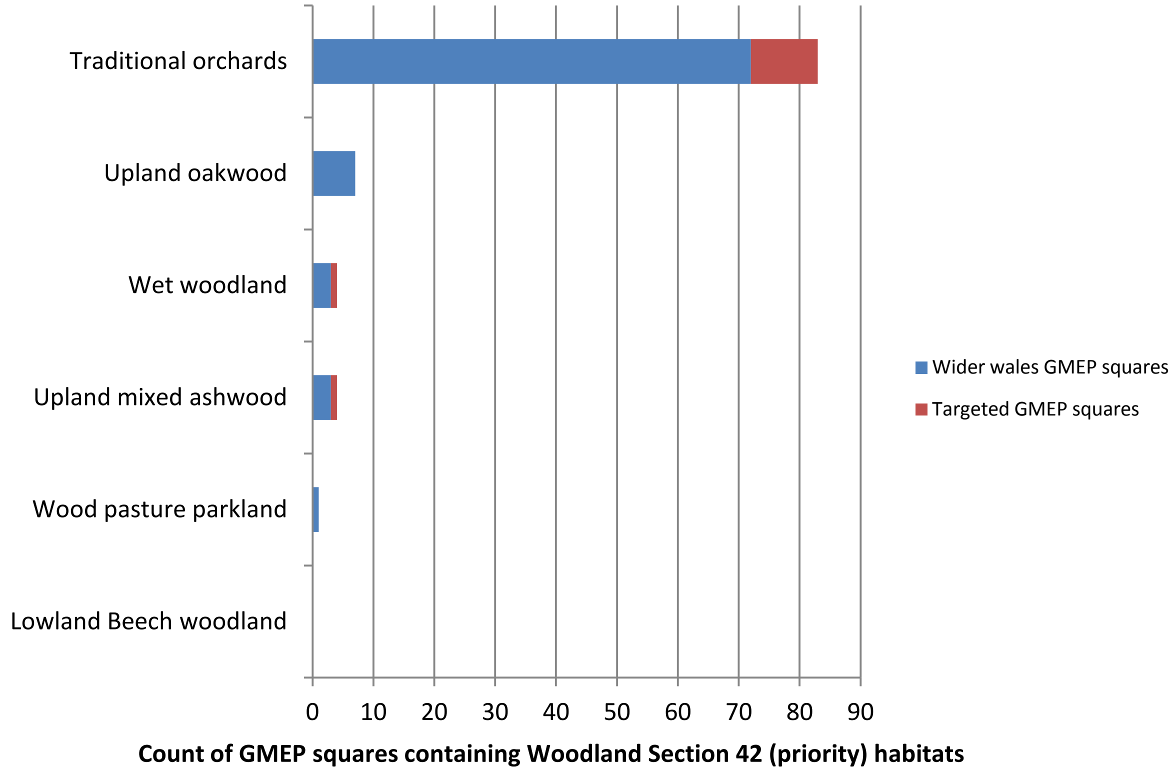

Figure 7.7.2.1 Frequency of section 42 (Priority) woodland habitats in Wider Wales sample squares selected for survey in 2013-2016. Based on intersecting the Countryside Council for Wales LBAP inventory with 1km sample square locations.
Targeted squares have only been chosen for year 1 so numbers may double or more with the inclusion of Targeted squares for future years. This will depend upon the priorities set by the Welsh Government which are currently Carbon and Water. This graph does not show the frequency of priority habitats in Glastir.

7.7.3 Integrated analysis of multiple biodiversity responses and multiple drivers including Glastir

Although woodland is presented in a separate chapter, analyses will be carried out as for the other habitat types and more can be seen about potential methods and analytical processes in the biodiversity chapter. A lot of data is collected in the field survey on woodland habitats that can be exploited. Datasets have also been obtained from NRW and NFI that will be used in analyses alongside the field monitoring data.

Reporting for the impact of Glastir interventions will be focused on developing an evidence base of Impact Indicators for Glastir interventions. Appendix 7.1 shows an example of mapping Glastir Management options to Targets and response variables. We have included all options that may be related to both woodland creation and management and also to improved connectivity of woodland habitats. Data will be integrated from GMEP field survey with external sources e.g. NRW, EA, NFI where necessary to understand both the impacts of Glastir options on woodlands themselves and the subsequent impacts of changes to woodland management, extent and condition on other elements within the landscape e.g. water quality and quantity. Figure 7.7.3.1 is a flow chart (similar to those in the Biodiversity chapter) with woodlands as the target and options associated with woodland creation and management (those in bold on the target checker) identified and linked to GMEP survey response variables and an indication of the analytical pathway.

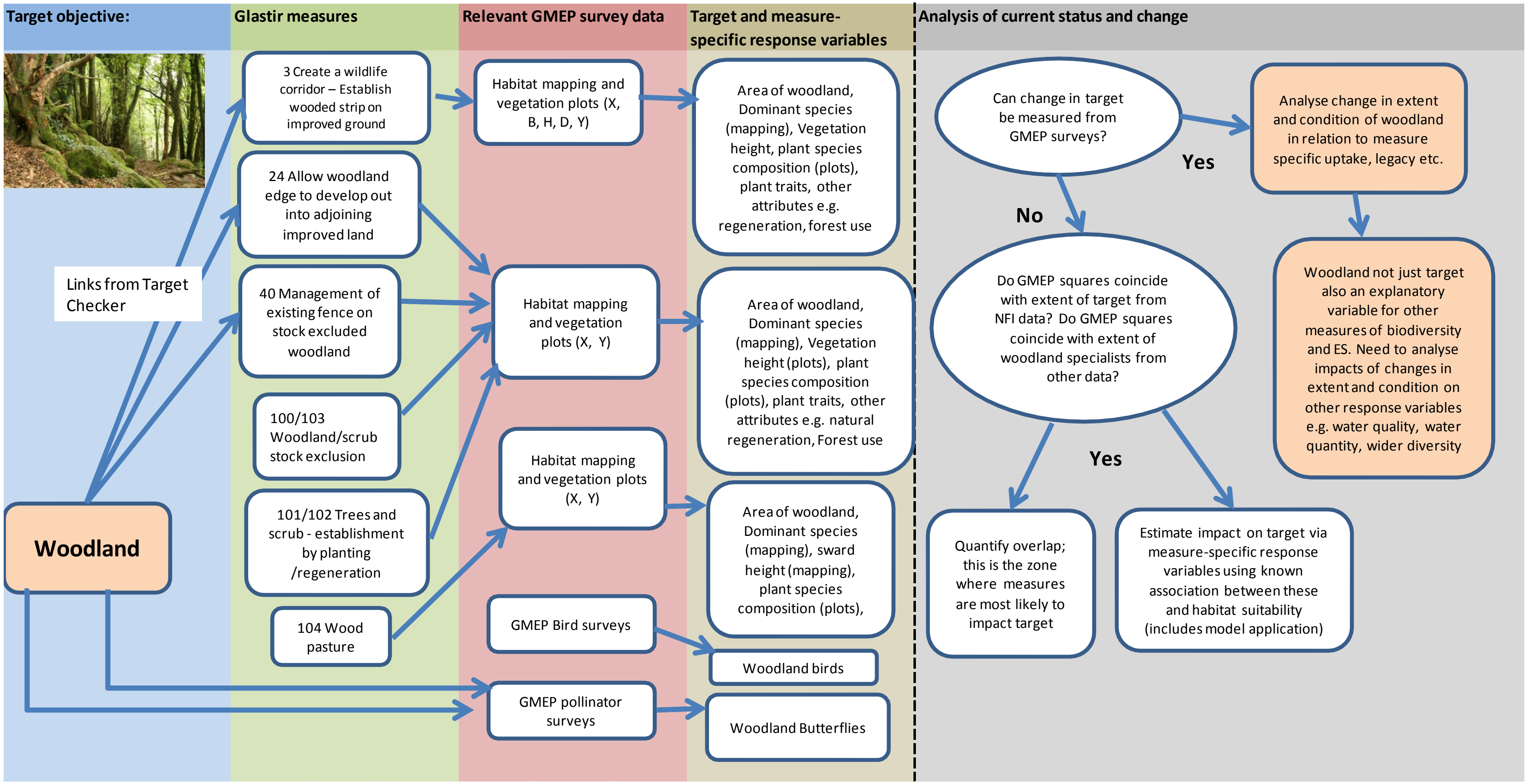

Figure 7.7.3.1 Case study example of analytical pathway with woodland as the target, Glastir woodland options and response variables from the GMEP survey identified.

