Interreg
EUROPEAN UNION
France (Channel Manche) England
Channel Payments for Ecosystem Services
European Regional Development Fund

CPES

Field demonstration of the efficacy of cover crops to reduce nitrate leaching : 2018-21

Date/Version: November 2021

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Phacelia & oat cover crop mix; December 2020

The INTERREG VA France (Channel) England programme is financed through the European Regional Development Fund (ERDF).

Overview

The aim of this study was to demonstrate the feasibility of growing cover crops ahead of spring crops as a means of reducing over-winter nitrate leaching losses from the shallow chalk soils found across much of Portsmouth Water's catchment area. The study also evaluated the effect of cover cropping on yields and gross margins to demonstrate the benefits and trade-offs of cover crops for the farm business. The work was undertaken on a commercial farm in Hampshire over three cropping seasons (2018-2021).

Key findings:

- There was clear evidence that cover crops can reduce nitrate leaching losses by up to 90% compared to weedy stubble.
- Weed and volunteer growth on stubble can be beneficial, but effects on nitrate leaching are variable and inconsistent.
- Drilling date (early – ideally before the end of August) and soil conditions (sufficient moisture) are important for successful cover crop establishment.
- Leaching losses vary depending on the amount of mineral N (nitrate and ammonium) in the soil in the autumn, soil texture, depth and over winter rainfall.
- Reductions in nitrate leaching losses can increase soil N supply in the spring leading to a decrease in the N fertiliser requirement of the following cash crop. This was found in one of the three seasons studied; further work is required to understand the amount and timing of N release captured by cover crops.
- The cover crops had no effect on the yield of the following spring barley crop, except in 2021 when yields were *c.* 0.4 t/ha lower following the phacelia/oat cover crop.
- Net margins were highest where no cover crop was grown due to the absence of any yield benefit and cost of cover crop seed and establishment. The costs assessment does not account of any support payments which may be introduced to reflect the wider benefits of growing cover crops, particularly for water quality, but also potential improvements in soil quality and biodiversity on farm. Cover cropping is currently incentivised by Countryside Stewardship and will also be part of the Sustainable Farm Incentive currently being piloted as part of the forthcoming Environmental Land Management (ELM) scheme.

Cover crop treatments and assessments

The work was undertaken over three seasons at a farm within Portsmouth Water's catchment area in West Sussex, with a new experiment established each year in a different field reflecting the farm rotation (Table 1). Two cover crop treatments (Table 2) were drilled in August each year along a 100m length of a single 'tramline' width (36m) and compared with an adjacent area without cover crop (weedy stubble). The cover crops were established using a single pass of the farm 'Bio Drill' mounted on a 'Top Down' cultivator. This comprised a combination of discs working to 30mm depth, followed by a set of tines working to 120-140mm depth, followed by a set of levelling discs after which the seed was broadcast and finally rolled. The cover crop species were selected to give a 'simple' low cost option (oats) compared to a mix that would have qualified for an Ecological Focus Area green cover (EFAGC) payment (oats & phacelia) in 2018/19. It should be noted that this payment is no longer available as farming in England transitions to the new Environmental Land Management (ELM) scheme.

Table 1. Demonstration trial fields

Season	Field name	Texture (% clay)	Depth to chalk (cm)	Previous crop	Cover crop drilled	Cover crop destroyed
2018-19	Busto	Silty clay loam (23%)	60	Winter wheat	28/8/18	13/2/19*
2019-20	Telegraph	Silty clay loam (29%)	40	Winter wheat	22/8/19	29/1/20
2020-21	Windmill	Clay (52%)	>90	Spring barley	17/8/20	17/3/21*

*Note frost in January 2019 destroyed the phacelia cover crop and in February 2020 all covers were partially destroyed by frost. The dates given in this table refer to when glyphostate was applied to destroy any remaining vegetation prior to drilling the spring barley cash crop.

