

Does mixed vs separate sheep and cattle grazing reduce soil compaction?

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Abstract

Degradation of soil in the United Kingdom (UK) is compromising the ecosystem services that flow from this natural capital asset, including water flow regulation. Soil compacted by grazing livestock, for example, results in an increase in overland flow following rainfall and is thought to be one of the key factors contributing to increased severity of UK winter flooding in recent years. Practical farm-scale changes in livestock management that lead to improvements in water flow regulation therefore need to be identified. This pilot study aimed to assess the impact of (i) changing stocking composition, and (ii) temporary grazing exclusions, on soil natural capital quality on a sheep and beef cattle farm in Northumberland, England. I found evidence of improved soil bulk density under mixed sheep and cattle grazing compared to cattle-only grazing over a 3-month summer grazing season; bulk density in 'cattle-only' pastures increased from 0.836 to 0.875 g cm⁻³ from June to September 2017, compared with a small decrease of 0.875–0.871 g cm⁻³ in 'cattle to mixed sheep and cattle' pastures (difference significant at $p < .05$ level). Changing from sheep-only grazing to mixed grazing, and exclusion of grazing, did not significantly influence bulk density change ($p > .05$). This study indicates that rapid improvements in soil physical properties can be achieved through realistic changes to livestock management. If this finding can be confirmed over multiple grazing seasons, this potentially offers a straightforward means to enhance soil health on grazed land in the UK, improving delivery of water flow regulation and other ecosystem services.

KEYWORDS

bulk density, grazing livestock, soil compaction, soil physical properties, water flow regulation

1 | INTRODUCTION

The cost of soil compaction in the United Kingdom (UK) has been estimated at £472 million per year, through decreased productivity of compacted soils and increased flood damage (Graves et al., 2015). Sheep and

cattle (hereafter livestock) treading compact soil by decreasing macroporosity (Cournane et al., 2011; Drewry & Paton, 2005; Houlbrooke & Laurenson, 2013), which reduces the infiltration rate of water into soil (Heathwaite et al., 1990; Mulholland & Fullen, 1991). This has been linked to increased overland flow at a farm/sub-catchment

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scale (Heathwaite et al., 1990; Marshall et al., 2009; Meijles et al., 2015; Meyles et al., 2006). Although there remains a lack of evidence of the effect of soil degradation on flood regulation at the whole-catchment scale, livestock-mediated increases in overland flow due to soil compaction are assumed to increase flood hazard (Dadson et al., 2017; Graves et al., 2015).

Recent UK flooding has generated interest in managing agricultural land to improve water flow regulation, in efforts to reduce flooding severity (Dadson et al., 2017). Mitigating increased overland flow caused by livestock trampling would improve the sustainability of UK livestock farming. Furthermore, managing the natural capital assets of soils in the UK has moved rapidly up the political agenda, demonstrated by the 25 Year Environment Plan commitment to improve soil health (HM Government, 2018). However, there is currently a lack of evidence to inform realistic land management changes that enable some degree of livestock production whilst alleviating soil compaction to reduce flood hazard in a UK context.

Although many livestock farmers keep both sheep and cattle and often graze them together, the impact of mixed versus separate grazing has not previously been studied in the UK. In New Zealand, cattle-only grazing has been shown to have a greater deleterious effect on soil physical properties than sheep-only (Cournane et al., 2011; Drewry et al., 2000; Houlbrooke et al., 2011), potentially because a single cow, due to its greater weight per surface area of hoof, exerts a greater static pressure (160–192 kPa) on soil than a single sheep (83 kPa) (Willatt & Pullar, 1984). There is also some evidence from the United States to suggest mixed sheep and cattle grazing impacts soil properties less than separate grazing (Abaye et al., 1997). Sheep are commonly stocked at five times the density of cattle in the UK, potentially resulting in greater total compaction forces per area of soil. If either sheep or cattle cause more compaction than the other under typical UK stocking densities, then shifting from single stocking to mixed stocking (or vice versa) could be a simple measure to reduce UK soil compaction that is contributing to increased flood hazard. Furthermore, removal of livestock has been demonstrated in previous studies to improve soil physical properties (Drewry, 2006) and reduce overland flow (Marshall et al., 2014). Interestingly, the length of time required for measurable improvements in soil physical properties following livestock exclusion has been found to range from a matter of 4 months (Drewry & Paton, 2000) to 30 months (Greenwood et al., 1998). Thus, depending on the timescales required under UK climatic and pedological conditions, temporary livestock exclusion could be an attractive tool to improve soil physical properties and, by extension, reduce flood hazard.