An important component of all our analyses includes incorporating the legacy effects of previous scheme impacts. In winter 2013-14 we will specifically include those attributable to woodland management. This analysis will provide important evidence about the effectiveness of past AES management and lessons critical to the success of the implementation of Glastir. Analyses will be carried out across species groups and habitats. Detecting signals across multiple biological or environmental variables e.g. soils, waters, plants, birds and invertebrates are a key analytical objective. Year 2 will involve agreeing and testing the technical means necessary to execute these analyses which will form a much broader integrated analytical strategy that seeks to quantify relationships among groups of organisms and to drivers and response variables being measured in multiple work packages.

In addition, the GMEP modelling team will provide ongoing scenario modelling of projected outcomes into the future. In year 1 this included scenario assessment of two woodland Glastir Interventions (see Chapter 2):

- Allow Woodland Edge to Develop Out into Adjoining Field (AWE No. 24)
- Create Streamside Corridor with Tree Planting (AWE 9B)

The Habitats Work Package has ongoing work on habitat connectivity, creating an indicator, (using existing models such as BEETLE and Conefor, attempting to improve model permeability scores and comparing and contrasting between them) and detecting changes in habitat connectivity for woodland species within a 1km square. There is also work extrapolating outside of a 1km square, making the use of the fine scale detailed information collected in the GMEP field survey to find new ways to scale up to the wider countryside and land outside of the 1km squares which will be particularly relevant to woodland, one example being the creation of a linear product mapping woody linear features using the Land Cover Map, CS squares, LIDAR and aerial photography.

See Chapters 2 and 4 for further information.

Finally, GMEP will provide useful indicators for tracking progress on the aims of the Wales Woodland Plan. Figure 7.7.3.2 shows a draft figure mapping outcomes from the woodland for Wales plan to GMEP activities. If desired this could be taken further and broken down into more detail with the plan and indicators already agreed. One option is to establish a woodland topic group to discuss how to ensure best use of all the ongoing monitoring work and how to combine this to track outcomes of the different the Welsh Government policies.

7.8 Plans for Year 2

- The Glastir monitoring and Evaluation Programme will analyse the impacts of Glastir woodland measures on ecosystem services and biodiversity using different analytical and statistical techniques and modelling described in detail in other chapters.
- A Woodlands topic group will be formed to advise and comment on the objectives, analysis, and outputs of GMEP woodland work

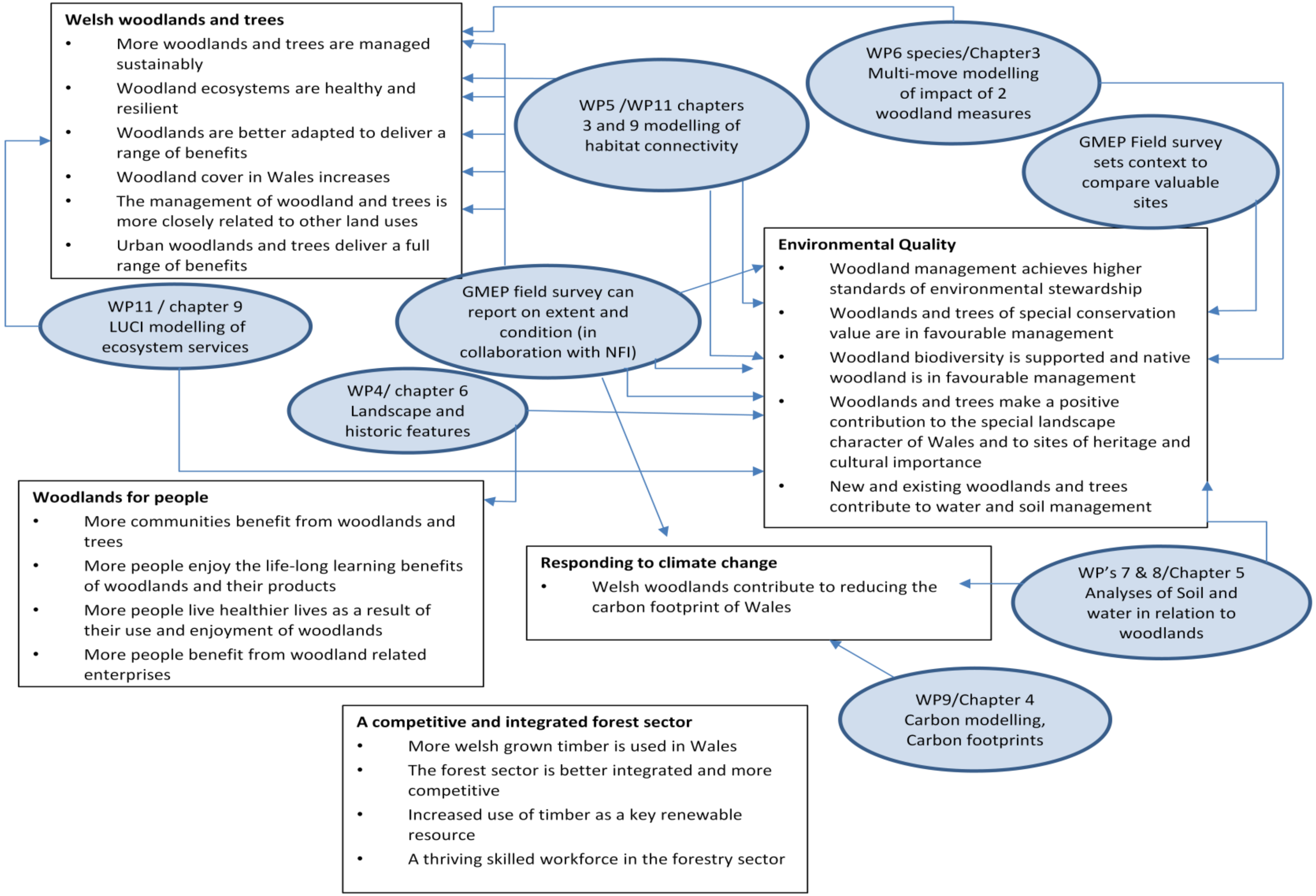

Figure 7.7.3.2 Mapping Woodland plan for Wales onto GMEP activities

8. Soil natural capital and water flow and quality

Robinson, D.A[1]., Edwards, F[2]., Barrett, G[1]., Bradley, D[3]., Carter, H[4]., Cigna, F.[5], Creer, S.[6], Emmett, B.A[1]., Evans, C.[1], Grebby, S.[5], Greene, S[2]., Hughes, S.[1], Jones, D.[6], Keith, A.[4], Kelly, M.[7], Lallias, D.[6], Lebron, I[1].,McDonald, J.[6], Pereira, MG.[4] and Rawlins, B.[5]

[1] CEH Bangor, [2]CEH Wallingford, [3]APEM, [4]CEH Lancaster, [5]BGS , [6]Bangor University, [7]Bowburn Consultancy

Farmers not only provide the food and nutrition supporting human existence, but they act as stewards of the land. Good stewardship can unlock nutrients from soils and manage water effectively to create and sustain biodiverse habitats. Conversely, poor understanding of best management practice, or poor stewardship, can lead to habitat degradation and a depletion of soil natural capital stocks. Farmers are often asked by society to tread a narrow path, producing food without degrading the landscape. Agricultural management and disturbance can be important for unlocking nutrition and enhancing water, soils and biodiversity, but too many inputs, over stocking, or emphasis on monocultures can lead to environmental damage. Aside from food production, water and soils fulfil important regulating and cultural ecosystem services (NEA, 2011). Clean water from reservoirs minimizes treatment for human consumption; soils can buffer floods and droughts which can cause major social and economic damage. Regulation of water quality and flows is inextricably linked with soils and their functionality. Moreover, soils control and regulate the recycling of waste and nutrients, but excessive nutrient inputs can lead to runoff and pollution of water bodies. Soils are a major carbon store and can either help to reduce climate change by sequestering CO_2 from the atmosphere, or in some circumstances add to climate change through methane and nitrous oxide emissions. Soil and water bodies also provide important habitat and gene pools; antibiotics were first extracted from soils and now fulfil vital roles in human and animal medicine (Robinson *et al*, 2013a). Soils and surface waters are vulnerable to degradation and threatened by over-intensive landuse, pollution and climate change, and must be managed with care.

