Value of mob grazing to support historic and ecological asset management

A Quick Scoping Review

March 2025

Natural England Commissioned Report NECR573

www.gov.uk/natural-england

NATURAL ENGLAND

About Natural England

Natural England is here to secure a healthy natural environment for people to enjoy, where wildlife is protected and England's traditional landscapes are safeguarded for future generations.

Further Information

This report can be downloaded from the Natural England Access to Evidence Catalogue. For information on Natural England publications or if you require an alternative format, please contact the Natural England Enquiry Service on 0300 060 3900 or email enquiries@naturalengland.org.uk.

Copyright

This publication is published by Natural England under the Open Government Licence v3.0 for public sector information. You are encouraged to use, and reuse, information subject to certain conditions.

Natural England images and photographs are only available for non-commercial purposes. If any other photographs, images, or information such as maps, or data cannot be used commercially this will be made clear within the report.

For information regarding the use of maps or data see our guidance on how to access Natural England's maps and data.

© Natural England 2025

Catalogue code: NECR573

Report details

Author(s)

Anthony Millington, Katy James, Todd Jenkins, Nicola Randall

Natural England Project Manager

Report commissioned by Dawn Enright, Principal Historic Environment Specialist and managed by Louise Brown, Senior Historic Environment Specialist

Contractor

Centre for Evidence-Based Agriculture, Harper Adams University, Newport, Shropshire, TF10 8NB

Keywords

Biodiversity, Grazing, Historic environment, Pasture, Productivity, Soil, Trees

Acknowledgements

The authors would like to thank the members of the steering group for their valuable contributions to this review, namely: Claire Horrocks, Natural England; Katey Stephens, Natural England; Sarah Poppy, Historic England.

Citation

MILLINGTON, A., JAMES, K., JENKINS, T., RANDALL, N. 2024. Value of mob grazing to support historic and ecological asset management. A Quick Scoping Review. NECR573. Natural England.

Harper Adams University

Foreword

Holistic or ‘Mob’ grazing is a little used livestock management tool in England, however there is some occasional and patchy evidence to suggest that not only does it deliver for tree and soil health, but also contributes to carbon sequestration, enhances grassland biodiversity, improves animal health, reduces fertiliser inputs, increases insect abundance and reduces costs. It is also of interest to the historic environment sector for two reasons. The first is that the majority of archaeological sites comprise soils, and so management that increases soil health while reducing the need to disturb the soil is of great benefit to a fragile, non-renewable resource such as archaeological sites. Secondly, there is growing evidence that some of our oldest and most important trees within historic parklands are under stress (e.g. Moccas Park, a registered parkland and a NNR with extensive grazing but with significant tree health issues). These sites are internationally famous and comprise living works of art. Management practices that enhance these landscapes and ensure the longevity of the trees within them is therefore of great importance and is urgently needed.

No assessment has been undertaken previously that looks to compare new grazing practice with a particular reference to nature-based solutions, carbon storage, conservation of the historic environment as well as tree and soil health. Consequently, through a literature review, this project looks to establish the evidence base to understand the wider benefits of mob grazing to identify what goods and natural capital are delivered. It will seek to provide the evidence to show whether this type of grazing will deliver improved soil health and tree health (thereby benefitting the historic environment and delivering cultural capital), increased biodiversity, improved animal welfare, cleaner water (through reduced fertiliser use) and be of economic benefit to land managers. It will also assess the evidence for carbon storage and the potential of this form of grazing to deliver nature-based solutions for climate change and seek to identify any evidence of the potential for blended finance and carbon trading, which this form of nature based solution lends itself to.

This project delivers across several 25YEP objectives and is therefore significant in terms of its integration and ability to deliver not only for the environment but across government commitments including those outlined in the government's Heritage Statement 2017.

Natural England commission a range of reports from external contractors to provide evidence and advice to assist us in delivering our duties. The views in this report are those of the authors and do not necessarily represent those of Natural England.

Executive summary

Background

Mob grazing is a term to describe keeping large numbers of grazing animals on small areas of pasture and moving them frequently. The grazed land has a long rest period before the grazing animals are returned. This mimics the natural system of large herds in the wild that graze and trample the ground before moving on. This management tool is used infrequently in England but is thought that the practice may deliver benefits not only to the farmer but also the environment and historic assets. Through literature review and stakeholder consultation, this project sought to establish the evidence base to better understand the wider benefits of this grazing practice, what goods and natural capital are delivered and the drivers and barrier to uptake. The scope of the project was set by the funder Natural England.

