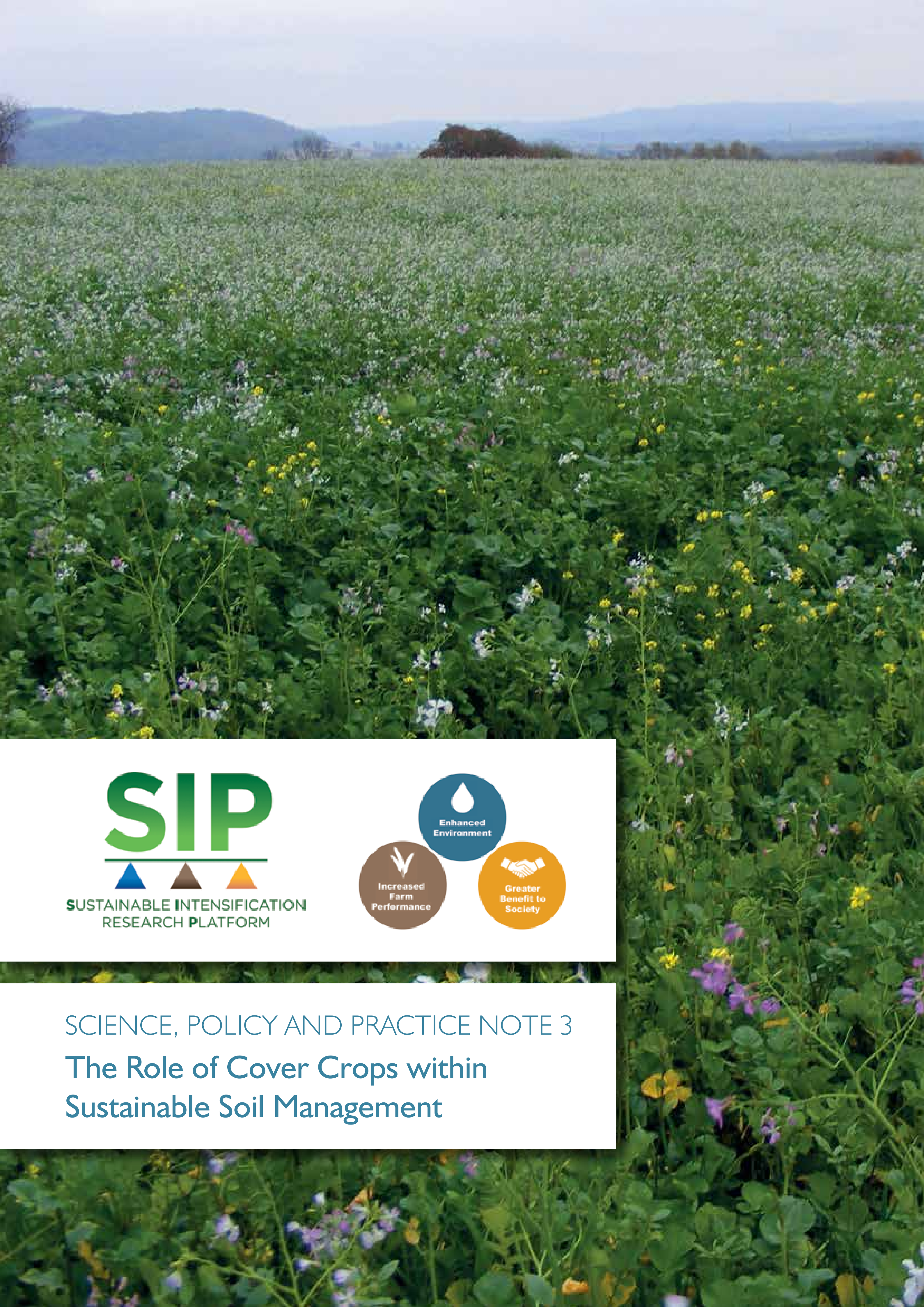


SIP

SUSTAINABLE INTENSIFICATION RESEARCH PLATFORM

Enhanced Environment

Increased Farm Performance

Greater Benefit to Society

SCIENCE, POLICY AND PRACTICE NOTE 3

# The Role of Cover Crops within Sustainable Soil Management

## The Issue

Healthy soils are vital, not only for the long term performance of farming systems but also their wider implications for soil erosion, water pollution and flooding risks. Cover crops can contribute to enhanced soil sustainability, as well as providing other benefits for farming and land management. They have been found to improve the soil structure and enhance soil biology, depending on cover crop type and circumstance. However, cover crops can sometimes create challenges for farmers, such as conflicts within crop rotations. There is a need for more information, particularly from long-term and field-scale studies. Beneficial effects on the soil, crop performance or the environment may only become apparent after several years or over a large area. Much of the research outlined in this Science, Policy and Practice Note is based on on-going long-term research to address these issues.