8.1 Major achievements in Year 1.

Work to establish an effective and efficient monitoring programme for soils and water has been undertaken in Year 1. Major achievements include:

Freshwater (see also modelling work in Chapter 2)

- Successfully trained 13 surveyors to deliver the recognised biomonitoring standard protocols for streams where they occurred in the 60 1km survey squares. Methods compatible with EA/WFD data and also other long running monitoring programmes such as Countryside Survey CS, Environmental Change Network.
- Delivered established and proven techniques for ponds (there is no standard UK/EU protocol as for streams) compatible with Countryside Survey data, and pond survey data provided by the Fresh Water Habitats Trust.
- Strict biocontrol and H&S policy followed
- Successfully delivered first survey of its kind to simultaneously monitor freshwater invertebrates + diatoms (streams only) + macrophytes + physical habitat + water chemistry, in both ponds and streams.
- Obtained added value on ponds through molecular tracer work on great crested newts
- Transferred all the field forms for all these biomonitoring techniques into a holistic software package

Soil (see also modelling work in Chapter 2 for erosion)

- Main survey pilot and preparation:
  - Trained 13 surveyors in soil sampling methods.
  - Made a 25 minute training film of how to sample the soils.
  - Developed new lab protocols and tested / bought equipment to improve efficiency including methods tested for quantifying soil biodiversity uniquely for all Welsh soils.
- Topsoil sampling: 1500 samples collected from 300 plots coincident with permanent botanical survey using methods appropriate for physical, microbial, chemical, carbon and invertebrate analysis.
- Climate change:
  - Proof of concept work completed for measuring change in peat height using remote sensing.
  - Proof of concept work completed for identifying bare peat, susceptible to erosion, from air photos.
- Erosion: BGS has provided model runs of soil erosion by water and wind using the PESERA model for Wales (see also Chapter 2)
- External data sources: Gathered other sources of soils data including NRW data sets to enhance and compare data collected within GMEP

8.2 Status and trends

Freshwater

The National Ecosystem Assessment reported that Welsh upland rivers are particularly vulnerable to acidification, while those draining more intensive agricultural land are at risk of eutrophication through nutrient loading. Recent assessments indicate that from 1990 to 2008 river water quality has improved (NEA, 2011, Smart *et al*., 2009). Nutrient loading is a major threat with 8% of Welsh rivers being regarded as high in phosphates, and monitoring indicating an increase in algal blooms during the 1990's associated which high nitrate concentrations, which since 2000 appears to be declining. Acidification has also been observed to be declining in upland freshwaters, whereas Dissolved Organic Carbon (DOC) has been increasing.

Soil

Countryside Survey (Emmett *et al*., 2010) produced the most recent results for state and change trends of topsoil across Wales over the last 25 years; a summary of the major findings from that report and other recent material follows:

Soil organic carbon: develops soil structure, retains nutrients and water, whilst soils act as the major terrestrial carbon store buffering change in climate. The importance of soils to carbon mitigation is demonstrated by the calculation that a 1% loss of carbon from UK soils would be equivalent to the UK's annual fossil fuel emissions (PB13297, 2009). Soil carbon was thought to be showing a major decline in England and Wales initially linked to climate change (Bellamy, 2005) and then land management (Kirk and Bellamy 2010) but analysis of Countryside Survey (CS) and other soils data have subsequently shown no overall change at a national scale at GB level or its constituent countries (Reynolds, 2013; Chapman, 2013). The one consistency between all three surveys is a decline in soil carbon in arable systems assumed to be due to constant tillage and high nutrient inputs.

Soil pH: Soil pH gives an indication of soil acidity, prevalent in the Welsh uplands, and therefore has direct policy relevance in a number of areas. Acid soils increase the availability of aluminium, toxic to many plants, whilst decreasing the availability of nutrients and thus determining habitat suitability for plants. Moreover, it helps determine the response of plant species to changes in atmospheric nitrogen and acid deposition. CS showed that the most acid soils in Wales were those beneath

Coniferous Woodland (pH 4.14) in 2007. Soils beneath the enclosed farmland Broad Habitats were the least acidic reflecting both the inherent soil properties of the soil exploited by different land uses and different inputs during management. The mean pH of soils increased significantly between 1978 and 1998 accounting for much of the significant increase in mean soil pH between 1978 and 2007 indicating much of the benefit of reduced acidic inputs has already been gained. For Coniferous Woodland, Acid Grassland and Dwarf Shrub Heath however, there were no significant changes in mean soil pH between any of the Surveys or across the entire period between 1978 and 2007 (Emmett *et al*., 2010) reflecting their low buffering capacity and weathering rates and thus slow recovery times. Several reports have shown that many Welsh grasslands are increasingly sub-optimal for sward/forage production (PCC, 2012; Gibbons *et al*., 2013). Results reported in the recent EA report on Glastir (EA, 2012) found that 80% of all fields tested were too acidic for optimal plant growth, which also poses a leaching risk to water courses. Analysis of farms under the Cefn Conwy Programme revealed that this sub optimal pH is due to a reduction in lime application, primarily for economic reasons (PCC, 2012). While the immediate impact of operating at sub-optimal pH is lower livestock live-weight gain, it also results in inefficient use of N and P which is an economic loss to farmers and is potentially highly damaging to the environment (*i.e.* increased N_2O emissions, increased P and N loss to freshwaters). It remains critical therefore to simultaneously monitor the trends in both soil acidity and nutrient levels to see if this represents a long-term decline and how Glastir interventions affect this.

Olsen-P: is widely used in England and Wales to assess the fertility of agricultural soils (MAFF 2000). It is also helpful when used in conjunction with the phosphorus sorption index to provide an index of the leaching risk of dissolved P from soils to freshwaters (Hughes *et al*., 2000). Olsen-P has been recommended as a UK indicator for environmental interactions between the soil and other linked ecosystems such as freshwaters (Black *et al*., 2008). Concentrations in soil (0-15cm) were measured by Countryside Survey in 1998 and 2007 (Emmett *et al*., 2010), data indicated there had been a significant decrease in Olsen-P concentrations in topsoils for the improved grasslands and infertile grassland. The recent data from EA (EA, 2012) showed that 31% of farmers fields tested were below optimum levels for P, however, they note that in many situations this was on upland soils, which are not naturally productive, nor suited to retaining P. Conversely, 32% of fields were at index 3 or above requiring no extra inputs. Whilst only 1% of fields tested had very high P levels posing a leaching risk.

Total Nitrogen: Soil total nitrogen concentration and stock are important measures of soil fertility. They are relatively insensitive to short-term changes, but over a longer time period give an overall indication of trends in soil fertility and changes in nutrient status in relation to other parameters such as carbon (Emmett *et al*., 2010). The only Broad Habitat to have sufficient data to provide stock and change statistics in Wales was improved Grassland, and showed no significant change in soil N concentration between 1998 and 2007. Total N density in Improved Grassland in Wales in 2007 (7.2 t/ha) was relatively high compared with other countries and with GB as a whole. Infertile Grassland and Fertile Grassland were the only vegetation types in Wales to have sufficient sample points to provide valid statistics for stock and change showing mean concentrations of total N did not change significantly between 1998 and 2007 in either vegetation types.