Method

This research project was conducted in a two-stages: 1) a Quick Scoping Review (QSR) to collate and synthesise published and unpublished literature about holistic or mob grazing and 2) selected interviews with industry practitioners and influencers to understand: why practitioners adopt mob grazing practices, what the multiple and linked benefits to farmers, ecological and historic assets are, and what the barriers are to the adoption of mob/holistic grazing.

Key findings

- There is no single definition of mob or holistic grazing, and a wide variety of terms are used by authors, to describe keeping large numbers of grazing animals on small areas of pasture and moving them frequently.
- Very little primary research has been conducted in the UK on mob/holistic grazing. Most of the available research to date is from overseas where soil, climatic, social and economic conditions may be very different to the UK.
- Research evidence was often conflicting in terms of the impact and potential benefits of mob/holistic grazing (e.g. for pasture productivity, biodiversity and water infiltration).
- The research collated suggested that over time mob grazed pasture quality may improve so that grazing becomes more efficient. However, more long-term studies are needed to test this especially within the context of the UK.
- There is little evidence regarding the benefit of mob grazing to trees.
- No research studies were found that investigated the effect of mob grazing on the historic environment.
- There was no evidence of the potential for blended finance and carbon trading.

- Although evidence suggests that there are benefits in terms of productivity of adopting mob/holistic grazing, the system requires significant investment in infrastructure and time/labour inputs.
- First time adopters in the UK face a steep learning curve, and clear guidance is lacking about the practice and what the benefits are. This is compounded by the often-conflicting evidence of the potential impacts of mob/holistic grazing on the wider environment.

Implications and recommendations for policy, practice and research

- Clear definition and consistent use of terminology by researchers investigating mob or holistic grazing are needed.
- This review highlights the need to fund long-term experiments in the UK to investigate and fully understand the potential benefits of mob grazing and to identify what goods and natural capital are delivered. Once this is known clear guidance about practicing mob/holistic grazing and what the benefits are needs to be developed and disseminated to stakeholders.
- Further research is required to investigate the potential for blended finance and carbon trading from the use of mob grazing.
- Research is required to investigate the effect of mob grazing on the historic environment including trees.
- The authors of this review are aware of an on-going research project funded by Defra that is comparing mob grazing and conventional grazing systems at nine farm sites across the country, in terms of livestock performance, soil quality, biodiversity, and diffuse pollution (nitrate leaching, ammonia and nitrous oxide emissions). It is expected that the results of the project will contribute significantly towards the evidence base in the UK.

Contents

Background....9
Aim....9
Objective....10
Methods....11
Searching for literature....11
Coding literature....13
Interviews....13
Critical appraisal....13
Meta-data coding....13
Results....15
Quick scoping review statistics....15
Primary research study findings....16
Review papers....30
Interviews....34
Barriers to mob/holistic grazing (primary research studies and interviews)....38
On-going projects....40
Limitations of the review....41
Key findings and knowledge gaps....41
Implications and recommendations for policy, practice and research....42
Conclusions....42
References....45

Figure 1 Literature included and excluded at each stage of the quick scoping review process (adapted from Haddaway and others, 2017) 16

Figure 2 The number of captured primary research studies published per year (1973 to 2022) 17

Figure 3 Country of study for the 81 primary research studies 18

Table 1 Components of the PICO key elements 10

Table 2 Online sources searched for published and grey literature 11

Table 3 Coding variables for primary research studies 14

Table 4 Term used to describe the grazing intervention in the 81 research studies 18

Table 5 Interviewee occupation and farm attributes 34

Background

Mob grazing is a term to describe keeping large numbers of grazing animals on small areas of pasture and moving them frequently. They leave behind a concentration of manure and large amounts of plant residues both above and below the soil surface which provide soil nutrients and soil organic matter (Zaralis and Padel, 2017). The grazed land then has a long rest period before the grazing animals are returned. This mimics the natural system of large herds in the wild that graze and trample the ground before moving on (Chapman, 2012).

Mob/holistic grazing is a little used livestock management tool in England, however there is some occasional and patchy evidence to suggest that it may deliver for tree and soil health, and also contribute to carbon sequestration, enhance grassland biodiversity, improve animal health, reduce fertiliser inputs, increase insect abundance, and reduce costs.