**Cover crops** are crops grown when the soil would otherwise remain bare, usually in the autumn and winter prior to establishing a spring-sown crop. However, they can also follow an early harvested crop, prior to establishing an autumn-sown crop. They are primarily used to improve soil structure and biological activity, making the soil more resilient, for example to adverse weather conditions. Examples include mustard, radish, grasses, buckwheat, Phacelia, vetches and clovers or usually mixtures of these. They can be ploughed in as a green manure afterwards, although more commonly they are sprayed with glyphosate herbicide in order to kill weeds within the field at the same time, before the spring crops are drilled. Some may be used or grazed as forage for livestock.

## SIP's Response

As one component of the Sustainable Intensification research Platform (SIP), farming practices with the potential to improve crop or livestock productivity and at the same time deliver environmental benefits were evaluated on a number of Study Farms.

Building on previous research initiatives and linked to on-going projects, SIP work at Morley (NIAB TAG) in Norfolk on a sandy loam soil and at Loddington (Game and Wildlife Conservation Trust (GWCT) in Leicestershire on challenging clay soils, has been examining the effects of cover crops and their interactions with tillage system on soils, environment and on crop yield.

## Morley Cover Crop Studies

**Studies on cover crops were undertaken at a range of scales at Morley and in the nearby Wensum study area.**

1. The New Farming Systems project based at Morley includes a large replicated plot experiment that was established in 2007. It is examining cover crop and tillage system effects on the output and sustainability of conventional arable farming systems. The SIP study has involved a comparison of three tillage approaches:

- plough;
- shallow non-inversion (around 10 cm);
- deep non-inversion (around 20 cm);

all with or without cover crops, within a rotation, based on winter wheat alternating with spring-sown combinable crops. The brassica cover crop, radish (*Raphinus sativus*), was sown as autumn cover before spring crops. Combinable crops grown over the period 2008 to 2017 included spring oilseed rape, spring beans, spring barley, winter oilseed rape, spring oats and winter wheat.

2. Split commercial field studies lasting between one and three years were undertaken on five fields, to investigate the benefits of over-winter crops on the following crop performance, soil nitrogen retention, and soil earthworm population. Cover crops used were: legumes, such as clover and vetch; grasses and cereals, such as black oats; brassicas, such as radishes; and other commercial mixes. They were planted in field strips prior to a sugar beet crop, and compared to areas with no cover crops.

3. The Wensum Demonstration Test Catchment project aims to help farmers to reduce diffuse water pollution from agriculture using land management measures. As part of this project, nine whole fields at Salle Farm had been split between three blocks, to compare conventional ploughing without cover crops to minimal tillage and direct drilled approaches that both included cover crops. This enabled the SIP study to examine system effects on crop performance and soil properties at a larger scale.

## Loddington (GWCT) Cover Crop Studies

**The research at Loddington tested the potential benefits of cover crops on challenging clay soils. The particular focus was on improving soil structure and organic matter, retaining nutrients, limiting erosion and black-grass control. Over three years a series of cover crop experiments were performed, assessing the impact of different cover crop mixtures on a field scale. For example, a rigorously designed and replicated experiment examined three different mixtures prior to a direct-drilled spring oat crop. These were:**

- oats and Phacelia (C+P);
- oats, Phacelia and radishes (oil and tillage) (C+P+R);
- oats, Phacelia, radishes and legumes (vetch and clovers) (C+P+R+L).

A bare, over-winter stubble was used as a control plot in each of the three fields in which the experiment was replicated. Data were gathered on soil physical, chemical and biological properties (including earthworm activity). The economics of the various cover crops were evaluated.

## What SIP Learnt

### Key Findings from the Morley Cover Crop Studies

- Positive crop yield responses were observed where a brassica cover crop (radish) was included in the rotation, but not with all tillage systems or in all years.
- The most consistent yield benefits were observed from cover crops within the shallow non-inversion tillage system (for example see Figure 1 showing response of winter wheat yield to cover crop use and cultivation system).
- In the shallow non-inversion tillage system, the only appreciable negative yield effect was on winter oilseed rape grown after repeated use of a brassica cover crop in the rotation.
- The cost of regularly including a cover crop in a winter wheat/spring break rotation may not be fully recouped by an increase in crop output, even when used in a shallow non-inversion system. However, depending on the cover crop cost, shallow non-inversion with a cover crop can produce a higher margin than a plough/no cover crop system.