Recent years have also seen an increasing uptake of outwintering livestock (e.g. on brassicas, maize) irrespective of whether they are in agri-environment schemes. The benefit of this management strategy is that it reduces cost, improves livestock welfare and also provides valuable habitat for farmland birds. Monitoring under Tir Gofal, however, showed that outwintering both cattle and sheep caused a decline in soil quality and greatly exacerbated the risk of soil erosion (Jones *et al*., 2012). This highlights the trade-offs between the potentially positive benefits (e.g. birds) and negative consequences (e.g. soil quality) of individual agri-intervention measures.

8.3 Aims of Glastir

The aim of the Glastir monitoring of soil and water quality is to collect evidence for the effectiveness of bundles of management interventions in helping deliver improved soil and water quality that will address the outcomes of interest related to climate change, biodiversity, soil and water quality and woodland expansion. The compatibility of the current monitoring with Countryside Survey means it can draw on this data record to understand and disentangle changes in national trends from the specific impact of intervention bundles. The monitoring is also required to collect evidence to quantify the status and trend of water and soil quality in general for other reporting requirements and this work will provide an important counterfactual evidence base. Synthesis and analysis of this data will seek to identify how the Welsh environment is being impacted by drivers of change, such as landuse, climate and pollution over and above Glastir interventions. Much of the data from the soils work package will not only provide evidence in the integrated analysis, but will also help support he modelling previously described in this report for specific bundles of interventions.

With regard to water and soils GMEP aims to elucidate the spatial and temporal links between land management interventions and the quality of freshwaters, in particular ponds and head water streams. These small water bodies reflect their surrounding area, unlike larger rivers and lakes that reflect whole catchments areas. Thus the chemical and ecological quality of streams and ponds are a good indicator of Glastir interventions and any potential effects. For the first time in a survey of this scale and scope, the programme will simultaneously survey macroinvertebrates, diatoms (streams only) and macrophytes to maximise the potential to detect ecological patterns and trends, and our ability to link them to soil and water quality. Habitat surveying will provide a measure of habitat degradation/modification, which can strongly influence the ecology and may make freshwater bodies more susceptible to other stressors such as nutrients, low flows or fine sediment. The holistic approach delivered by GMEP will 1) provide us with greater power to detect deviations from baseline/reference conditions, 2) enhance our ability to disentangle the effects of multiple stressors and of Glastir interventions, and 3) help us attribute reasons for changes to ecological quality.

When expecting to see the impact of interventions it is important to consider that based on the findings of the soil quality monitoring performed under Glastir, alongside previous national surveys (e.g. Countryside Survey), it can be expected that major changes in soil quality at the national level will not be revealed in the short-term. For example, 10 years of monitoring are typically required to reveal significant changes in soil carbon status. Although the rolling monitoring programme implemented under Glastir has greater statistical power than previous surveys, it is still unlikely that trends in soil C will become apparent for at least 5 years or possibly longer, though it has the advantage of linking to the 30 year Countryside Survey data set which will provide greater statistical power. In contrast, changes in soil pH may occur within a shorter timescale if there are significant changes in the frequency or amount of lime that farmers apply. In terms of below-ground diversity, shifts in soil organisms will occur over the same timescale as changes in soil carbon and pH, however, they will also reveal changes in current and emerging plant, animal and human pathogens. If they are occurring, we would expect to see significant change within a 5-10 year timescale. In the case of extreme events (e.g. extensive upland fires during very severe droughts, excessive winter rainfall) then the changes in soil physical, chemical and biological indicators may be seen much faster depending on the number of samples taken before and after the extreme event (< 3 years after the event). The archive of soil and its DNA will also allow us to retrospectively investigate an impact of an extreme event for variables which are not currently being measured (e.g. viruses, radionuclides, unusual elements such as fluorine, organic contaminants which may impact on soil after from atmospheric contamination or landspreading activities).

8.4 Benefits of past schemes

In Wales, funding from agri-environment schemes (AES) has been available since the early 90s including ESAs, the Habitat Scheme, Woodland Grant scheme, Farm and Conservation grant scheme, Tir Cymen, Tir Cynnal, Tir Gofal and now Glastir. Monitoring of farms under Tir Gofal (Welsh Government, 2013) reported that, 'Soil pH and extractable phosphorus levels were observed to be lower on Tir Gofal farms compared to non- scheme farms. However, this difference may not be due to Tir Gofal management, and was thought instead more likely to be attributable to Tir Gofal management options being applied to areas of more marginal land. Across all the remaining soil quality indicators (bulk density, erosion vulnerability, depth of peat material, organic carbon and carbon to nitrogen ratio) no positive differences were recorded between Tir Gofal and non scheme farms.' Although the report revealed few positive benefits to soil quality in comparison to farms that had not entered the scheme, this finding could be due to several factors. Firstly, the monitoring timescales (< 3 years) may have been too short to determine significant change, secondly the pair-wise comparison of farms in and out of the scheme may have been the wrong sampling approach (*i.e.* not enough samples, incorrect pairing), and thirdly there may actually have been no significant benefit from the scheme. As it is impossible to resolve which of these three are valid, it is hoped that the current Glastir monitoring statistical design will help resolve these issues.

The 2007 Countryside Survey (CS) reported for Wales that the area of standing waters and rivers and streams remained stable since the previous CS in 1998. The number of ponds increased by 18% in Wales between 1998 and 2007, with most of the increase taking place in the lowlands. In 2007, ponds supported an average of 10.7 wetland plant species per pond. Only 5% of ponds were deemed to be in good condition based on physical and ecological assessments. Plant species richness in streams remained stable between 1998 and 2007 though there was considerable turnover of species. The physical characteristics of streams improved between 1998 and 2007, driven by an increased occurrence of in-stream and bank-side gravel bars, river-side trees and a greater diversity of natural features e.g. fallen trees and debris dams. Plant species richness of streamsides, in particular the richness of butterfly larval food plant species, decreased in Wales between 1990 and 2007. Over time there has been a successional process with vegetation becoming taller, particularly in lowland areas. This trend has also been seen across the whole of Britain since 1978.It is unclear top what extent this was deliberate amelioration or an indirect effect of waterside natural succession.

Exploring the evidence base for impacts of agri-environment schemes beyond Wales, Defra commissioned a report published this year (FERA, 2013) to determine what evidence there is for management options supporting outcomes. The following is a summary from the synthesis conducted:

Climate change: The report noted that, 'The evidence for impacts on carbon sequestration in particular is weak as much is based on assumptions rather than measured impacts and is dependent upon the change being maintained.' Of the work conducted Defra commissioned several pieces of work to determine the impact of different management options on greenhouse gas (GHG) emissions compared to no added interventions (BD5007; BD2302). The synthesis reports that, 'This work compared the greenhouse gas emissions from stewardship options with a baseline (arable cropping). It identified that any option that resulted in a reduction in the use of inputs, especially nitrogen fertiliser, and or the removal of land from production would result in a reduction of emissions from that land.' In addition, it reported that, 'One of the clear areas that demonstrated the potential for large greenhouse gas emission savings was the protection and restoration of blanket bog.' It also noted that an improvement in definition and mapping would be helpful in this effort.