This grazing strategy is also of interest to the historic environment sector for two reasons. The first is that management that increases soil health while reducing the need to disturb the soil is of great benefit to a fragile, non-renewable resource such as archaeological sites. Secondly, there is growing evidence that some of the oldest and most important trees within historic parklands are under stress. Management practices that enhance these landscapes and ensure the longevity of the trees within them is therefore of great importance.

No assessment has been undertaken previously that looks to compare new grazing practice with a particular reference to nature-based solutions, carbon storage, conservation of the historic environment as well as tree and soil health. This project looks to establish the evidence base to understand the wider benefits of mob grazing to identify what goods and natural capital are delivered. The scope of the project was set by the funder Natural England.

Aim

The aim of this research project was to understand the wider benefits of mob grazing and to identify what goods and natural capital are delivered. The project sought to collate evidence to indicate whether this type of grazing is likely to deliver improved soil health and tree health (thereby benefitting the historic environment and delivering cultural capital), increased biodiversity, improved animal welfare, improved water absorption and cleaner water (through reduced fertiliser use) and be of economic benefit to land managers. The review will also assess the evidence for carbon storage and the potential of this form of grazing to deliver nature-based solutions for climate change and seek to identify any evidence of the potential for blended finance and carbon trading, which this form of nature-based solution lends itself to.

Objective

This research project was conducted in two-stages: 1) a Quick Scoping Review (QSR) to collate and synthesise relevant published and unpublished literature and 2) selected interviews with industry practitioners and influencers to understand: why practitioners adopt mob grazing practices, what the multiple and linked benefits to farmers, ecological and historic assets are, and what the barriers are to the adoption of mob/holistic grazing.

Quick scoping review

A Quick Scoping Review (QSR) was chosen as the method to review the literature. QSRs are seen to be more robust and reliable than traditional literature reviews but quicker and less costly than full systematic reviews or systematic maps. This QSR was conducted following the Defra/NERC guidelines for the production of Quick Scoping Reviews and Rapid Evidence Assessments (Collins and others, 2015). This method focuses on a specific question and aims to answer it, using standardised, systematic methodology to search for evidence (published and unpublished academic and grey literature from multiple sources) and collate, and synthesise it to answer the review question.

The QSR addressed the following primary question:

Primary question

“What is the impact of mob/holistic grazing on historical and ecological assets?”

The Primary Question is framed using population (P), intervention (I), comparator (C) and outcome (O) key elements. Table 1 shows the PICO components of the primary question.

Table 1. Components of the PICO key elements

Key element	
Population	Soil, environment, animals, humans, heritage
Intervention	Mob/holistic grazing/adaptive multi paddock grazing
Comparator	No mob/holistic grazing; other grazing regime; before and after
Outcome	Impacts on biodiversity, soil health, animal health, water quality and absorption, carbon sequestration, heritage, insect abundance, economics, natural capital, the potential for blended finance and the implications for tree health

Secondary questions

The following secondary questions were also addressed using the evidence gathered for the primary question:

- What is the evidence for the potential of mob grazing to deliver improved soil health and tree health, increased biodiversity, improved animal welfare, cleaner water and be of economic benefit to land managers?
- What is the evidence for the potential of mob grazing to deliver carbon storage and nature-based solutions for climate change?
- Is there any evidence of the potential for blended finance and carbon trading?

Methods

Searching for literature

A comprehensive search to capture an un-biased sample of published and grey literature was undertaken using multiple information sources including: Online bibliographic databases and websites of relevant organisations.

The searches endeavoured to be as thorough as possible within the timescale of this project. The search string was adapted to the syntax of each source searched and a record of each search made. Database and repository searches were conducted in the English language. Online sources searched to identify relevant literature are presented in Table 2.

Table 2. Online sources searched for published and grey literature

Bibliographic databases	**Web of Science (Harper Adams University)** **CAB Abstracts (Harper Adams University)** **CORDIS (EU projects)** **Ethos (PhD theses)**
Organisation Websites	AHDB ADAS Soil Association Agricology Farmers weekly

Search string and scoping searches

The search string was formulated in discussion with Natural England and using scoping searches to test keywords for specificity and sensitivity using the online databases Web of Science and CAB Abstracts. These scoping searches indicated that the volume of literature underpinning this topic was likely to be low. The final search string therefore only

comprised of intervention keywords, known synonyms for mob/holistic grazing, to ensure that results returned were not restricted.