In this pilot study, I examined the effect of stocking regime and grazing exclusion on soil compaction, using

bulk density as a metric, on a UK sheep and cattle farm. I hypothesised that sheep cause overall greater soil compaction than cattle at UK-relevant stocking densities (i.e. five sheep to one cow), and therefore predicted that mixed sheep and cattle grazing will result in a smaller increase in soil bulk density over a three-month summer grazing season compared to sheep-only grazing, and conversely a greater increase in bulk density than cattle-only grazing. Furthermore, I tested whether three months of livestock exclusion from pasture was sufficient time to detect a change in soil bulk density suggestive of decreased compaction.

2 | MATERIALS AND METHODS

The study was conducted at a marginal sheep and beef cattle production unit in Northumberland, England (55.41°N, 1.72°W), on permanent pasture dominated by perennial ryegrass (*Lolium perenne*) and white clover (*Trifolium repens*). Soils were slowly permeable seasonally wet acidic clays (Cranfield University, 2020). Breeding ewes were 2- to 6-year-old Texel crossbreds (average 75 kg liveweight) with March/April born Beltex-sired twin lambs, whilst suckler cows were 2- to 12-year-old Simmental crossbreds (average 600 kg liveweight) with March/April or September/October born Limousin- and Belgian Blue-sired calves.

Farm management units were used as the unit of replication in this study. The total number of livestock in each management unit was determined by grass availability as visually assessed by the farmer, which varied between units. As such, stocking densities varied from 840 to 3,770 kg liveweight per hectare (Table 1). Because some management units comprised parcels with differing historical management, these were separated into blocks to account for existing variation within soil physical properties. Hence, management units contain a variable number of blocks and blocks are not of a constant size (Table 1). In addition, areas likely to have atypical soil properties (field margins, gateways, areas of scrub) were excluded from sampling. Within blocks (i.e. the areas sampled within each management unit), sample sites were chosen using random coordinates generated in ArcMap 10.3, Esri (Figure 1). The same sites were sampled for baseline and endline measurements.

In the 30 years preceding the study, management units had been consistently grazed with either cattle or sheep, apart from two management units which were mix-grazed. To investigate stocking regime, three control levels were maintained—‘sheep-only’ (SS), ‘cattle-only’ (CC) and ‘mixed sheep and cattle’ (MM)—and two interventions were imposed—previously ‘sheep-only’ grazing to ‘mixed sheep and cattle’ grazing (SM), and previously ‘cattle-only’ grazing to ‘mixed sheep and cattle’ grazing (CM) (Table 1). Each was replicated across two management units. Because of the stocking regime treatments being

TABLE 1 Livestock numbers (ewes, lambs, cows, calves) in each management unit at the baseline (June 2017) and implemented during the treatment (continuous set-stocked grazing from June–September 2017)

Management unit	Baseline stocking density						Treatment stocking density						Block			
	ID [†]	Area (ha)	Ewes	Lambs	Cows	Calves	kg LW/ha	LSU/ha	Ewes	Lambs	Cows	Calves	kg LW/ha	LSU/ha	ID [†]	Area (ha)
SS1		5.62	90	100	0	0	1,823.84	3.03	90	100	0	0	1,823.84	3.03	SS1	2.94
SS2		8.21	98	180	0	0	1,662.61	2.76	98	180	0	0	1,662.61	2.76	SS2	3.69
CC1		2.65	0	0	10	10	3,773.58	6.29	0	0	10	10	3,773.58	6.29	CC1	1.01
CC2		11.9	0	0	14	4	840.34	1.40	0	0	14	4	840.34	1.40	CC2	1.65
MM1		1.91	19	27	2	2	2,078.53	3.46	19	27	2	2	2,078.53	3.46	MM1	0.49
MM2		24.2	31	0	38	36	1,335.74	2.23	18	32	38	36	1,341.74	2.24	MM2	8.05
SM1		6.68	100	170	0	0	2,013.47	3.35	82	138	4	4	2,242.51	3.73	SM1a	0.81
															SM1b	1.94
SM2		14.3	140	250	0	0	1,346.15	2.24	140	250	30	30	1,371.87	2.28	SM2a	2.37
															SM2b	2.86
															SM2c	3.23
CM1		4.43	0	0	18	9	2,844.24	4.74	31	0	14	5	2,646.73	4.41	CM1a	1.27
															CM1b	1.04
CM2		21.6	0	0	30	30	1,388.89	2.31	140	250	30	30	1,371.87	2.28	CM2a	1.62
															CM2b	1.15