Table 2. Cover crop treatments

Treatment	Description
1	Conventional practice (bare/weedy stubble)
2	Cereal (oats) cover crop (@40 kg/ha)
3	Cereal (oats) and phacelia cover crop (ratio 9:1 @ 40 kg/ha)

Soil samples were taken to depth in September each year to quantify soil mineral nitrogen (ammonium-N & nitrate-N: SMN) and porous ceramic water samplers were installed to just above the chalk bedrock (40-90cm depending on the field, Table 1), with 12 pots installed per treatment to measure over-winter nitrate leaching losses (sampled every 2 weeks or after 25mm drainage). SMN was also measured in the spring shortly after cover crop destruction, which together with an assessment of total cover crop biomass and nitrogen (N) uptake, gave an estimate of soil nitrogen supply (SNS) to the following spring barley crop. Spring barley was harvested using a yield mapping combine each year and the results analysed using the ADAS agronomic software to establish if there was a treatment effect on grain yields.

Effect of cover crops on over-winter nitrate leaching

The phacelia/oat cover mix performed well in all three seasons, providing between 70 and 90% cover, capturing *c.* 20-50 kg/ha N and reducing nitrate leaching losses by 70-90% relative to the weedy stubble control (Table 3; Plate 1). Establishment of the oat cover crop was more variable, particularly in 2018/19, where weedy growth on the control treatment produced greater cover, N uptake and reductions in nitrate leaching. This was attributed to late drilling into a dry seedbed. Greater cover and reductions in nitrate leaching were achieved by the oat cover in subsequent seasons (Table 3). There was a clear relationship between crop cover and nitrate leaching loss across all treatments including the weedy cover on the control (Figure 1).

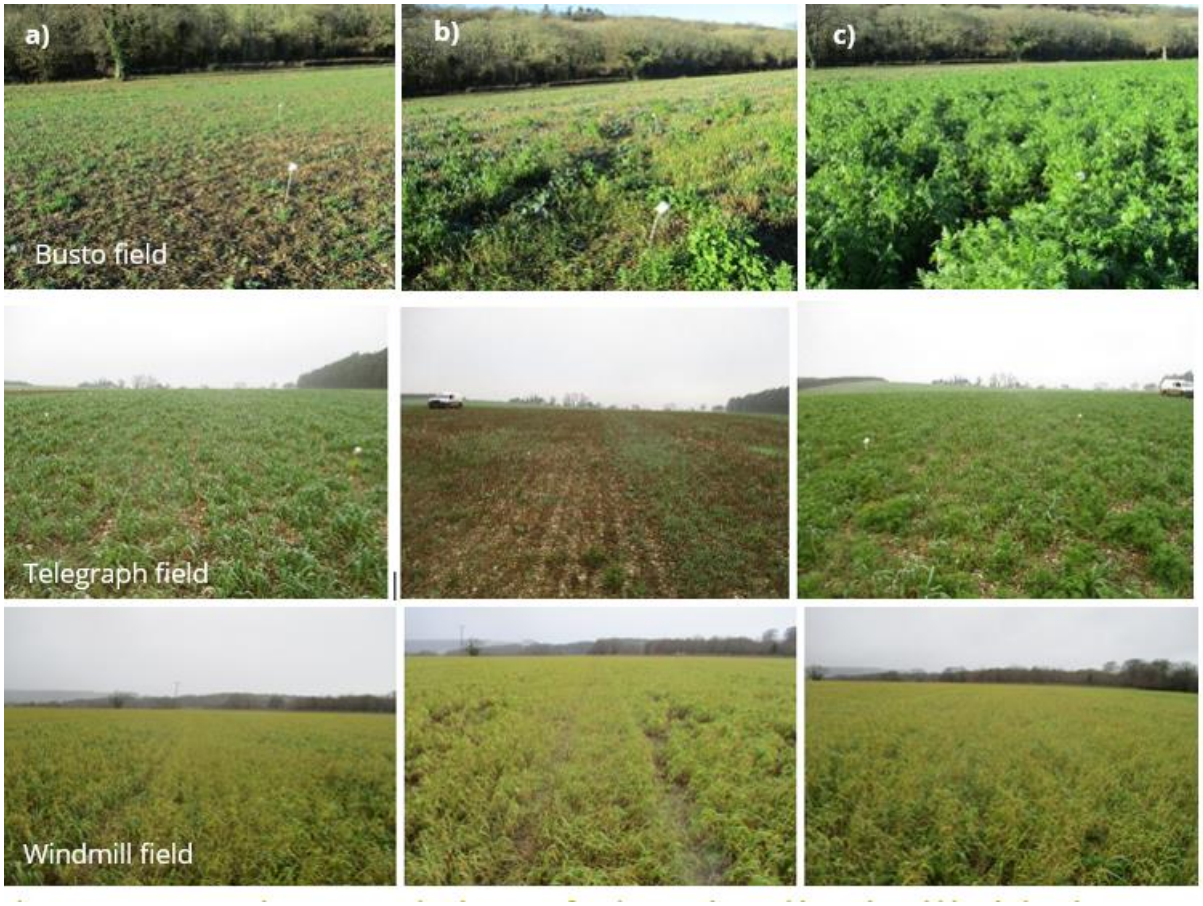

Plate 1. Treatment tramlines in December/January of each year: a) Oats; b) weedy stubble; c) Phacelia & oats