"mob graz*" OR "mob stock*" OR “holistic graz*” OR “time-controlled graz*” OR “ intensive short-duration* graz*” OR “rapid rotation* graz*” OR “ high frequency short duration graz*” OR “season-long graz*” OR “high-intensity short duration graz*” OR “multipaddock graz*” OR “ intensive rotation* system*” OR “ cell graz*” OR “tall grass graz*” OR "flash graz*" OR “Time-Controlled Graz*” OR “Intensive Short-Duration Graz*” OR “Savory Graz*” OR “Planned Graz*” OR "techno graz*" OR "short rotation* graz*"

Screening

Screening literature

All retrieved articles were imported into the specialised systematic reviewing software (EPPI-Reviewer4) and screened for relevance against the pre-defined inclusion criteria. Screening of articles was conducted at two levels (i) title and abstract (screened concurrently for efficiency), (ii) full text. Where full text could not be obtained a record of the article was made. The number of articles included and excluded at each stage of the screening process was recorded.

Inclusion criteria

Inclusion criteria were developed using the PICO key elements of the primary question and elements of the secondary questions.

Inclusion criteria:

- Population: Soil, environment, animals, humans, heritage
- Intervention: Mob/holistic grazing by herd animals of relevance to UK farming
- Comparator: No mob/holistic grazing; other grazing regime; no control
- Outcomes: impacts on biodiversity, soil health, animal health, water quality and absorption, carbon sequestration, heritage, insect abundance, economics, natural capital, the potential for blended finance and the implications for tree health

Exclusion criteria:

- Species of grazing animal: Studies about non-herd animals and herd animals that are not of relevance to UK farming were excluded
- Geographical: Studies on tropical soils excluded
- Date: No date restrictions were applied
- Language limitations: English language only. Where non-English language articles had an abstract in English these articles were included but only coded at abstract.

Coding literature

All included literature was catalogued in a searchable database, containing key information (metadata) for each study/review in a standard format. Any relevant ongoing projects identified in searches for evidence and where results not yet available were catalogued. The depth of detail of coding was agreed with Natural England. For review articles coding of metadata was limited to bibliographic information, measured outcomes and key findings. More detailed coding was carried out for primary research studies as shown in Table 3.

Interviews

Industry practitioners and influencers were selected for interview through: Literature sourced in the review; identification of ongoing research projects; online searches for and recommendations from stakeholders and from Harper Adams academic staff (who have extensive links with the farming community and related industries, including farms in England and Scotland that are already undertaking holistic and mob grazing).

Semi-structured interviews were used to identify:

1. why practitioners adopt mob grazing practices.
2. to understand the multiple and linked benefits to farmers, soil, biodiversity, water, carbon, inputs etc. and heritage conservation.
3. barriers to the adoption of mob grazing practices.

Semi-structured interviews enabled interviewees to freely discuss their opinions and views on the topic, whilst at the same time allowing the interviewer to impose structure to the interview using open-ended questions. Interviews were conducted using online video conferencing platforms and participants were treated as anonymous. Ethics approval for this research came from Harper Adams University. Informed consent was attained from all participants prior to interview to allow recording and storing of data in accordance with GDPR.

Critical appraisal

This review did not critically appraise the included research. Recommendations made by the authors of the included studies should therefore be interpreted with caution.

Meta-data coding

Table 3 shows the coding variables from which meta-data was extracted from all eligible primary research studies, to provide detail about the article the study appears in (i.e. author, title, year, publication type) and more in-depth detail of each study. Meta-data extracted is presented as a searchable Excel database.