Note: Total summed sheep and cattle liveweight (LW) and livestock units (LSU) for each management unit are given per hectare (ha). LSUs were calculated following UK government convention (Natural England, 2013), where a 600 kg beef cow is 1 LSU. All other LSUs are calculated proportional to animal liveweight. As such, the 75 kg ewes are attributed a LSU of 0.125. Because lambs and calves were growing over the study period, average weights of 35 kg for spring 2017-born lambs (0.058 LSU), 200 kg for spring 2017-born calves (0.333 LSU) and 400 kg for autumn 2016-born calves (0.667 LSU) were used. Management units MM1, MM2 and CM1 contained cows with spring-born calves, and CC1, CC2 and CM2 contained cows with autumn-born calves. The ID and areas of blocks (i.e. the areas sampled from within management units) are also given (see Figure 1).

Abbreviations: CC, cattle-only (baseline & treatment); CM, cattle-only (baseline & treatment); MM, mixed sheep & cattle (baseline & treatment); SM, sheep-only (baseline) to mixed sheep & cattle (treatment); SS, sheep-only (baseline & treatment).

[†] ID reflects stocking regimes for each management unit.

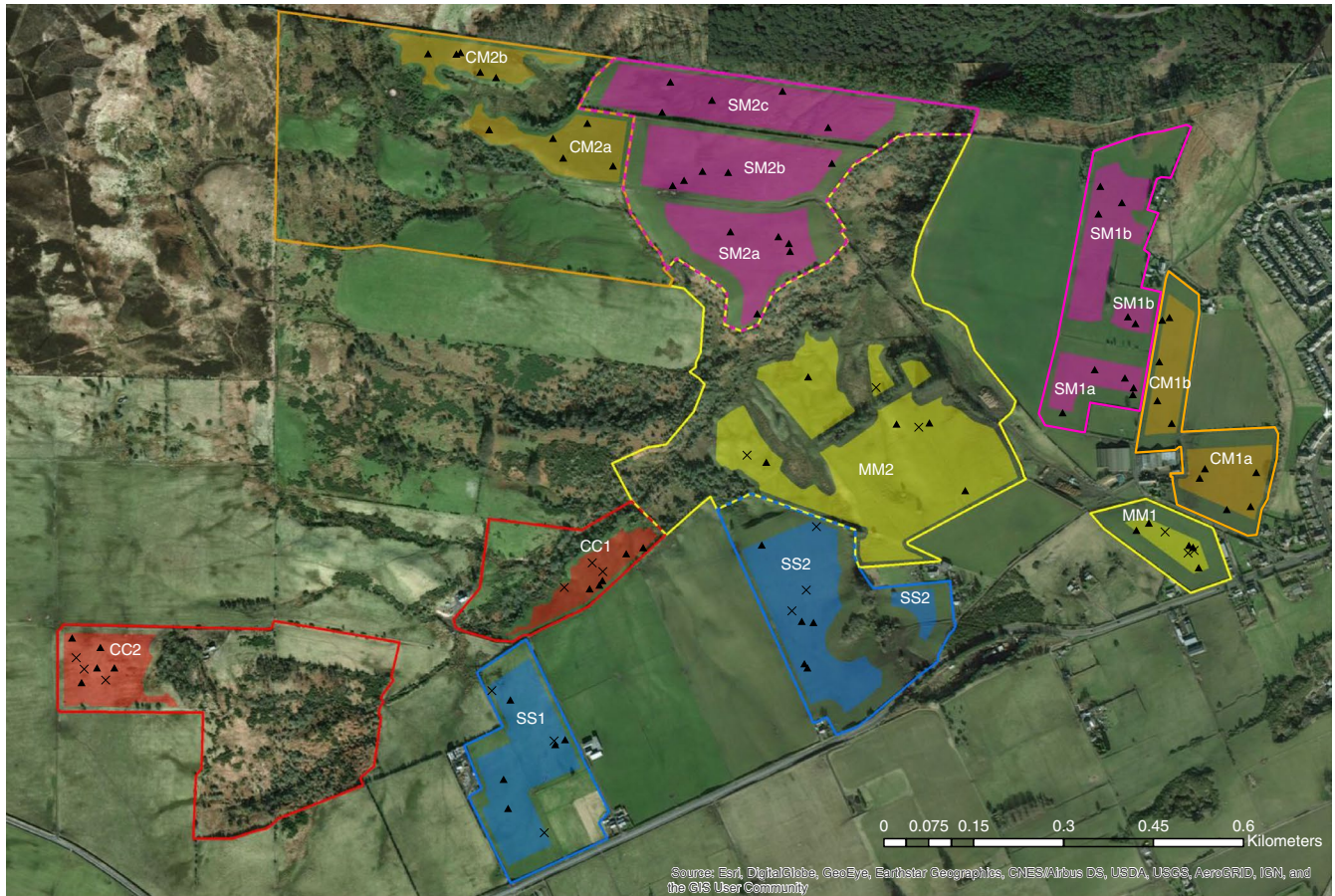


FIGURE 1 Study site, Northumberland, England (55.41°N, 1.72°W). Management units delineated by solid lines (red = CC, cattle-only; blue = SS, sheep-only; yellow = MM, mixed sheep and cattle; orange = CM, cattle-only to mixed sheep and cattle; pink = SM, sheep-only mixed sheep and cattle). Translucent shaded areas show blocks where sampling occurred (labelled, colours consistent with management units). The variable number and size of blocks within management units is due to blocks separating areas with differing historical management to account for existing variation in soil properties. Sampled plots are marked by solid triangles (grazed) or crosses (ungrazed; SS, CC and MM management units only). See Table 1 for stocking densities at baseline and during treatments

dependent on historic grazing management, it was not possible to randomly assign treatments to management units. Five plots were sampled in every block of each management unit (solid triangles, Figure 1), although the differing number of blocks within management units resulted in a non-constant number of total samples per management unit.