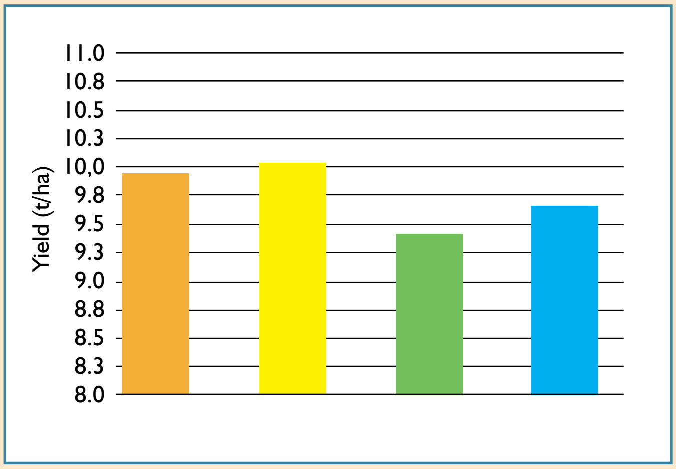



*Figure 1. Response of winter wheat yield (mean values over four years) with and without cover crop use (CC) and comparing ploughing with shallow non-inversion cultivation*

A number of soil related benefits from cover crop inclusion were observed in the Morley studies, including:

- **increased earthworm numbers** in the soil, prior to sowing spring crops, where a cover crop had been grown in the autumn;
- uptake of available nitrogen by cover crops during the autumn, resulting in a **reduction in the amount leached to depth** in the soil by the spring.

## Key Findings from the Loddington (GWCT) Cover Crop Studies

- **Improvements in soil structure** were recorded through the winter where a cover crop had been used, compared to an over-winter stubble area.
- All cover crops **suppressed grass weeds** to a certain extent, both within the cover crop and in the following crop.
- **Higher yields** in the following cereal crop were obtained – the average increase in oats yield associated with the cover crop use was 0.5 tonnes/ha (35%), worth around £60/ha.
- Some cover crops **improved the activity of earthworms and millipedes, with potential benefits for organic matter incorporation** (see Figure 2 showing the abundance of earthworms in soils planted with different cover crops compared to no cover crops).

- Some cover crops **improved the activity of earthworms and millipedes, with potential benefits for organic matter incorporation** (see Figure 2 showing the abundance of earthworms in soils planted with different cover crops compared to no cover crops).

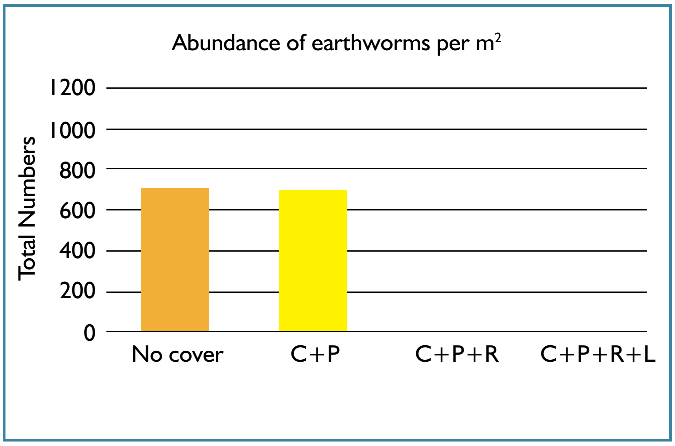



*Figure 2. Abundance of earthworms in soils planted with different cover crops, compared to no cover crops*

## Opportunities for Policy and Practice

The implications of this research for policy and practice are as follows.

### Benefits of Cover Crops

The cover crop research has indicated a number of potential benefits including improved soil structure, soil biology (with an increase in earthworm activity) and organic matter, weed suppression and possible increased crop yields. Wider implications of improved soil properties are reduced nitrate leaching, and enhanced water flow through soil thereby helping to reduce flooding and soil erosion.

### Barriers to Cover Crop Use

There are also barriers to the use of cover crops, including: their establishment; predictability; rotational complications and cost. Farmers need to be clear about the purpose of the cover crop and need to choose cover crop species and appropriate management systems that fit in with their own situation.

### Training and Further Research

With financial benefits not certain, identifying ways to improve the reliability and reduce the cost of establishing cover crops (and the crops that follow them) is essential. More research is needed to aid the evaluation of cover crop effects under different situations, including soil types and weather conditions. Training for farmers on good management practices and provision of information on cover crop benefits would be beneficial.