Table 3. Coding variables for primary research studies

Category		#	Coding Variable
Bibliographic Information		1	Unique article id
		2	Author(s)
		3	Title
		4	Year
		5	Publication Type (Journal, Book etc)
		6	Publication Title
Study Background		7	Country of study
		8	Study availability (abstract or full text)
		9	Farm information e.g. mixed, arable etc
		10	Upland/lowland
		11	Vegetation
Study Details	Population	12	Soil
		13	Animals
		14	Environment
		15	Human
		16	Heritage
	Intervention	17	Intervention Form (mob/holistic grazing etc)
		18	Tested in combination
		19	Length of exposure, length of gap
		20	Stocking density
	Comparator	21	No mob/holistic grazing; other grazing regime; before and after
	Outcome	22	Outcome measured (e.g. impacts on pasture, biodiversity, soil health, animal health, water absorption, carbon sequestration, heritage, insect abundance, economics, natural capital, the potential

Category		#	Coding Variable
			for blended finance and the implications for tree health)
		23	Parameter measured
		24	Author reported conclusion (effect, no effect, inconclusive)
		25	Does the author highlight any data needs or research gaps?
		26	Barriers
	Other	27	Other
Notes		28	Any other notes

Results

Quick scoping review statistics

A total of 486 articles were identified through online searches of academic databases. Following duplicate removal and screening, a total of 90 articles were eligible for inclusion, comprising of 81 primary research studies and nine review papers. No additional primary research studies were identified through grey literature searches. Figure 1 shows the literature included and excluded at each stage of the quick scoping review process expressed as a flow diagram (adapted from Haddaway and others, 2017).

The literature was sub-divided into the following categories:

1. Research studies
2. Review papers

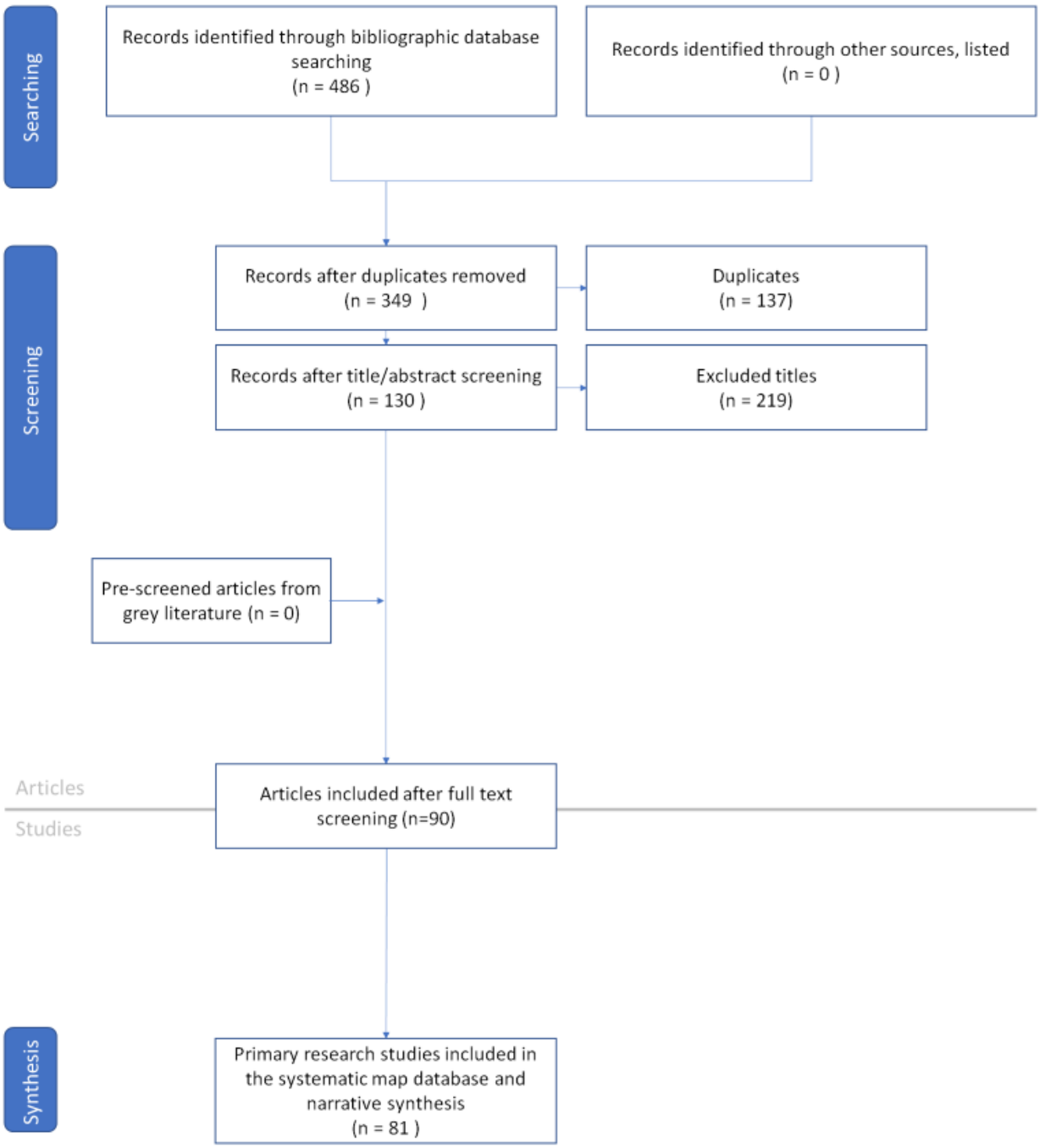

Figure 1. Literature included and excluded at each stage of the quick scoping review process (adapted from Haddaway and others, 2017)

Primary research study findings

Of the 90 articles included from searches of the academic databases, 81 were primary research studies. From these studies meta-data was extracted using the coding variables in Table 3.

Year of publication

Studies were captured from 1973 to 2022. The number of studies published per year (shown in Figure 2) has fluctuated over time but has remained below eight per year suggesting that the topic is under-researched. The majority of the research has been published in peer-reviewed journals (n=68), followed by conference proceedings (n=8), reports (n=4) and academic theses (n=1).

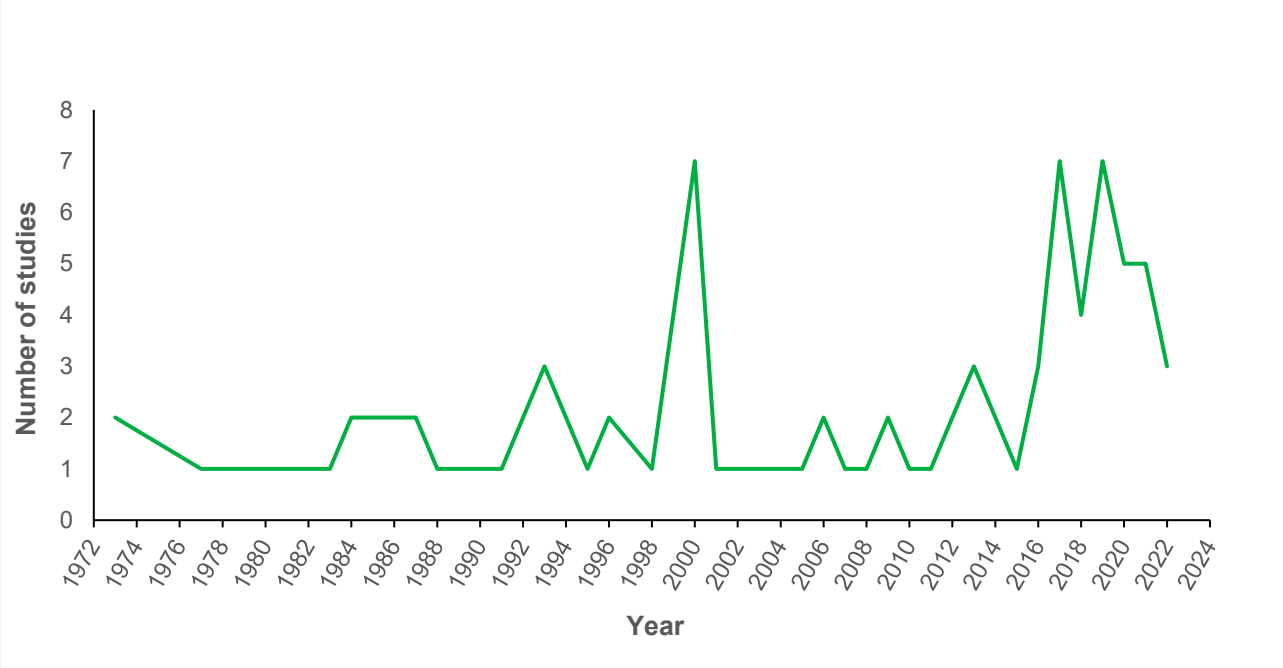

Figure 2. The number of captured primary research studies published per year (1973 to 2022)

Country of study

Most of the research studies were carried out in the USA (39%), Australia (26% or New Zealand (13%). Figure 3 shows the country of study for the 81 research studies found.