The two grazing exclusion treatments were as follows: (i) ‘grazed’—grazed both before and during the study, and (ii) ‘ungrazed’—grazed before the study but ungrazed during the study. The ungrazed treatment was implemented by excluding livestock from treading and grazing 1.5-m² plots, using metal hurdles secured with wooden posts. To avoid confounding variation, this treatment was only applied in the six ‘control’ management units of the stocking regime factor (i.e. SS, CC and MM). Three ‘grazed’ plots and three ‘ungrazed’ plots were sampled in each block (solid triangles and crosses, respectively, Figure 1), where the three ‘grazed’ plots were the same as the first three plots sampled for stocking regime.

For each plot, a 31.5-mm-diameter aluminium soil corer was used to take four soil cores to a depth of 50 mm, one from each corner of a 1 m by 1 m quadrat, following the methodology described in Blake (1965) and McLaren and Cameron (1996). Soil cores were dried at 105°C until the samples reached a constant weight (found to occur within 24 hr), from which bulk density was calculated (dry soil mass per unit area).

Baseline measurements were taken in June 2017, followed by the erection of enclosures where applicable, and experimental manipulation of stocking regime (Table 1). Management units were continuously grazed at this set stocking for the duration of the study. Endline measurements were taken in September 2017. The heuristic of 5 sheep = 1 cow, routinely used on the farm to determine stocking rates and as in Abaye et al. (1997), was applied when moving sheep and cattle between fields to impose the treatments for the stocking regime factor (Table 1).

Soil bulk density data were analysed in R version 3.2.3. Linear mixed models (*lmer* function, *lme4* package) were

used to analyse the effect of stocking regime. A split-plot ANOVA (*aov* function, *car* package) was used to analyse the effect of grazing exclusion to account for the nested nature of the design (i.e. grazing regime nested within stocking regime, because of grazing exclusion being tested across the SS, CC and MM levels of the stocking regime factor). Stocking/grazing regime and time (baseline/endline) were modelled as an interaction, with block size included as a fixed effect and management unit, block and plot IDs as a nested random effect which captured the uneven number of plots sampled per management unit. Marginal and conditional R^2 values were used to assess model fit, following the convention of Nakagawa and Schielzeth (2013). Post hoc paired *t* tests (with a Bonferroni correction to reduce the chance of a type I error) were used to establish significant differences in bulk density from baseline to endline. Uncorrected *p*-values are also presented, because the penalty from the Bonferroni correction is considered severe (Perneger, 1998) and the *t* tests were conducted to enable effective interpretation of model outputs rather than the predominant statistical analysis of the data.