## Authors

Nathan Morris (Farming Systems and Soils Specialist, NIAB TAG, Morley, Norfolk)

Felicity Crotty (Soil Scientist, GWCT, Loddington, Leicestershire)

Caroline Kettlewell (Technical Author, Harper Adams University, Shropshire)

## Further Resources

Stobart, R., Morris, N., Hinton, N., Fielding, H. and Stoate, C. (2016) *Evaluation of sustainable soil management and cover crop practices*. 14th ESA Congress, Scotland

## Acknowledgements

SIP funding from Defra and Welsh Government, The JC Mann Trust, The Morley Agricultural Foundation, The Chadacre Agricultural Trust, Wensum DTC project, Morley Farms, Salle Farms Company, Game and Wildlife Conservation Trust

---

*The Sustainable Intensification Research Platform (SIP) is a multi-partner research programme comprising academia, farmers, industry experts, environmental organisations, and policymakers.*

*Funded by Defra and the Welsh Government, the platform explores the opportunities and risks of Sustainable Intensification (SI) from a range of perspectives and landscape scales across England and Wales.*

*The Platform, run from 2014-17, has investigated ways to increase farm productivity, reduce environmental impacts, and increase the benefits that agricultural land provides to society.*

SIP
SUSTAINABLE INTENSIFICATION RESEARCH PLATFORM

## More Information

Visit: **www.siplatform.org.uk**

Contact: Nathan Morris (NIAB) nathan.morris@niab.com

Felicity Crotty (GWCT) fcrotty@gwct.org.uk

2018CLES005

## Awduron

Nathan Morris (Arbenigwr Systemau Amaethyddol a Phridd, NIAB TAG, Morley, Norfolk)

Felicity Crotty (Soil Scientist, GWCT, Loddington, Leicestershire)

Caroline Kettlewell (Technical Author, Harper Adams University, Shropshire)

## Adnoddau pellach

Stobart, R., Morris, N., Hinton, N., Fielding, H. and Stoate, C. (2016) *Evaluation of sustainable soil management and cover crop practices*. 14th ESA Congress, Scotland

## Cydnabyddiaethau

Cyllid SIP gan Defra a Llywodraeth Cymru, Ymddiriedolaeth JC Mann, Sefydliad Amaethyddol Morley, Ymddiriedolaeth Amaethyddol Chadacre, prosiect Dalgylch Prawf Arddangos (DTC) Wensum, Ffermydd Morley, Cwmni Ffermydd Salle, Ymddiriedolaeth Anifeiliaid Hela a Bywyd Gwyllt

---

*Rhaglen ymchwil aml-bartner yw'r Platfform Ymchwil i Ddwysáu Cynaliadwy (SIP) sy'n cynnwys academia, ffermwyr, arbenigwyr y diwydiant, sefydliadau amgylcheddol, a gwneuthurwyr polisi.*

*Ariennir y platfform gan Defra a Llywodraeth Cymru, ac mae'n archwilio'r cyfleoedd a'r risgiau sydd ynghlwm wrth Ddwysáu Cynaliadwy o amrywiaeth o safbwyntiau a graddfeydd tirwedd ar draws Cymru a Lloegr.*

*Mae'r Platfform, a oedd yn gweithredu o 2014-17, wedi ymchwilio i ffyrdd o gynyddu cynhyrchiant ffermydd, lleihau effeithiau amgylcheddol, a chynyddu manteision tir amaethyddol i'r gymdeithas.*

SUSTAINABLE INTENSIFICATION RESEARCH PLATFORM

## Mwy o Wybodaeth

Ymwelwch â: **www.siplatform.org.uk**

Cysylltwch â: Nathan Morris (NIAB) nathan.morris@niab.com

Felicity Crotty (GWCT) fcrotty@gwct.org.uk

## Cyfleoedd ar gyfer Polisi ac Ymarfer

Mae goblygiadau'r gwaith ymchwil hwn i bolisi ac ymarfer fel a ganlyn.

### Buddiannau Cnydau Gorchudd

Mae'r ymchwil i gnydau gorchudd wedi nodi nifer o fanteision posibl gan gynnwys gwelliannau i strwythur y pridd, bioleg y pridd (gyda chynnydd mewn gweithgarwch llyngyr daear) a deunydd organig, atal chwyn a'r posibilrwydd o gynyddu pwysau'r cnwd. Y goblygiadau ehangach sydd ynghlwm wrth briodweddau gwell ar gyfer priddoedd yw llai o drwytholchi mewn perthynas â nitradau, a llif dŵr gwell drwy briddoedd, gan helpu i leihau llifogydd ac erydu pridd drwy hynny.

