MM20: Legume-Grass Mixtures

Category

Cropland and grassland management: nutrient management

Overview

N_2O emissions arising from the use of synthetic N fertilisers can be reduced by relying more on biologically fixed nitrogen in crop production. Biological nitrogen fixation occurs in N fixing crops (legumes) form symbiotic relationships with bacteria (*Rhizobia*) in the soil that allows them to transform atmospheric N_2 to N compounds and use this in place of N provided by synthetic fertilisers. Besides the fixed N supporting the growth of the legume crop (e.g. clover), part of these N compounds also become available to the grass plants, reducing their need for synthetic N. This effect becomes substantial above a clover content of around 20%-30% in the sward. The effect is robust and persistent across legume species and climatic regions, as shown by a series of experiments in Europe over three years, where savings of 300 kg N ha^{-1} were achieved without compromising the yield, though grass-clover pastures tend to receive very low level of N and therefore their yield on average can be lower than highly fertilised grass swards (see a review in Lüscher *et al.* 2014). Evidence suggests that the biological fixation itself does not lead to significant emissions – the IPCC 2006 recommendations (IPCC 2006) removed legumes as a source of direct N_2O emissions (Lüscher et al. 2014). Another effect of clover in the swards on GHG emissions is that the proportion of N leached into the ground (and eventually to ground and surface water) can increase if the clover content is too high (Lüscher et al. 2014).

Legumes showed to affect animal performance in some experiments (see e.g. Egan *et al.* 2018), but the evidence is not conclusive (Enriquez-Hidalgo *et al.* 2014, Ribeiro Filho *et al.* 2005). The potential negative environmental effect of clover ingestion is the reduced dietary N utilisation and increased N excretion – though this can be counterbalanced by using high sugar content grass varieties in the mix (Lüscher et al. 2014). Forage legumes might also be capable or reducing enteric CH_4 emissions, partly through their condensed tannin content (Jayanegara *et al.* 2012), though the evidence is not conclusive yet (Lüscher et al. 2014).

The growth pattern of the grass-clover sward is different from grass-only swards, as clover requires higher temperature for growth, delaying the peak growth by a month, but providing higher yields (and better digestibility) later in the season. Furthermore, the protein content of clover is higher than perennial ryegrass; a 20% clover content increasing the protein content of the silage 2%. It needs to be noted that the clover needs to be introduced into the diet gradually to avoid bloating problems (AHDB 2016).

Mixed swards containing multiple species of grass and legumes show higher yield than average monocultures (though lower than the best performing monocultures) (Cardinale *et al.* 2007, Cong *et al.* 2018), and draught tolerance – an important aspect in adapting to the changing climate, particularly in south England (Finn *et al.* 2018).

Upon establishing the grass-clover mix by using a seed mixture high in clover, the mix needs to be maintained, as over the years the clover tends to be outcompeted by the grass, particularly if more N is added than the recommended low levels. Good management includes preventing poaching and adjusting grazing and fertilisation to balance clover and grass growth (AHDB 2016). Clover varieties are being developed to suit different management needs (AHDB 2019).

Mitigation summary

Table 1 Effects on emissions

GHG categories	Effect*	Notes
Enteric CH_4		
Manure CH_4		
Manure N_2O		
Soil N_2O: applied N	-	
Soil N_2O: grazing		
Energy CO_2: fieldwork	(-)	
Energy CO_2: other		
CO_2 liming and urea		
CO_2 sequestration below ground		
CO_2 sequestration above ground		
Pre-farm emissions	-	Production of fertiliser
Post-farm emissions		
Substitution of higher C products		
Production increases by more than the emissions		
	Rating	
Confidence in mitigation effect	High	
Cost-effectiveness**	Low	
Confidence in cost-effectiveness	High	

* ”-“ GHG reduction, “+”: GHG increase, “ ”: no significant effect
** low: =< £0/tCO_2e, moderate: £0/tCO_2e< >SCC, high: >SCC

Related measures and potential synergies

Table 2 Likely effects on the abatement potential of other measures

Measure	Impact
	-
	-

Inclusion in other marginal abatement cost curves

Table 3 Past assessment of the measure

UK 2008	UK 2010	UK 2015	Ireland 2012	France 2013	France 2019
Yes	Yes	Yes	Yes	Yes	?

What does the measure entail?

This measure is about both increasing the legume-grass mix areas as opposed to grass only areas, and also increasing the proportion of clover in the mixed swards to maintain it at least at 20%.

In temporary grasslands (including those in rotations) it entails using grass-clover mixes for sowing (white clover seed rate 1-4 kg ha^{-1}, red clover seed rate 7 kg ha^{-1}) and keeping the fertilisation (considering both added organic and synthetic N and also N excreted while grazing) at the recommended level. In permanent grasslands clover can be introduced (or clover content can be increased) by various techniques without cultivation (e.g. direct drilling), using a clover seed rate of 4 kg ha^{-1} (AHDB 2016).

Abatement rate

The abatement calculation is based on the reduction in N fertilisation, accounting for the on-farm effect only (not including the change in emissions from fertiliser use). The substantially reduced fertilisation leads to reduced machinery use and related CO_2 emissions.