3 | RESULTS

3.1 | Stocking regime

I found a significant interaction ($p < .05$) between the effect of stocking regime and time on the change in bulk density for pastures historically grazed by cattle; bulk density in 'cattle-only' (CC) pastures increased from 0.836 to 0.875 g cm^{-3} from June to September, compared with a small decrease of 0.875 to 0.871 g cm^{-3} in 'cattle to mixed sheep and cattle'

(CM) pastures (Table 2, Figure 2). However, the small marginal R^2 value of 0.0316 indicates that the fixed effects (stocking regime, time and block size) explain little variation in the data. Results from the post hoc *t* tests suggest that soil bulk density significantly increased in block CC2 and significantly decreased in block CM1a from June to September ($p < .001$, uncorrected *p*-values; Table 3, Figure S1a).

The interaction between stocking regime and time was not significant for treatments on pastures historically grazed by sheep ($p > .05$, Table 2). Bulk densities in both 'sheep-only' (SS) and 'sheep to mixed sheep and cattle' (SM) pastures increased from June to September (1.45–1.48 g cm^{-3} , and 1.22–1.27 g cm^{-3} , respectively; Table 2, Figure 2), with the marginal R^2 of 0.319 implying a good model fit. Significant increases in bulk density from June to September were found in blocks SS2 and SM1a ($p < .05$, uncorrected *p*-values; Table 3, Figure S1b).

No significant changes in bulk density from baseline to endline measurements for the stocking regime treatments were found in *t* tests with Bonferroni-corrected *p*-values.

3.2 | Grazing exclusion

Soil bulk density increased from June to September for both grazed and ungrazed treatments (0.974–0.985 g cm^{-3} and 1.01–1.03 g cm^{-3} , respectively; Figure 3), but the interaction between grazing treatment and time was not significant ($p > .05$; Table 4). Low marginal and conditional R^2 values suggest that the model explained little variation in the data. In the ungrazed treatments on the sheep-only pastures, soil bulk density significantly decreased from June to September in management unit SS1

TABLE 2 Model outputs for analysis of stocking regime treatment on soil bulk density (g cm^{-3})

Model component	Treatment	
	'cattle-only' & 'cattle to mixed sheep and cattle'	'sheep-only' & 'sheep to mixed sheep and cattle'
Intercept: 'only' level at baseline	0.836 ± 0.128	1.45 ± 0.123
Stocking Regime: 'only' to 'mixed'	0.0389 ± 0.0612	−0.230 ± 0.117
Time: baseline to endline	0.0436 ± 0.0169	0.0301 ± 0.0128
Stocking Regime*Time	−0.0474 ± 0.0207	0.0189 ± 0.0239
Interaction <i>p</i> -value	0.0225*	0.427
Marginal R^2	0.0316	0.319
Conditional R^2	0.544	0.735
Observations (baseline, endline)	120, 120	140, 140

Note: All values given to three significant figures. Standard errors are given for the coefficients. *p*-values are given for interaction coefficients.

* $p < .05$.

FIGURE 2 Soil dry bulk density (g cm^{-3}) for each level of the stocking regime treatment at baseline (June 2017) and endline (September 2017) measurements. CC = cattle-only; CM = cattle-only to mixed sheep and cattle; MM = mixed sheep and cattle; SM = sheep-only mixed sheep and cattle; SS = sheep-only. Bar height indicates the mean bulk density across all blocks in management units with that stocking regime, error bars represent the standard error of the mean, and shading indicates timing of measurements