### Rhwystrau i Ddefnyddio Cnydau Gorchudd

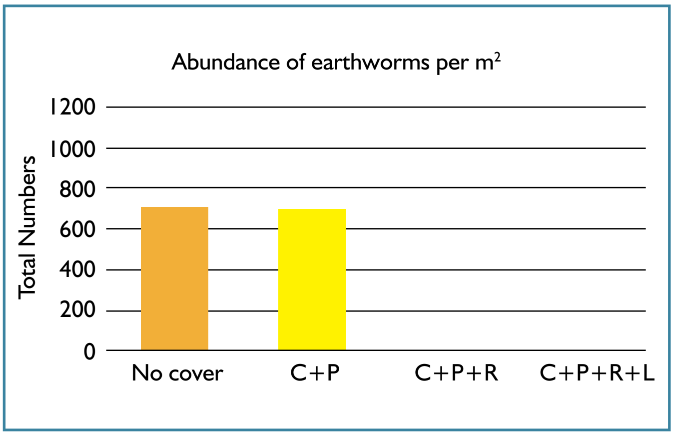
Ceir rhwystrau i ddefnyddio cnydau gorchudd, gan gynnwys: y broses o'u sefydlu; pa mor rhagweladwy ydynt; cymhlethdodau cylchdro a'r gost. Mae angen i ffermwyr fod yn glir ynghylch diben y cnwd gorchudd ac mae angen iddynt ddewis rhywogaethau i'r cnwd gorchudd a systemau rheoli priodol sy'n cyd-fynd â'u sefyllfa eu hunain.

### Hyfforddiant a Gwaith Ymchwil Pellach

Gyda manteision ariannol ansicr, mae'n hanfodol nodi ffyrdd o wella eu dibynadwyedd a lleihau'r gost o sefydlu cnydau gorchudd (a'r cnydau sy'n eu dilyn). Mae angen mwy o ymchwil i gynorthwyo'r gwaith o werthuso effeithiau cnydau gorchudd mewn sefyllfaoedd gwahanol, gan gynnwys mathau o bridd ac amodau tywydd. Byddai'n fuddiol i ffermwyr gael hyfforddiant ar arferion rheoli da a gwybodaeth am fanteision cnydau gorchudd.

## Canfyddiadau Allweddol o Astudiaethau Cnydau Gorchudd (GWCT) Loddington

- Cofnodwyd gwelliannau yn strwythur y pridd yn ystod y gaeaf lle y defnyddiwyd cnwd gorchudd, o'i gymharu ag ardal â sofl dros y gaeaf.
- Roedd yr holl gnydau gorchudd wedi atal chwyn i raddau helaeth, o fewn y cnwd gorchudd ac yn y cnwd dilynol.
- Cafwyd pwysau uwch yn y cnwd grawnfwyd dilynol – y cynnydd cyfartalog ym mhwysau'r ceirch sy'n gysylltiedig â'r defnydd o gnwd gorchudd oedd 0.5 tunnell/ha (35%), gwerth tua £60/ha.
- Roedd rhai cnydau gorchudd wedi gwella gweithgarwch llyngyr daear a miltroediaid, gan greu manteision posibl i ymgorffori deunydd organig (gweler Ffigur 2 sy'n dangos digonedd o lyngyr daear mewn priddoedd sydd wedi'u plannu â chnydau gorchudd gwahanol o'u cymharu â phriddoedd heb gnydau gorchudd).




*Ffigur 2. Digonedd o lyngyr daear mewn priddoedd sydd wedi'u plannu â chnydau gorchudd gwahanol o'u cymharu â phriddoedd heb gnydau gorchudd*

## Astudiaethau Cnydau Gorchudd (GWCT) Loddington

**Yn yr ymchwil yn Loddington profwyd manteision posibl cnydau gorchudd i briddoedd clai heriol. Roedd y ffocws penodol ar wella strwythur y pridd a deunydd organig, cadw maethynnau, cyfyngu ar erydu a rheoli cynffonwellt du. Dros dair blynedd, cynhaliwyd cyfres o arbrofion ar gnydau gorchudd, gan asesu effaith cymysgedd gwahanol o gnydau gorchudd ar raddfa cae. Er enghraifft, bu arbrawf a ddyluniwyd yn ofalus ac a ailgynhyrchwyd yn archwilio tri chymysgedd gwahanol a dyfwyd cyn cnwd ceirch y gwanwyn a ddriliwyd yn uniongyrchol. Y tri chymysgedd oedd:**

- ceirch a Phacelia (C+P);
- ceirch, Phacelia a rhuddygl (olew a throi'r pridd) (C+P+R);
- ceirch, Phacelia, rhuddygl a chodlysiau (ffacbys a meillion) (C+P+R+L).