Table 4 Data from literature on abatement

Abatement	Value	Country	Reference
N need	High (20-30%) clover content: -200 kg N ha^{-1} (66% reduction) Low clover content: -30 kg N ha^{-1} (10% reduction)	UK	(SRUC 2013)
N need	High (30%) white clover content: -150 kg N ha^{-1} High (30%) red clover content: -250 kg N ha^{-1}	UK	(AHDB 2016)

Cost

The costs of establishing and maintaining a grass-clover mix include the cost difference between grass-only and grass-clover seed mix (once in every 2 and 5 years for temporary and permanent grass, respectively), the savings from the reduced use of synthetic N fertiliser, one less fertiliser spreading event per year, and, in the case of permanent grasslands, the additional cost of seeding (assuming direct drilling; once in every five years).

Table 5 Financial costs and benefits of the measure

Costs/savings	Value ('-' sign for savings)	Notes

Costs/savings	Value ('-' sign for savings)	Notes
Difference in seed cost	£10 ha^{-1}	https://www.bostonseeds.com/products/1/Grass-Seeds/3/Agricultural-Grass-Seed/#product1369 BS Permanent Pasture - without Clover, 5+ yrs Ley Mixture: sowing rate 35 kg ha^{-1}, 14 kg bag: £63 (£155 ha^{-1}) BS Permanent Pasture - with Clover, 5+ yrs Ley Mixture: sowing rate 35 kg ha^{-1}, with 1.73 kg ha^{-1} white clover, 14 kg bag: £67 (£165 ha^{-1}) BS Cut and Graze - Long Term, 3-5 yrs Ley Mixture – without clover: sowing rate 35 kg ha^{-1}, 14 kg bag: £64 (£158 ha^{-1}) BS Cut and Graze - Long Term, 3-5 yrs Ley Mixture – eith clover: sowing rate 35 kg ha^{-1}, with 1.73 kg ha^{-1} white clover, 14 kg bag: £68 (£168 ha^{-1})
Cost of one fertiliser spreading event	£10.16 ha^{-1} (range: £7.41-31.84 ha^{-1})	(SAC 2018)
Cost of direct drilling (for permanent grass only)	£52.85 ha^{-1} (range: £42.01-61.63 ha^{-1})	(SAC 2018)

Applicability

The measure is applicable on all improved grasslands (i.e. grassland which is fertilised).

Current uptake and maximum additional future uptake

According to the latest Farm Practices Survey (Defra 2018) 46% of grassland is seeded with clover mix in England. From the Countryside Survey[1] Anthony concluded that the proportion of improved or semi-improved grassland with white clover in 2007 was 21, 35 and 44% in England, Wales and Scotland, respectively (*pers. comm.* Anthony in Eory *et al.* 2015). Based on these data we assumed that 35% of grassland in England and Wales and 44% in Scotland and Northern Ireland have clover mixes.

Future additional uptake relates to grass swards that currently have no legumes or have legume content below 30%. Unfortunately there is no available information on what proportion of the fields has sufficient clover to fix significant proportion of the N requirements apart from information on Scottish dairy farmers. In a survey by Glenk *et al.* (2014) 35% of farmers indicated that they have high clover content swards (above 20% DM). Furthermore, this GHG mitigation measure is one of the most favoured measure amongst those who have not adopted it. We assumed that currently 75% the grass-clover swards have sufficient legume content, consequently the current uptake is 26.25% in England, Wales, and 33% in Scotland and Northern Ireland. The additional uptake can be 73.75% in England, Wales, and 67% in Scotland and Northern Ireland.

[1] https://countrysidesurvey.org.uk/

Assumptions used in the MACC

Parameter	Change in value	Notes
Synthetic N rate on grassland[1]	Baseline - 200 kg N ha^{-1} (or 0 if baseline value < - 200 kg N ha^{-1})	
Diesel use for drilling (on permanent grassland)	+18.9 l ha^{-1} every 5 years	(SAC 2018)
Diesel use for fertilising	-1.57 l ha^{-1}	(SAC 2018)
Fuel conversion factor (diesel (average biofuel blend), net CV)	2.59411 kg CO_2e l^{-1}	(BEIS 2019)
Seed cost	£10 ha^{-1}	

[1] Note that the grassland N fertilisation rate in the MACC dataset is already an average value of pure grasslands and mixed clover-grass swards, and smaller than 200 kg ha^{-1}, therefore the mitigation might be underestimated by this method

Wider effects

Table 6 Wider effects of the measure

Aspect	Effect	Reference
Positive effects		
Off-farm GHG	Reduced GHG emissions from synthetic fertiliser production	
Production		
Adaptation		
Environment	Reduced energy use and NH_3, NO_x emissions and N leaching from synthetic fertiliser use and production	
Negative effects		
Off-farm GHG		
Production		
Adaptation		
Environment	N leaching can increase	(Lüscher *et al.* 2014)

Identified implementation challenges and barriers

Table 7 Potential barriers of the measure

Barrier to uptake	Reference
Management: more attention is needed to the maintenance of the mixed swards than to grass only swards	
Other key risks/uncertainties	**Reference**

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