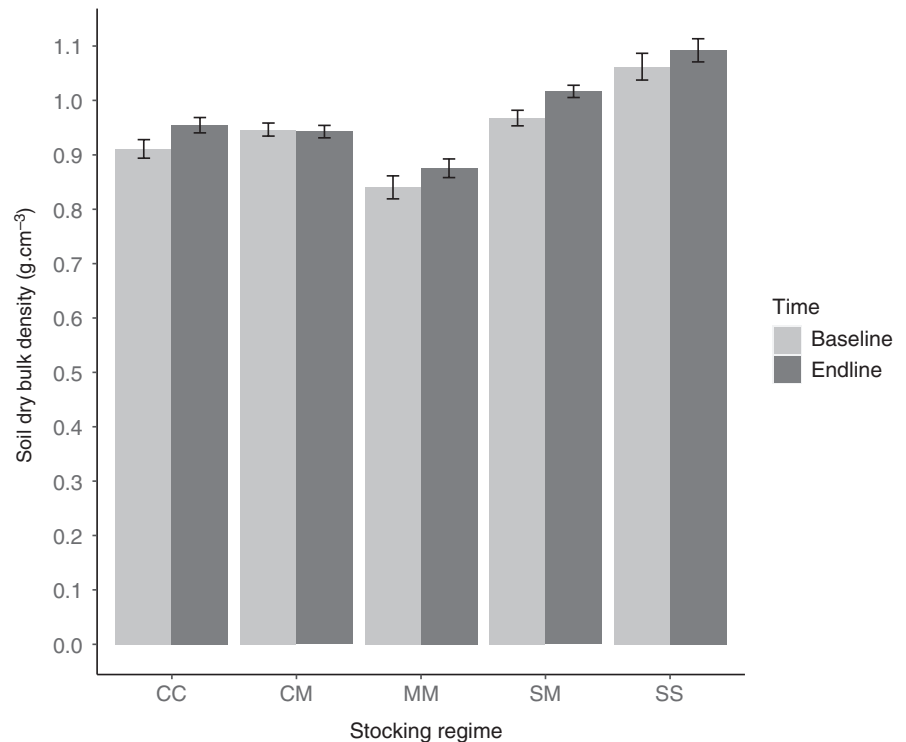


TABLE 3 Post hoc paired *t* tests: mean change in soil bulk density between baseline and endline measurements for each block in the sheep-only (SS), sheep to mixed sheep and cattle (SM), cattle-only (CC) and cattle to mixed sheep and cattle (CM) Stocking Regime levels

Block [†]	Mean change in bulk density (g cm^{-3})	<i>p</i> -value	Corrected significance	Uncorrected significance
SS1	0.0171	.625	-	-
SS2	0.0431	.0381	-	*
SM1a	0.0637	.0256	-	*
SM1b	0.0456	.291	-	-
SM2a	0.0489	.107	-	-
SM2b	0.0480	.0279	-	*
SM2c	0.0388	.149	-	-
CC1	0.0126	.701	-	-
CC2	0.0746	.00721	-	**
CM1a	-0.0573	.00460	-	**
CM1b	0.0296	.0713	-	-
CM2a	0.00493	.834	-	-
CM2b	0.00742	.739	-	-

Note: Values given to three significant figures. For corrected *p*-values (Bonferroni correction), **p* < .00385. For uncorrected *p*-values; **p* < .05 level, ***p* < .01.

[†] Five plots sampled in all blocks, with four measurements per plot.

(sheep-only, *p* < .05, Bonferroni-corrected *p*-value), but significantly increased in SS2 (sheep to mixed cattle and sheep, *p* < .01, Bonferroni-corrected *p*-value) (Table 5, Figure S2). Bulk density also significantly increased on the ungrazed treatment of the CC2 (cattle-only) pasture (*p* < .01, uncorrected *p*-value). No other blocks showed significant changes in bulk density from baseline to endline.

4 | DISCUSSION

4.1 | Does mixed sheep and cattle grazing improve soil properties compared to sheep or cattle alone?

I found evidence that introducing sheep into pastures previously grazed by only cattle mitigated an increase in soil