Table 3. Effect of the cover crop treatments on nitrate leaching

Field & year	Rainfall (drainage)[1] (mm)	Treatment	Autumn SMN (kg/ha)	Cover crop		Total N flux (kg/ha)	Nitrate[2] (mg N/l)
				% cover	N uptake (kg/ha)		
Busto 2018-19	520 (270-303)	Stubble	81	49	25	32	11.3
		Oats	114	31	10	64	21.2
		Phacelia/oat	105	91	49	8	2.9
Telegraph 2019-20	854 (493-502)	Stubble	27	49	13	25	5.0
		Oats	25	31	37	12	2.3
		Phacelia/oat	25	91	43	3	0.7
Windmill 2020-21	640 (436-443)	Stubble	68	48	20	13	2.9
		Oats	57	68	22	5	1.1
		Phacelia/oat	69	81	19	4	0.9

[1]Average (30 year) annual rainfall for Thorney Island met station = 469mm; drainage varied between treatments according to the level of crop cover.

[2]Flow-weighted NO_3 N concentration

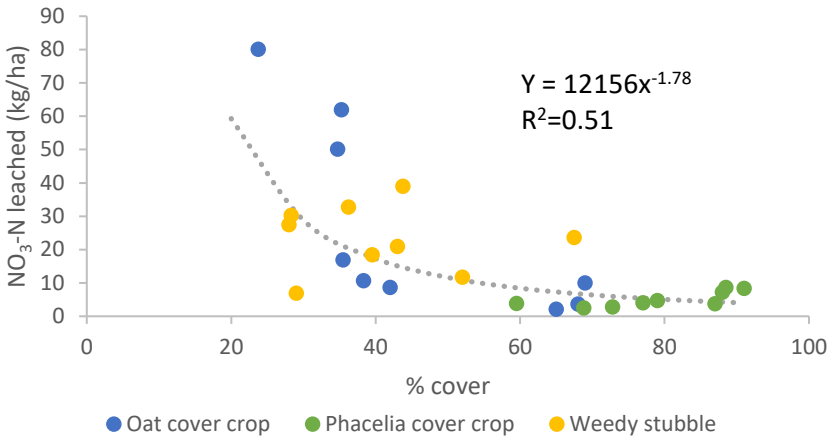

Figure 1. Relationship between above ground cover and nitrate leaching loss

The amount of N lost via leaching depends on the amount of mineral N in the soil at the onset of drainage (i.e. autumn SMN), the soil type and overwinter rainfall and drainage. This could be clearly seen in this demonstration study (Table 3), where losses were greatest in 2018-19 in Busto field which had the highest autumn SMN (c. 100kg/ha to 60cm depth) compared to Telegraph field (c. 25 kg/ha to 40cm depth). Busto field also had the highest flow weighted nitrate concentrations in the drainage water samples due to a combination of high nitrate load and low drainage volume. On the stubble and oat cover crop treatments in this field, the concentrations were in excess EU limit of 11.3 mg NO_3-N/l. The lowest losses and nitrate concentrations were measured in Windmill field over winter 2020-21 where winter rainfall was above average and drainage volumes high.

Interestingly, concentrations in the drainage waters began to increase (albeit still at low levels) after the cover crops had been destroyed by either frost or glyphosate (Figure 2).