Resource protection (soil and water quality): The report found that relatively few studies investigated the effect of specific options on resource protection or provided evidence for the effect of agri-environment schemes overall on soil and water quality. In England soil erosion is a major concern from arable production; this is a much lesser issue in Wales where the emphasis is grassland production. A statement still relevant to Wales was that, 'for nutrient management, reducing nutrient inputs at source and reducing the pool of nutrients (within the soil) available for loss can be one of the most effective methods for reducing nutrient pollution from agriculture (Newell Price *et al*., 2011).' Winter cover crops have been shown to be effective at reducing nitrate leaching losses. Whilst taking field corners out of management can be effective at intercepting sheet wash like riparian buffer strips which are also very effective preventing watercourse pollution, but have no impact on pollutant losses via drain flow. Low input grassland produced limited additional benefit reducing nitrogen inputs at source, reducing leaching. With regard to upland soils there are interventions that should protect organic soils with practices such as grip blocking, livestock exclusion and shepherding. However, the synthesis reports that, 'there is very little or inconsistent science-based evidence on the effectiveness of these measures on bog restoration or water quality and no information on the effectiveness of specific environmental stewardship options.

Biodiversity: interventions and evidence reported on biodiversity focuses predominantly on birds, with insects and mammals being reported. There are no interventions linked to maintaining, or enhancing, soil biodiversity so there is no evidence base regarding interventions and soil biodiversity.

Woodland expansion: not considered

8.5 GMEP Methods for Soil and Water

The statistical design of the sampling is robust and intended to determine status and trend of the countryside and the Glastir interventions particularly those prioritised by the Welsh Government in the Advanced Element. Thus location for sampling in our Targeted Survey is proportional to the points available in the Advanced Element for different parcels of land. The sampling methodology for soils and water has been used effectively by the Countryside Survey for the last 30 years (Reynolds *et al*., 2013) The water methodology and techniques are those adopted through the Water Framework Directive and the soils technique has more recently been adopted by the EU for the monitoring of agricultural ecosystems across Europe under the LUCAS program (Toth *et al*., 2013). New developments include adding additional metrics (e.g. more wide ranging biodiversity measurements and peat monitoring methods) and the combining and co-location of chemical, biological and physical measurements (e.g. the freshwater sampling).

8.5.1 Water Quality

The 60 squares were sampled for 1 headwater stream and 1 pond when present. These small water bodies are the best representatives of water quality because they reflect the biological processes and pressures that are found in each square, unlike a wider river or lake, which reflect whole catchments and basins.

The techniques deployed in rivers are all the accepted biomonitoring standards as adopted at the UK and EU level, thus our results can be directly compared to Environment agency WFD monitoring data, and our findings will be presented against the background of wider EU legislation. These survey techniques were macroinvertebrates (RiVPACS), diatoms (only, DARES), macrophytes (MTR) and habitats (RHS). In ponds, the techniques most widely used, and recommended by the Freshwater Habitats Trust, were used (there is no recognised standard technique at either the UK or EU level) to monitor macroinvertebrates, macrophytes and habitats.

These techniques will able us to determine chemical water quality as well as ecological quality, the principle end point of the WFD. See Chapter 3 for a fuller description of sampling methods.

The range of metrics undertaken will allow direct or indirect assessment of the impact of individual or bundles of Glastir interventions (Table 8.5.1.1).

Outcomes	**Glastir Entry management option bundles**	**Glastir Advanced management option bundles**	**Water quality measurements contributing to understanding of how interventions impact outcomes**
Climate change mitigation			
Soil and water quality Resource protection	Creation of streamside corridors, reducing erosion runoff into streams via rough grassland field corners or by planting cover crops. Pond creation	Low input management, buffer zones to prevent erosion and runoff, streamside corridor management	Width/depth, Substrate, Shading Map variables: Altitude, distance from source (stream only), slope (streams only) Alkalinity, Nitrogen,
Biodiversity	Creation of streamside corridors, Pond creation and buffers.	streamside corridor management	Macroinvertebrate survey, Diatom survey (streams only), Macrophyte survey, Habitat survey
Woodlands		Woodland stock exclusion	Incidence of poaching, river habitat survey

Table 8.5.1.1 Table demonstrating how outcomes are linked to major management intervention bundles in Glastir Entry and Advanced and how the major measurement parameters map onto these for the stream and pond survey. Measurements are also used in combination with the modelling described in chapter 3 to test how measures impact outcomes.

8.5.1.1 Examples of intervention assessment streams and ponds

Creation of streamside corridors and corridor management (e.g. measures 7A-9 & 173)

Streamside corridors are important for water quality and biodiversity because they provide a buffering zone between the terrestrial and aquatic environments. They are of direct importance to streamside fauna such as some birds and mammals which rely on riparian zone habitat of good quality. Streamside corridors are beneficial to water quality because they retain pollutants in run-off and soil water, such as fine sediments and nutrients. This improves the chemical quality, as well as the habitat quality of streams and rivers, and thus ultimately governs to a great extent ecological quality. We are taking direct measurements of the quality of the riparian zone through habitat surveying and also make direct measurements of chemical water quality. Our proxy measurements are focused on ecological quality and essentially describe the plant, algal and invertebrate communities using standard bio-monitoring techniques. Data analysis will include not only information the land and Glastir interventions within the 1km sampling square but also the context of the land and type of interventions in the catchment upstream of the sampling point.

Pond creation and protection (e.g. measures 35B & 36)

Ponds often have unique biodiversity in their fauna and flora which is not found in rivers and streams, or larger standing waters such as lakes. At the landscape level, the number of ponds and the distance between them is important to maintain this biodiversity; for example if a pond dries over the summer, the recolonisation by biota is very dependent on neighbouring ponds. Thus it is important to maintain wide networks of ponds, and create new ones where they have been removed or heavily modified. It is also essential to exclude cattle and other livestock from ponds to maintain the physical quality of the habitat, particularly the marginal zone which often provides a refuge for juveniles of invertebrates and amphibians. We are taking direct measurements of the chemical quality and physical quality of ponds, and in the same way as streams, we use the plant and invertebrate communities to assess ecological quality, and provide a proxy for the effectiveness of management measures.

8.5.2 Soil Natural Capital Stocks

Soil samples are taken from 0-15 cm in each 1km sampling grid square; there are 60 squares in the first year and 90 in subsequent years. Each plot is divided into 5 segments and 5 plots are randomly located in the square, 1 in each segment, and used to assess flora and soils. At each plot five soil samples are taken, a physical, chemical, and mesofauna core, a composite core for soil microbiology and a composite core for soil carbon that will only be taken in the first year for comparison with other cores. The soil sampling methodology and basic analysis are similar to that described in Emmett *et al*. (2010) for Countryside Survey. However, GMEP has expanded analysis in areas that will better help explain soil status and trends for the reporting requirements for four of the Glastir outcomes; climate change, biodiversity, water and soil quality and woodlands. Moreover, the sampling fits with an assessment of soil natural capital, something for which a framework has been proposed but is yet to be more widely agreed upon (Robinson et al., 2009; Robinson et al., 2012b). Table 8.5.2.1 presents this natural capital framework, and shows how the sampling used to address the outcomes also assesses the different components of soil natural capital.

Soil Natural capital	**Measurable or quantifiable soil stock**
MASS	
Solid	***Inorganic material I) Mineral stock and II) Nutrient stock***
	Organic material I) OM/Carbon stock and II) Organisms
Liquid	***Soil water content***
Gas	*Soil air*
ENERGY	
Thermal Energy	*Soil temperature*
Biomass Energy	***Soil biomass***
ORGANIZATION / ENTROPY	
Physicochemical Structure	*Soil physicochemical organization, soil structure*
Biotic Structure	***Biological population organization, biodiversity*** *and food webs*
Spatiotemporal Structure	*Connectivity, patches and* ***gradients***

Table 8.5.2.1. A summary of the soil natural capital classification adapted from Robinson et al. (2009); the table does not provide an exhaustive list but acts as a guide for classification and demonstrates how the analysis conducted to report on outcomes for the GMEP also addresses assessment of many soil natural capital stocks, highlighted in bold.

This monitoring represents a major sampling effort resulting in the collection of 1,500 soil samples in year 1. The soil samples from the 300 locations will be processed and analyzed for 20 major analytes resulting in a data set with more than 6,000 measurements. See Chapter 3 for a full description.