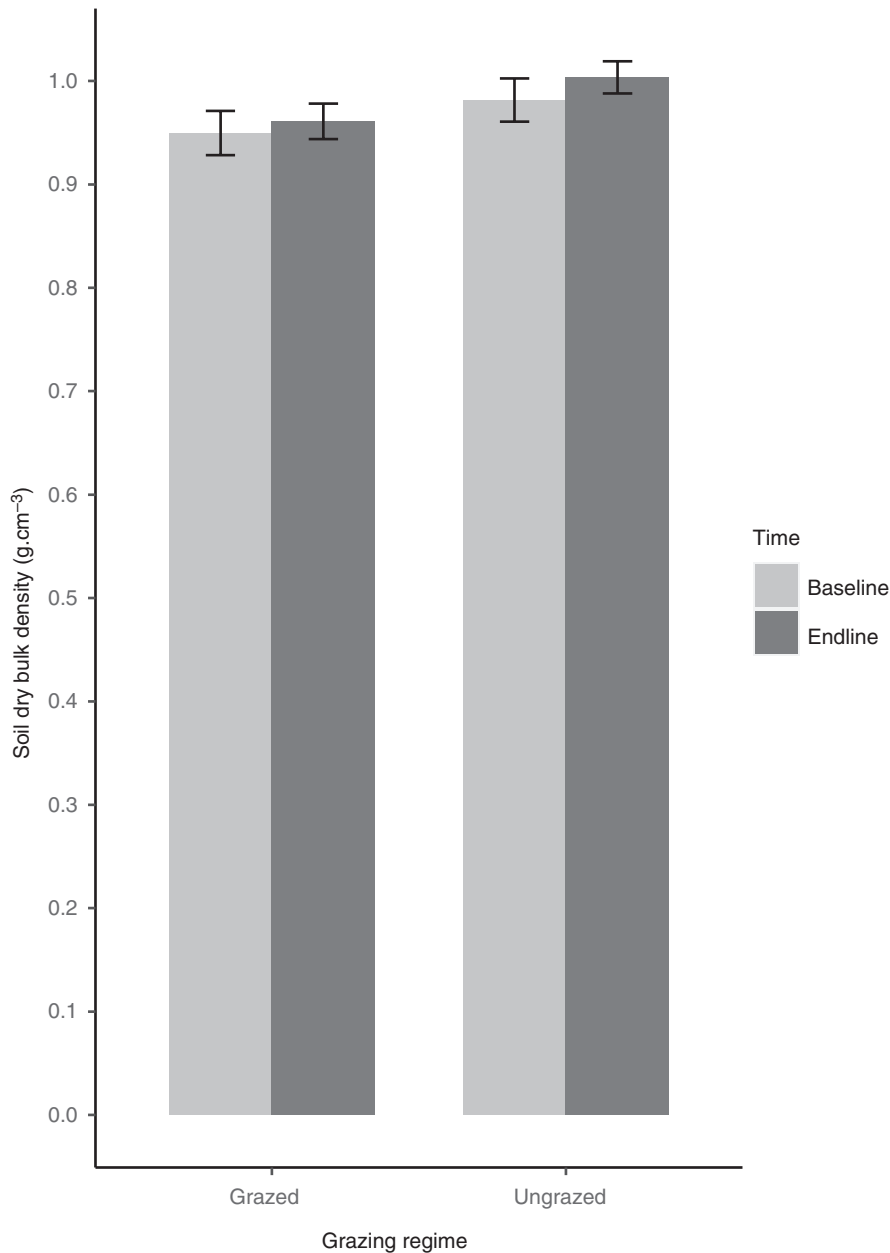


FIGURE 3 Soil dry bulk density (g cm^{-3}) under grazed and ungrazed treatments. Bar height indicates the mean bulk density across all management units with that grazing regime treatment, error bars represent the standard error of the mean, and shading indicates baseline (June) and endline (September) measurements

compaction over a summer's grazing (June to September). This contrasts with my expectation based upon the static pressure exerted on the soil by five sheep versus one cow (5×84 kPa versus 160–192 kPa, from Willatt & Pullar, 1984). Nevertheless, my finding aligns with previous work from the United States which found limited evidence of lower soil bulk density under mixed sheep and cattle compared to separate grazing, using the stocking equivalence of one cow to five sheep implemented here (Abaye et al., 1997). My result also concurs with previous findings from New Zealand across a range of stocking densities that cattle grazing has a greater deleterious effect on soil physical properties than sheep when grazed separately (Cournane et al., 2011; Drewry et al., 2000; Houlbrooke et al., 2011), although Cournane et al. used a similar stocking ratio (one cow equivalent to six sheep) to this study.

I did not find a corresponding increase in soil bulk density when sheep-only grazing was changed to mixed sheep and cattle, which would be expected if cattle caused a more deleterious effect on soil physical properties than sheep. This may be because livestock could not be manipulated to ensure a 50:50 relative stocking ratio between cattle and sheep in the mixed sheep and cattle treatments, because of the restrictions of conducting this study on a working farm. Therefore, in terms of grazing requirements, there were far fewer cows than sheep, even relative to '5 sheep = 1 cow' heuristic used, particularly in management unit SM1 (Table 1). Future work should seek to achieve a greater equivalence between sheep and cattle in mixed grazing treatments, to establish whether any improvements in soil physical properties by converting from cattle-only to mixed grazing are at risk of being offset by a corresponding deterioration in soil physical properties

TABLE 4 Model outputs for grazing regime analysis

Model component	Treatments 'grazed' & 'ungrazed'
Intercept: 'grazed' level at baseline	0.974
Grazing Regime: 'grazed' to 'ungrazed'	0.0319
Time: baseline to endline	0.0113
Grazing Regime*Time	0.0105
Interaction P-value	0.771
Marginal R^2	0.0271
Conditional R^2	0.111
Observations (baseline, endline)	144, 144

Note: All values given to three significant figures. Standard errors cannot be calculated for split-plot ANOVA models containing random factors. p -value is given for interaction coefficient.