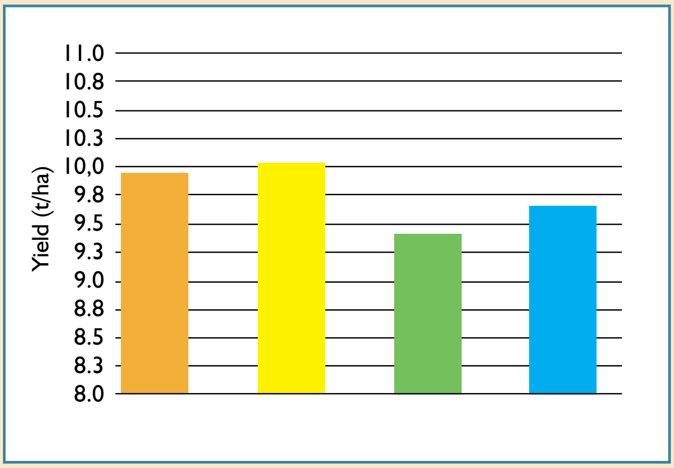
Defnyddiwyd sofl dros y gaeaf fel plot rheoli ym mhob un o'r tri chae lle y cafodd yr arbrawf ei efelychu. Casglwyd data ar briodweddau ffisegol, cemegol a biolegol y pridd (gan gynnwys gweithgarwch llyngyr daear). Cafodd economeg y cnydau gorchudd amrywiol ei gwerthuso.

## Allwedd yr Hyn a Ddysgodd SIP

### Canfyddiadau o Astudiaethau Cnydau Gorchudd Morley

- Gwelwyd ymatebion cadarnhaol o ran pwysau'r cnwd pan gynhwyswyd cnwd gorchudd bresych (rhuddygl) yn y cylchdro, ond nid gyda phob system troi'r pridd nac ym mhob blwyddyn ychwaith.
- Gwelwyd y manteision mwyaf cyson o ran pwysau'r cnwd gan gnydau gorchudd yn y system ddi-wrthdroad fas (er enghraifft gweler Ffigur 1 sy'n dangos ymateb pwysau'r cnwd o wenith gaeaf o'i gymharu â'r defnydd o gnwd gorchudd a'r system trin y tir).
- Yn y system ddi-wrthdroad fas, yr unig effaith negyddol y gellid ei gwerthfawrogi ar bwysau'r cnwd oedd ar rêp had olew gaeaf a dyfwyd ar ôl defnyddio cnwd gorchudd bresych dro ar ôl tro yn y cylchdro.

- Efallai na fydd modd adennill y costau'n llawn sydd ynghlwm wrth gynnwys cnwd gorchudd yn rheolaidd mewn cylchdro gwenith y gaeaf/egwyl y gwanwyn drwy gynnydd mewn cynnyrch cnydau, hyd yn oed wrth ddefnyddio system ddi-wrthdroad fas. Fodd bynnag, yn dibynnu ar gost y cnwd gorchudd, gall system ddi-wrthdroad fas gyda chnwd gorchudd gynhyrchu mwy o elw na system aradr/heb gnwd gorchudd.




*Ffigur 1. Ymateb pwysau'r cnwd o wenith gaeaf (gwerthoedd cymedr dros bedair blynedd) gyda a heb ddefnyddio cnwd gorchudd a chymharu aredig gyda thrin y tir mewn dull di-wrthdroad bas*

Wrth ystyried astudiaethau Morley, gwelwyd nifer o fuddiannau sy'n ymwneud â'r pridd drwy gynnwys cnydau gorchudd, gan gynnwys:

- nifer gynyddol o lyngyr daear yn y pridd, cyn hau cnydau'r gwanwyn, lle roedd cnwd gorchudd wedi tyfu yn yr hydref;
- cnydau gorchudd yn cymryd nitrogen sydd ar gael, gan arwain at leihad o ran faint a drwytholchir yn ddwfn yn y pridd erbyn y gwanwyn.

## Y Broblem

Mae priddoedd iach yn hanfodol, nid yn unig ar gyfer perfformiad hirdymor systemau ffermio ond hefyd oherwydd eu goblygiadau ehangach ar gyfer erydu pridd, llygredd dŵr a pherygl llifogydd. Gall cnydau gorchudd gyfrannu at gynaliadwyedd gwell ar gyfer pridd a gwella bioleg pridd, yn dibynnu ar y math o gnydau gorchudd a'r amgylchiadau. Fodd bynnag, gall cnydau gorchudd weithiau greu heriau ar gyfer ffermwyr, fel gwrthdaro o fewn cylchdroadau cnydau. Mae angen mwy o wybodaeth, yn arbennig gan astudiaethau hirdymor ac ar raddfa maes. Efallai mai dim ond ar ôl sawl blwyddyn neu mewn perthynas ag ardal fawr y daw'r effeithiau buddiol ar y pridd, perfformiad cnydau neu'r amgylchedd i'r amlwg. Mae llawer o'r gwaith ymchwil a amlinellir yn y Nodyn Gwyddoniaeth, Polisi ac Ymarfer hwn yn seiliedig ar waith ymchwil hirdymor parhaus i ymdrin â'r materion hyn.