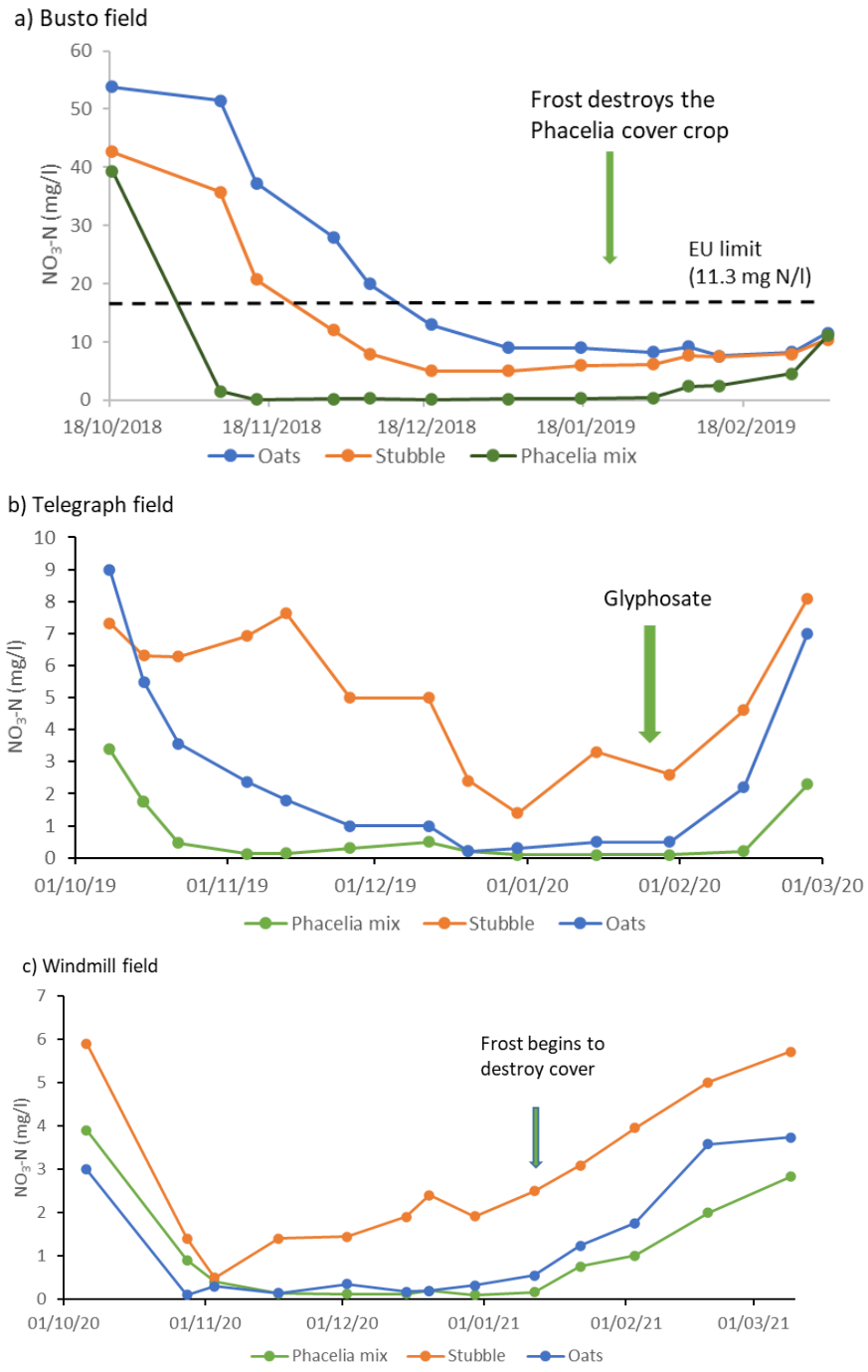

Figure 2. Nitrate concentration of the drainage waters; note the differences in scale on the Y axis, with much higher concentrations measured in 2018/19 from Busto field

Effect of cover crops on the performance of the subsequent cash crop

The reduction in nitrate leaching losses resulting from the phacelia/oat cover crop in 2018/19 (Busto field) increased the soil N supply (SNS) in the spring by over 35 kg/ha (Table 4) compared to the other cover crop treatments. Consequently, the amount of nitrogen fertiliser applied to the spring barley was reduced by 30 kg/ha. The SNS of the stubble and oat treatments was not sufficient to warrant a change in fertiliser policy for these two treatments in 2018/19. Likewise, in 2019/20 and 2020/21 (Telegraph and Windmill fields), there were only small differences in SNS ahead of drilling the spring barley which were insufficient to warrant a change in N fertiliser policy (Table 4).