8.5.2.1 Soil Biodiversity and function

Below ground biodiversity is largely overlooked in most ecosystem assessments, yet is fundamental to the health and wellbeing of habitats above ground (Wall and Moore, 1999). GMEP will take a global lead in the assessment of below ground biodiversity taking advantage of the revolution in genetic measurement techniques (Appendix 8.1), as there is increasing realisation that soil and the organisms contained therein are central to the delivery of many ecosystem services (e.g. landscape C storage, flood risk management, water quality, pollutant abatement, food security, nutrient cycling, pests and disease control (Wall, 2004). We need a step change in our understanding and ability to predict soil function. Establishing links between soil biota and soil function may hold the key, and these new techniques are proving promising. First steps include evaluation of the best DNA extraction methods for Welsh soils, which will allow evaluation of soil bacterial and fungal biodiversity, the challenge is then to determine how these species functionally link to soil processes and ecosystem services, and how management interventions may impact their functional role.

8.5.2.2 Soils and Climate Change
Soil samples measured in the Wales survey squares will be analyzed for soil carbon concentration and density. Two approaches are being pursued, a single core measured at every plot and analyzed for soil carbon, and a new composite sample representing the bulking of five auger cores taken from the corners and middle of the X-plots to compare with the single core samples. The strategy is to reduce measurement uncertainty and obtain a more representative determination of soil carbon concentration. These values will be compared with the 30 year Countryside Survey record. In addition, a range of explanatory variables are measured such as soil pH and texture that will better allow us to understand the dynamics of this carbon pool better. Also see section on vulnerable habitats where work on peatlands is described (Section 8.5.2.4)

8.5.2.3 Woodlands
Expanding woodlands is likely to lead to a range of changes in soil status. CS data reported in 2010 showed that soils under conifers were the most acidic in Wales, so there may be some expectation of a change to conifer acidifying soil. However, a change to Broadleaved Woodland showed an increasing pH in terms of direction of change. Carbon levels under broadleaved and conifer woodland showed no significant direction of change during CS and there is no current consensus as to whether trees increase or decrease soil carbon sequestration planted on grassland or moorland soils. Only on arable soils is there a clear evidence base. Moreover, tree rooting systems expand soils altering density and porosity often increasing soils capacity to infiltrate and absorb water. This is why the measurement of density and texture are important, and will help us to determine changes to water release characteristics that will help with better ecosystem modelling, In particular benefits of strips of trees planted in strategic parts of the catchment to capture runoff as observed in the Pontbren catchment are of interest (Carroll *et al* 2004). In addition, trees, especially conifers, can lead to the development of soil water repellency which changes soil infiltration from being predominantly piston flow to bypass flow; this may impact water regulation and nutrient cycling. This will be the first national survey to incorporate the measurement of soil water repellency.

Table 8.5.2.4.1 shows the linkage from outcomes that we are required to report on, the bundles of measurements aimed at contributing to these outcomes, and the major measurements we are making in order to assess the interventions. Some, for example carbon measured by loss on ignition are direct measurements, where as many are proxies for what we want to know and used in combination with other soil and environmental measurements to assess status and trend. In addition, the measurements are used interactively with the modelling effort described in chapter 3 providing much needed input data. The GMEP uses a stratified approach; although, even with this it is unlikely that the monitoring will be able to report on some of the least abundant habitat types such as saltmarsh and sand dunes, which is where the linkage with modelling is the most powerful approach allowing us to at least make a basic assessment. Many of the intervention in Glastir are designed to protect and build the quality and health of the soil. Building the quality of the soil is important because it can act as a buffer against market price shocks and sudden increases in fuel and fertiliser prices. Degraded soil is poor at retaining nutrients and water, whilst by building up the soil infrastructure with more carbon and organic material it can hold more nutrients that can act as a buffer, so that should a sudden and temporary increase in fertiliser price occur, the grower can draw on the nutrient stock that has been built up in the soil. The nutrient stock is not built up by adding manufactured fertiliser to degraded soil; the nutrients are simply lost, leached out causing pollution of water courses and ground water. In the following we look at some of the intervention bundles and how our measurements will address the assessment of them.

8.5.2.4 Examples of intervention assessment soils

Improved nutrient management and cycling (e.g. measures 14, 14B, 155 & low input systems)

Recycling nutrients from slurry reduces manufactured fertilizer inputs, but moreover puts organic material back into the soil often with some micronutrients. The organic material helps to develop the soil structure and quality. We will measure directly the carbon content, nitrogen and phosphorous content, and measure proxies such as pH, solution electrical conductivity, and hygroscopic water which allows us to determine if there is an increase in the soils ability to absorb water, a proxy for surface area, on which nutrients are retained; these measurements tell us more about soil health and inform changes observed in water quality.

Protection and restoration of bog and fen by reduced intervention (e.g. measures 139, 140, 141, 143, 144,160)

Drainage and heavy grazing in bogs causes problems because it erodes the organic soil. Carbon is oxidised and lost to the atmosphere by drainage and an increase in pH from liming, whilst heavy trafficking by livestock causes physical erosion. We will be measuring in bogs a wide range of metrics including the direct measure of carbon, the bulk density, and depth to 1m. Moreover, we will measure proxy parameters such as pH, water content and nitrogen content that help us to determine the status and quality of the bogs stability. Mapping the extent and change of bog area is challenging, time consuming and expensive, we have demonstrated that a combination of airborne and satellite borne remote sensing could be used at a resolution suitable for intervention assessment to determine extent of eroded peat, and bog height, for which the trend in time could indicate if a bog is accumulating or degrading.

Maintaining hay meadows (measure 22)

Hay meadows which are biodiverse above ground are often biodiverse below ground. Below ground soil biodiversity is considered to be important for maintaining the function of soils and the gene pool. Many people don't appreciate that we obtain important biomedical resources from soils, such as some antibiotics. Soils continue to provide unusual organisms that are useful for maintaining our wellbeing. It is likely that biodiverse meadows are less vulnerable to spreading pathogens, something we are interested in exploring. We are using a range of established and new direct measurements of soil biodiversity, the new ones using DNA extraction methods and assessment to identify groups of organisms.

Woodland management and expansion (e.g. measures 1, 1B, 13, 24,100,101,102)

Allowing woodland to expand is good for habitat development, sheltering livestock and sequestering carbon. We will be measuring a range of parameters allowing us to assess how soils are changing through the conversion of land to woodlands. Measurements include nutrients, carbon, hygroscopic water content Moreover, we are also measuring soil water repellency (SWR), traditionally associated with establishment of conifers. SWR changes the infiltration characteristics of the soils and has been associated with increased nutrient loss to water courses following burns, and large summer rainfall events.

Outcomes	Glastir Entry management option bundles	Glastir Advanced management option bundles	Soil measurements contributing to understanding of how interventions impact outcomes
Climate change mitigation	Orchard and individual tree planting, Slurry injection, Grazing management.	Slurry injection, Grazing management, woodland stock exclusion and tree planting, protection and restoration of bog and fen, conversion of	Total Carbon (LOI), Bulk density, Total Nitrogen, Soil texture (sand, silt, clay), Soil water content, Soil solution pH (water) (Remote sensing of Welsh peatlands, depth measurements to
Soil & water quality Resource	Slurry injection, Low input management, Bracken control,	Slurry injection, Low input management, maintenance of hay meadow, use of cover crops, soil sampling to aid	Soil solution pH (water), Soil solution pH (calcium), Soil solution electrical conductivity, Total Phosphorus, Available Phosphorous (Olsen-P), Soil
Biodiversity	Maintenance of hay meadow, Low input management, reduced spraying	Maintenance of hay meadow, Low input management, reduced spraying, conversion of improved grassland to semi-improved	Soil mesofauna physical extraction, Bacterial diversity (TRFLP), Fungal diversity (TRFLP), Bacterial community genus-level (MiSeq - Illumina platform), Archea community (MiSeq),
Woodlands	Orchard and individual tree planting,	Woodland stock exclusion and planting	Soil water repellency, Soil solution pH (water), Soil solution pH (calcium), Soil solution electrical conductivity, Total Phosphorus, Available Phosphorous