**Cnydau gorchudd** yw cnydau sy'n cael eu tyfu pan fyddai'r pridd fel arall yn llwm, fel arfer yn yr hydref a'r gaeaf cyn hau cnwd y gwanwyn. Fodd bynnag, gallant hefyd ddilyn cnwd a gynaeafwyd yn gynnar, cyn sefydlu cnwd yr hydref. Yn bennaf, cânt eu defnyddio i wella strwythur y pridd a gweithgaredd biolegol, gan wneud y pridd yn fwy gwydn, er enghraifft yn wyneb tywydd gwael. Ymhlith yr enghreifftiau o gnydau gorchudd mae mwstard, rhuddygl, glaswellt, gwenith yr hydd, Phacelia, ffacbys a meillion neu fel arfer cymysgedd o'r rhain. Gellid eu troi yn y pridd fel tail gwyrdd ar ôl hynny, er maent yn fwy tebygol o gael eu chwistrellu â chwynladdwr glyffosad er mwyn lladd chwyn yn y cae ar yr un pryd, cyn i gnydau'r gwanwyn gael eu plannu. Gellid defnyddio rhai ohonynt fel bwyd neu borthiant ar gyfer da byw.

## Ymateb SIP

Fel un elfen o'r Platfform Ymchwil i Ddwysáu Cynaliadwy (SIP), gwerthuswyd arferion ffermio sydd â'r potensial i wella cynhyrchiant cnydau neu dda byw a darparu manteision amgylcheddol ar yr un pryd ar nifer o Ffermydd a oedd yn rhan o'r Astudiaeth.

Gan ddatblygu mentrau ymchwil blaenorol a chysylltu â phrosiectau sydd ar y gweill, mae gwaith SIP yn Morley (NIAB TAG) yn Norfolk ar bridd lôm tywodlyd ac yn Loddington (Ymddiriedolaeth Anifeiliaid Hela a Bywyd Gwyllt (GWCT)) yn Swydd Gaerlŵr ar briddoedd clai heriol, wedi bod yn archwilio effeithiau cnydau gorchudd a sut y maent yn rhyngweithio â system troi'r pridd, yr amgylchedd a phwysau'r cnwd.

## Astudiaethau Cnydau Gorchudd Morley

**Cynhaliwyd astudiaethau ar gynau gorchudd ar amryw o raddfeydd gwahanol yn Morley a hefyd yn Wensum, ardal gyfagos sy'n rhan o'r astudiaeth.**

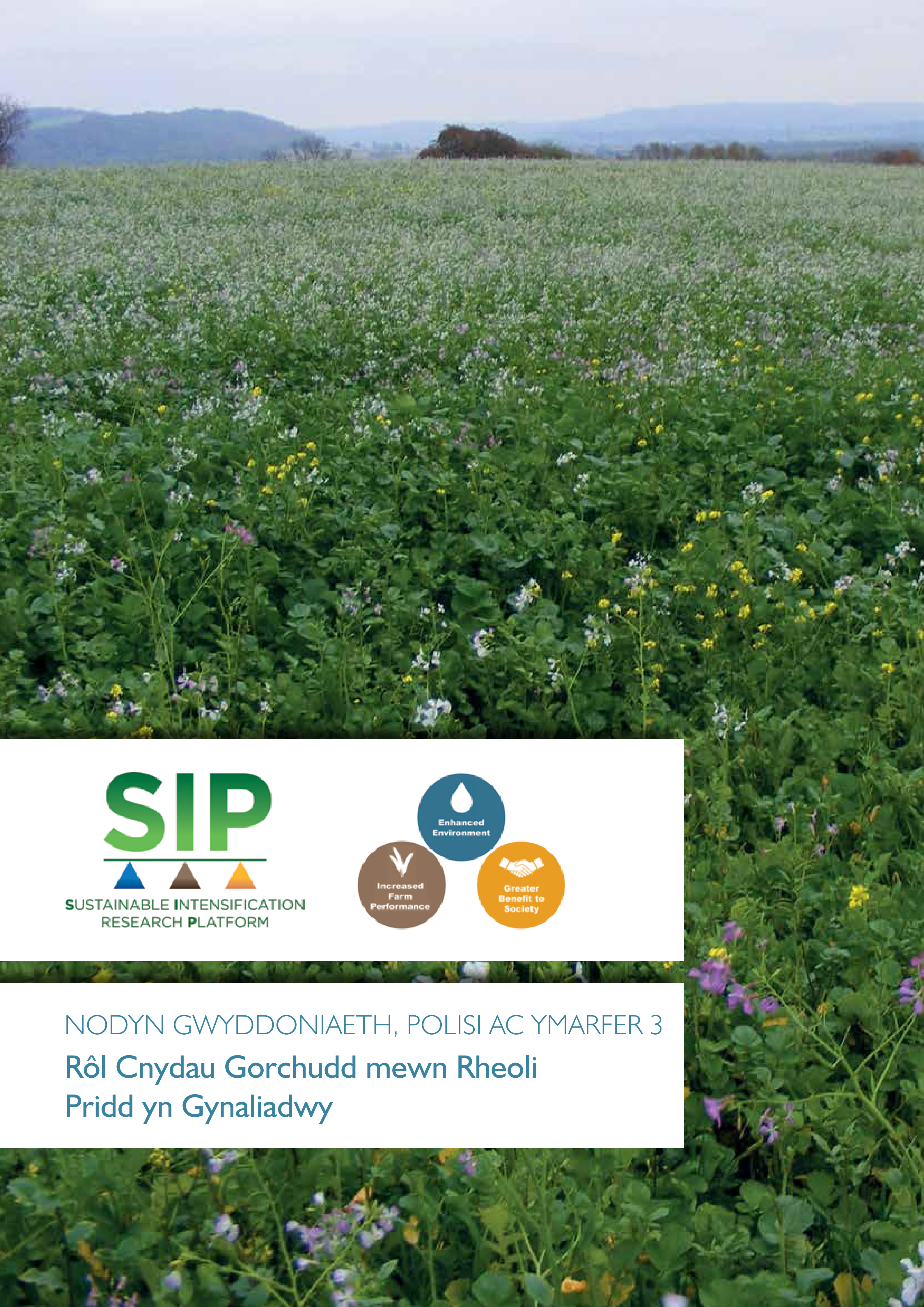
1. Mae'r prosiect Systemau Ffermio Newydd ym Morley yn cynnwys arbrawf ar blot mawr a ailgynhyrchwyd a sefydlwyd yn 2007. Mae'n archwilio effeithiau cnydau gorchudd a system troi'r pridd ar gynnyrch a chynaliadwyedd systemau ffermio âr confensiynol. Mae'r astudiaeth gan SIP wedi cymharu tri dull o droi'r pridd:

- aradr;
- di-wrthdroad bas (tua 10 cm);
- di-wrthdroad dwfn (tua 20 cm);

   bob un gyda neu heb gnydau gorchudd, o fewn cylchdro, yn seiliedig ar wenith gaeaf yn cael ei hau am yn ail â chnydau gwanwyn cyfunadwy. Cafodd y cnwd gorchudd bresych, rhuddygl (Raphinus sativus), ei hau fel cnwd gorchudd yr hydref cyn cnydau'r gwanwyn. Ymhlith cnydau cyfunadwy a dyfwyd dros y cyfnod 2008 i 2017 roedd rêp had olew y gwanwyn, ffa'r gwanwyn, haidd y gwanwyn, rêp had olew y gaeaf, ceirch y gwanwyn a gwenith y gaeaf.

2. Cynhaliwyd astudiaethau maes masnachol wedi'u rhannu a oedd yn para rhwng blwyddyn a thair blynedd ar bum cae, i ymchwilio i fanteision cnydau'r gaeaf o ran perfformiad y cnwd dilynol, y gallu i gadw nitrogen yn y pridd, a phoblogaeth llyngyr daear yn y pridd. Y cnydau gorchudd a ddefnyddiwyd oedd: codlysiau, fel meillion a ffacbys; glaswellt a grawnfwydydd, fel ceirch duon; cnydau bresych, fel rhuddygl; a chymysgedd masnachol arall. Cawsant eu plannu mewn stribedi cyn cnwd betys siwgr, a'u cymharu ag ardaloedd heb unrhyw gnydau gorchudd.

3. Nod prosiect Dalgylch Prawf Arddangos Wensum yw helpu ffermwyr i leihau llygredd dŵr gwasgaredig o amaethyddiaeth gan ddefnyddio mesurau rheoli tir. Fel rhan o'r prosiect hwn, cafodd naw cae cyfan yn Fferm Salle eu rhannu rhwng tri bloc, er mwyn cymharu dulliau aredig heb gnydau gorchudd â dulliau bras-droi'r pridd a drilio uniongyrchol a oedd ill dau yn cynnwys cnydau gorchudd. Galluogodd hyn i'r astudiaeth SIP archwilio effeithiau'r system ar berfformiad cnydau a phriodweddau priddoedd ar raddfa fwy.



SUSTAINABLE INTENSIFICATION RESEARCH PLATFORM

Enhanced Environment

Increased Farm Performance

Greater Benefit to Society

NODYN GWYDDONIAETH, POLISI AC YMARFER 3

# Rôl Cnydau Gorchudd mewn Rheoli Pridd yn Gynaliadwy