Table 4. Spring soil N supply, fertiliser applied and yield of the spring barley cash crop

Field/year	Treatment	Spring SNS[1] (kg/ha)	N fertiliser applied (kg/ha)	Grain yield (t/ha)
Busto 2018-19	Stubble	39	150	8.25 (± 0.15)
	Oats	25	150	8.12 (± 0.15)
	Phacelia/oat	79	120	8.40 (± 0.14)
Telegraph 2019-20	Stubble	36	150	8.25 (± 0.11)
	Oats	53	150	7.91 (± 0.19)
	Phacelia/oat	59	150	8.16 (± 0.37)
Windmill 2020-21	Stubble	57	150	6.22 (± 0.19)
	Oats	60	150	6.19 (± 0.23)
	Phacelia/oat	68	150	5.81 (± 0.19)

[1]SNS = cover crop N + soil mineral N

Yields were also almost 2 t/ha lower across all treatments in 2021 due to poor weather conditions during grain ripening. There was no significant effect of the different cover crop treatments on grain yields in the first two seasons, whereas in the final season, grain yields following the phacelia/oat cover crop were c. 0.4 t/ha lower than where no cover crop was grown (Table 4).

Cost/Benefit analysis

A simple cost-benefit assessment was produced each year, based on the various operations and inputs performed by the host farmer and using costs/prices that the farmer incurred (Table 5). Average site yields were used in 2019 (8.3 t/ha) and 2020 (8.1 t/ha) due to the absence of any statistically significant treatment effect on spring barley yield. However, in 2021 the individual treatment yields were used, reflecting the significantly lower yield measured following the phacelia cover crop. In each season, the highest net margins were achieved where no cover crop had been grown due to the cost of establishing the cover crop treatments (seed and establishment costs in the region £80-£90/ha). Only in 2018/19 were the cover crop establishment costs partially offset by savings in N fertiliser.

Table 5. Cost benefit analysis

Field/year	Treatment	Gross Margin (£/ha)	Net Margin (£/ha)
Busto 2018-19	Stubble	801	591
	Oats	793	513
	Phacelia/oat	806	526
Telegraph 2019-20	Stubble	807	597
	Oats	799	519
	Phacelia/oat	788	508
Windmill 2020-21	Stubble	770	560
	Oats	760	480
	Phacelia/oat	677	397

Whilst the use of cover crops is likely to increase farm costs it is important to consider the wider benefits they can provide, such as the improved water quality this study has demonstrated, as well erosion control, improved soil health and enhanced biodiversity. These benefits are an important consideration for mitigating against environmental pollution and providing ecosystem services to the wider public. The CAP Greening Measures (EFA) payment was established to reward farmers for some of these benefits, although the payments are no longer given in England, as the country transitions towards the new Environmental Land Management (ELM) scheme. An alternative means of recuperating the cost of establishing a cover crop would be to enter the land into Countryside Stewardship (option SW6 'winter cover crops') which paid £114/ha in 2020 and is open to new applications until 2023. In future, the new Sustainable Farm Incentive (part of ELM, currently being piloted in England) has measures to increase green cover over winter. The current pilot pays between £26 - £60/ha if the measure is undertaken on between 5 and 15% of the land entered into the scheme.

Conclusions

This study has clearly demonstrated that drilling a cover crop can reduce nitrate leaching losses by up to 90% compared to weedy stubble. Establishing the cover crop early (before September) is important to maximise the benefit, with overall leaching losses dependant on the amount of cover achieved, the amount of mineral N in the soil in the autumn, soil texture and over winter rainfall. The reductions in nitrate leaching losses can increase soil N supply in the spring leading to a decrease in the N fertiliser requirement of the following cash crop, although it is uncertain when the N captured by a cover crop is released. Spring barley grain yields were unaffected by the presence of a cover crop in two seasons, but decreased in 2021 where a phacelia/oat cover crop was grown, although this may not have been a direct consequence of the cover crop. As a result, net margins were higher where no cover crop was grown due to the absence of any yield benefit and cost of purchasing and establishing the cover crop. The assessment did not take account of the wider benefits of growing cover crops, particularly for water quality, but also potential improvements in soil quality and biodiversity on farm. This is currently incentivised by Countryside Stewardship and will also be part of the Sustainable Farm Incentive currently being piloted as part of the forthcoming Environmental Land Management (ELM) scheme