Table 8.5.2.4.1 Table demonstrating how outcomes are linked to major management intervention bundles in Glastir Entry and Advanced and how the major measurement parameters map onto these. Measurements are also used in combination with the modelling described in chapter 3 to test how measures impact outcomes

8.5.2.5 Vulnerable habitats and areas with high mitigation potential

Peat soils represent 3% of the land area of Wales, but contain an estimated 20-30% of Welsh soil carbon, and in good condition are an important long-term carbon sink. Poor management, particularly drainage can unlock the carbon stored in peats, leading to large CO_2 emissions as well as loss of high nature value habitat, and deterioration of water quality. Interventions in Glastir seek to protect peat soils; however, monitoring the state of peats poses considerable challenges to traditional fieldwork. We must be able to compare areas with Glastir intervention with the wider status and trend of Welsh peatlands. There are currently no accepted methods which are sufficiently non-invasive for monitoring changes in peat depth over large areas; such approaches can be very expensive with respect to manpower costs for fieldwork. Which is why the new methodology we present, capable of resolving 30 square meters, but deployable across the entirety of Wales holds such promise. In this section we describe work conducted by the British Geological Survey who conducted proof of concept investigation of two novel, remote-sensing techniques which can be applied from field scale to the whole of Wales to monitor:

- Changes in the surface elevation of peat across large regions using satellite imagery
- Changes in the area of bare (non-vegetated) peat which may be subject to enhanced rates of erosion (and loss of organic carbon stocks) using air-photos.
- In addition to this, a third approach is being investigated by CEH that complements the above work to determine carbon accumulation in peatlands through the development of a

proxy-based approach to determine carbon accumulation rate under specific vegetation types.

The research to date is described below with modules 1 and 2 having been completed in the first year and module 3 due to report at the end of the second year.

8.5.2.5.1 Monitoring changes in peat surface elevation by remote sensing

We used a new satellite image (SAR; synthetic aperture radar) processing technique (called ISBAS) which was developed recently. Previous approaches to processing such images could not establish reflective surfaces for radar pulses across rural areas. The new technique relaxes some of the requirements relating to such reflective surfaces making it possible to detect changes in surface elevation measured in millimetres across most of the land surface. This new technique had not been applied to areas of peat prior to this study and so the approach is entirely novel and, if successful, would be the first time such monitoring had been achieved for peat soils across the globe. The technical details of the approach are supplied in the Appendix.

We selected a region of North Wales where there were large areas of peat (see Figure 8.5.2.5.1.1). We processed images captured every 35 days between the years 1993 and 2000. Each measurement is from a square area with side length of 30 metres.

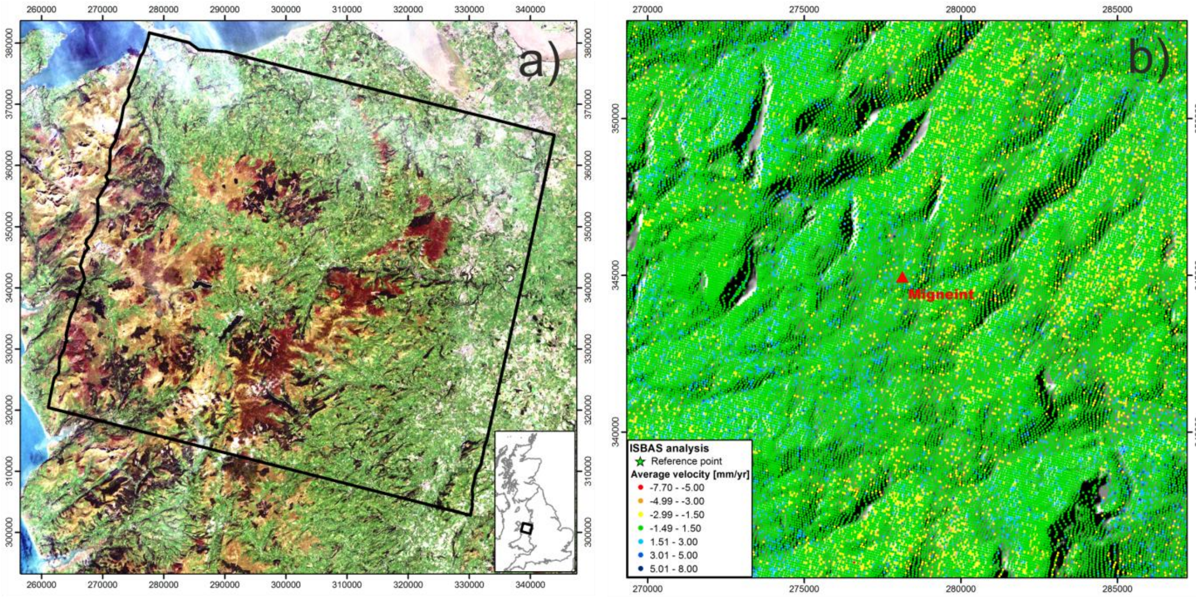

Figure 8.5.2.5.1.1 Application of remote sensing to detect changes in the surface elevation of peat: a) the broader study region selected for analysis highlights dark areas of peat, and b) a small peat dominated section of the larger study region around the Migneint showing average land surface velocity between 2000 and 2008. Grid references are metres on the British National Grid.

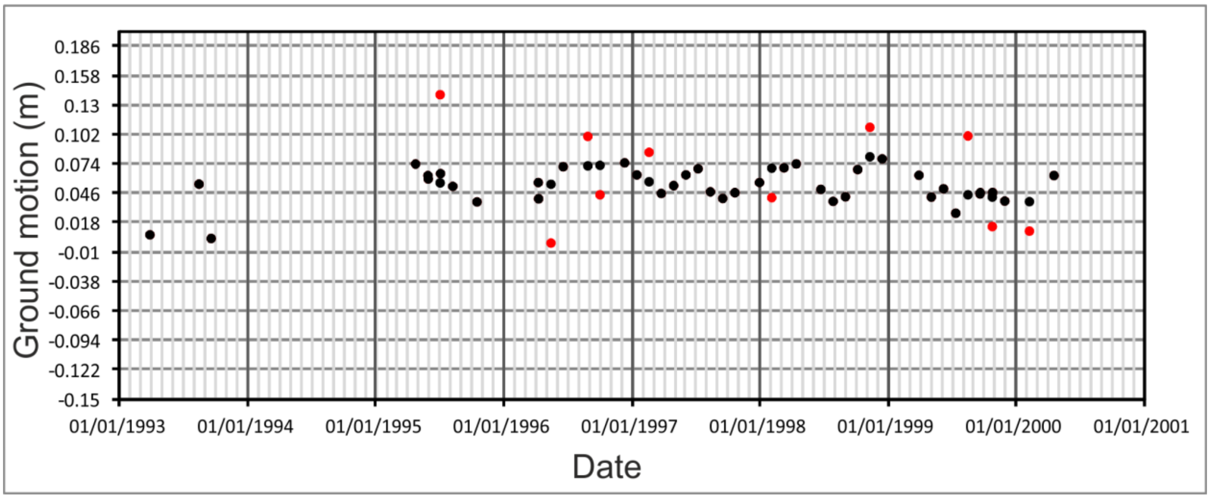

Figure 8.5.2.5.1.2 Time series of surface elevation for one point (30 metre square) over blanket peat at the Migneint between 1993 and 2000 (units are metres). The black discs are the corrected data showing the cyclical motion of the peat surface which appears to be related to wetting and drying cycles. The red discs are a series of associated, uncorrected measurements. No radar scenes were available during 1994.