* $p < .05$.

from the addition of cattle to sheep pastures, assuming total numbers of cattle and sheep were to be kept constant at the farm level.

In addition, these preliminary data revealed differing responses to the stocking regime treatment between blocks in the same management unit, implying that more samples per block and/or a longer study duration would be required to detect a consistent effect of changed stocking regime. Management units were separated into blocks in the experimental design in an effort to control for pre-existing variation in soil physical properties because of historical (>30 years ago) management differences, with the aim that soil properties would be sufficiently homogenous within blocks to justify a random sampling approach and that five sampling sites per block would be sufficient to capture any treatment

effects (due to sample size being limited by resource constraints). However, it is clear from these data—and the large differences in block area (Table 1)—that future work would benefit from a spatially stratified sampling approach, as this would ensure more representative sampling across management units.

4.2 | Can an improvement in soil physical properties be seen after short-term livestock exclusion in a UK context?

I did not find evidence of significant improvements in soil bulk density after three months of grazing exclusion, suggesting that livestock exclusion for a summer grazing season (e.g. by rotating fields for silage or hay across the farm) may not be an adequate strategy to alleviate soil compaction. This could be because many of the natural processes that improve soil physical properties, such as freeze-thaw and wetting-drying cycles (Drewry, 2006), are unlikely to occur in the UK summer months of June to September. Nevertheless, my finding is consistent with results from non-UK studies, which have suggested it takes from four months (Drewry & Paton, 2000) to 30 months (Greenwood et al., 1998) to begin to detect improvements in soil physical properties. Future work should take regular measurements following grazing exclusion over a longer time series, to investigate how long is required under UK conditions to observe an improvement in soil physical properties, and how rapidly that improvement is lost when grazing is resumed. This must be established before it can be determined whether temporary livestock exclusions are an effective farm-level management strategy to reduce soil compaction.

TABLE 5 Post hoc paired t tests: mean change in soil bulk density between baseline and endline measurements for each grazed (_G) and ungrazed (_U) treatments in the sheep-only (SS), cattle-only (CC) and mixed sheep and cattle (MM) management units

Treatment [†]	Mean change in bulk density (g cm ⁻³)	p -value	Corrected significance	Uncorrected significance
SS1_G	-0.0465	0.305	-	-
SS1_U	-0.144	0.00267	*	**
SS2_G	0.0366	0.266	-	-
SS2_U	0.108	0.000800	**	***
CC1_G	-0.00620	0.901	-	-
CC1_U	0.0140	0.661	-	-
CC2_G	0.0422	0.260	-	-
CC2_U	0.123	0.00429	-	**
MM1_G	0.0105	0.721	-	-
MM1_U	-0.00520	0.867	-	-
MM2_G	0.0313	0.418	-	-
MM2_U	0.0362	0.201	-	-

Note: Values given to three significant figures. For corrected p -values (Bonferroni correction), * $p < .00417$, ** $p < .000833$. For uncorrected p -values; * $p < .05$ level, ** $p < .01$, *** $p < .001$.

[†] Three plots sampled for each treatment, with four measurements per plot.

5 | CONCLUSION

I here present preliminary evidence that replacing cattle-only grazing with mixed sheep and cattle avoids an increase in soil compaction over a summer grazing season, but that three months of livestock exclusion is too short to deliver meaningful improvements in soil physical properties on a UK livestock farm. Reducing soil compaction on grazing land is an important strategy to improve water flow regulation services, as compaction reduces infiltration of water into soil and thus enhances overland flow (Heathwaite et al., 1990), ultimately linked to increased flood hazards on a catchment scale (Dadson et al., 2017). Negative consequences of soil compaction also include reduced pasture production—via restricted root growth, reduced soil water availability and increased nutrient loss in run-off (Graves et al., 2015), in turn impairing livestock productivity—in addition to modified soil chemical properties and microbial community structure (Hiltbrunner et al., 2012). Future work should verify whether the changes in management proposed in this study are effective in delivering improvements across these metrics. In all, this pilot study identifies management strategies with the potential to balance improvements in soil physical properties with continued livestock production, enhancing the delivery of benefits from soil natural capital assets.

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CONFLICTS OF INTEREST

I have no conflicts of interest to declare.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section.

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