Summary of research findings:

- We processed radar images covering an area of 4460km^2 of north Wales which encompassed large areas of upland blanket peat for the period between 1993 and 2000
- We showed that it is possible to detect and map small ground movements (expressed as average velocities in millimetres per year (mm/yr) in areas of upland peat soil.
- We showed that there are clear cycles showing changes in surface elevation through time for a peat site at Migneint. These appear to be related to variations in wetting and drying of the peat associated with rainfall and drier spells.
- This is the first application of remotely sensed monitoring of organic soil surface elevations anywhere in the world. This technique provides a cost-effective means of monitoring peat to detect any changes in surface elevation which would indicate changes in soil carbon stocks associated with future management interventions and which have implications for climate change.
- We need to analyse these data further to determine if there is a global trend in peat elevation (rising or falling)
- Future studies based on this method could investigate whether it is possible to detect differences in motion for peats subject to different historical management interventions which would provide evidence to determine the potential impacts of Glastir interventions.
- Further details of the study are available in the Appendix 8.2 or contact Dr Barry Rawlins (bgr@bgs.ac.uk) at the British Geological Survey.

8.5.5.2.2 Mapping bare peat to determine erosion risk of organic soil across Wales

There is concern that some land management practices such as fire and excessive grazing can lead to degradation of peatlands leading to the formation of bare peat which would be prone to erosion and the subsequent loss of this important habitat and associated soil carbon stock. A recent report stated that "Erosion resulting in bare peat is relatively confined [in Wales]" (Joint Nature Conservation Committee, 2011) and yet to our knowledge there is no map of bare peat areas for Wales. There is anecdotal evidence suggesting that as part of the CCW Phase I Habitat Survey, their surveyors mapped an area of around 450 hectares as eroding peat. This would have included entire erosion complexes rather than just bare peat areas, so would likely be an overestimate of the total area of bare peat. Local studies have attempted to create maps of bare peat from air photos in parts of England (Chapman *et al*., 2010) and Scotland (Keyworth, 2009), but to our knowledge no attempt has been made to systematically map bare peat at the national scale and to quantify its extent using air photos. If such an approach could be shown to be effective it could substantially reduce the costs associated with monitoring the state of peatlands and the potential impact of Glastir interventions over time.

We wished to evaluate the extent of the organic soil erosion risk across Wales by mapping the distribution of bare peat. At the national scale, the most practical and efficient approach to achieving this is clearly one based on the use of remotely sensed data. Accordingly, the BGS have been developing a methodology for discriminating and mapping bare peat across Wales using aerial photography — using both true-colour and colour infrared air photos. Areas of bare peat can be discriminated from non-bare peat areas (e.g., vegetated peat, non-organic soils, urban land cover) through their contrasting reflectance characteristics, which are captured by the aerial photographs with a pixel size of 0.5 metres. By 'learning' the reflectance characteristics of these two land cover types, computer-based algorithms can be applied to perform image classification and thus semi-automatically map the presence of bare peat in an aerial photograph (Figure 8.5.2.5.2.1). Numerous tests were conducted on a small independent validation site in the English Peak District in order to identify the optimal image classification routine for identifying bare peat. Subsequently, to map bare peat across Wales, the extent of organic soils was first identified from the 1:250,000 soil map for Wales and then the optimum image classification algorithm was applied to all aerial photographs that coincided with this extent (see Appendix 8.1 for a more detailed description of this methodology). Although semi-automatic, a considerable effort was still required since over 1800 aerial photographs of 1km x 1km size were selected for processing. In summary:

- The methodology is effective at highlighting areas of bare peat on a national-scale;
- Shadows and some water bodies had to be masked as they caused considerable classification confusion;
- Relatively minor misclassification persisted due to similarity with specific types of vegetation and remnant shadowing;
- A total area of 0.63km^2 was classified as bare peat from a total organic soil areal extent of 473km^2; this is equivalent to 0.13% of the total area of peat assessed.

Overall, the results of this study demonstrate that remote sensing is an effective tool for determining the organic soil erosion risk on a national scale. The employed methodology is capable of accurately highlighting areas of bare peat, which may then be subject to field-based investigation. Moreover, if applied to data acquired at different time periods, the methodology can be used as a tool for monitoring the erosion risk through time and its spatial alignment with Glastir interventions.

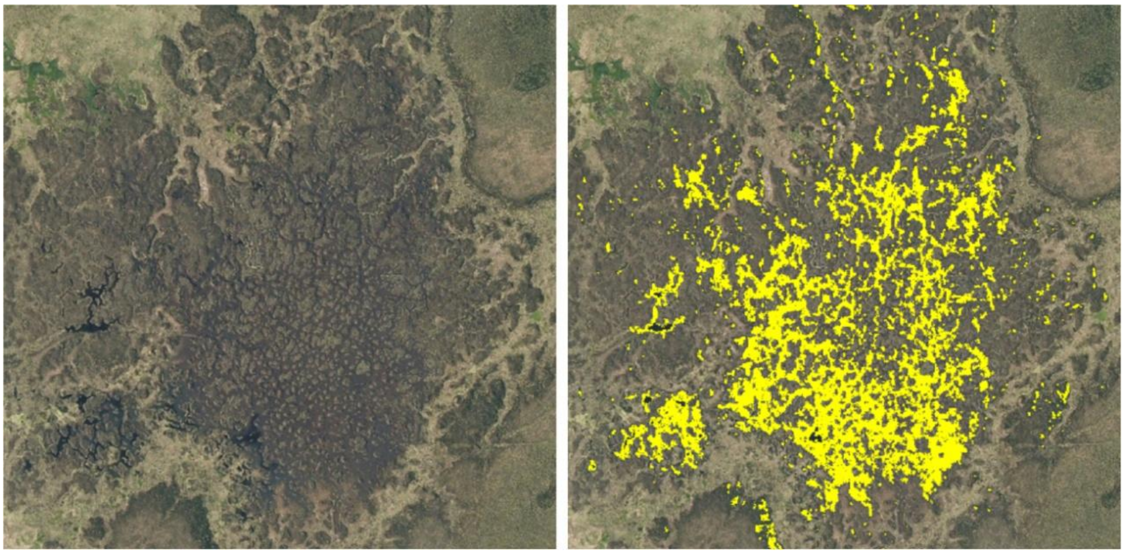

Figure 8.5.2.5.2.1 Example of the bare peat mapping. Left: aerial photograph showing bare peat; Right: Mapped bare peat shown in yellow.

8.5.5.5.3. A proxy based approach to determine carbon accumulation rates across Wales
Work that will continue in year 2 will seek to develop an indirect ‘proxy-based’ approach to characterise and monitor the peat carbon balance across Wales, combining i) existing and targeted new flux-based measurements of peat CO_2 balance with ii) a broader core-based approach to quantify rates of recent peat formation under different vegetation types; and iii) vegetation and land-use survey data collected on peatlands during the GMEP. The approach will effectively ‘calibrate’ vegetation data against peat accumulation and flux data from a smaller number of sites, removing the need to attempt to directly measure peat carbon balance at all sites. A similar approach has been widely used in Central Europe (Couwenberg *et al*., 2011) and is being considered for development in the UK, but requires additional UK-specific calibration data. With respect to Glastir, this approach offers the opportunity to link observed changes in vegetation or modelled changed from the MultiMOVE model (See Chapters 2 and 4) in the rolling national survey to impacts on greenhouse gas emissions.

8.6 Future plans

In year 2 the survey of squares will be expanded from 60, 1km squares to 90 meaning 450 locations will be sampled for soils. Soil cores for physical, chemical, biological and invertebrate analysis will be sampled. Work on peat accumulation will be on going, with the expectation of producing a methodology that could be incorporated into a future GMEP monitoring program by the end of the second year. We will continue to collate relevant datasets from other organisations and explore their potential for the integration with GMEP data to report on national trends. We will also develop automated scripts to detect impacts of interventions to deliver to the data portal in collaboration with the other team members. The number of streams and ponds surveyed will also increase with measurements repeated as for Year 1 squares. We will work with the LUCI catchment modellers to identify the impact of spatial location of interventions, upstream characteristics and Glastir activity on freshwater quality within our sample squares.

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