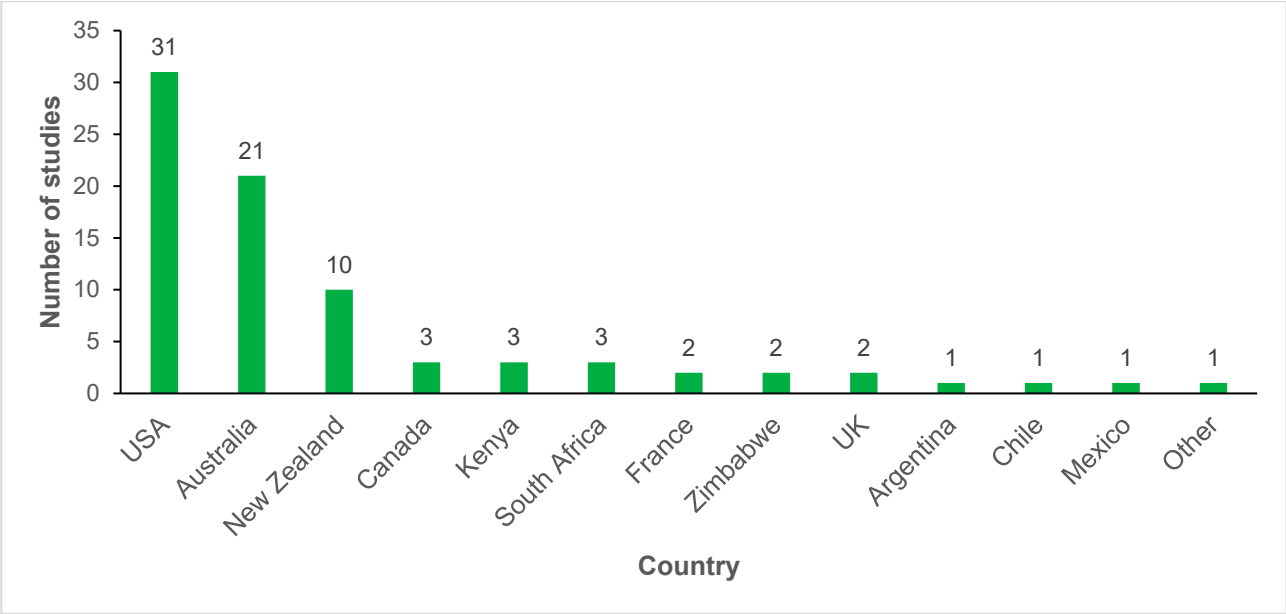

Figure 3. Country of study for the 81 primary research studies

Intervention terms

There are a variety of terms used by authors, including mob and holistic grazing, to describe keeping large numbers of grazing animals on small areas of pasture and moving them frequently. A list of terms used by the research study authors and the number of relevant studies where this intervention term was used can be found in Table 4.

Table 4. Term used to describe the grazing intervention in the 81 research studies

Intervention	No of Studies
Cell grazing	12
High intensity, Short duration/Time controlled grazing	10
Holistic grazing	9
Intensive rotational grazing	5
Mob grazing	12
Mob stocking	13
Multipaddock/Adaptive multipaddock grazing	8
Planned grazing	4
Rapid rotation grazing	1
Savory grazing	2

Intervention	No of Studies
Time controlled grazing	5

Grazing animals used in studies

Grazing animals used in research studies included cattle (n=55), sheep (n=28), goats (n=5) and bison (n=1).

Primary research study outcomes

Impacts on pasture – general impacts

The majority of primary research studies looked at impacts on pasture (n=42, 53%). The studies measured a variety of vegetation responses to grazing system interventions. These included:

- species composition, richness and persistence
- plant/ground cover
- pasture establishment
- herbage/root mass, vegetation height and density
- pasture diet quality

The impacts of mob grazing practices on pasture vegetation appear to vary between studies when compared with more conventional grazing.

For example, in a study conducted in the UK, Cook (2017) found that mob-grazing farms had greater dry matter on pasture when cattle were put onto it and when they were taken off, leaving a greater residual. The author concluded that these results support the idea that mob-grazing can be used to control foraging behaviour to the benefit of pasture productivity.

On the other hand, Andrade and others (2022) in an eight-year study, investigated whether the high level of trampling by cattle associated with mob grazing increased plant diversity and productivity of a subirrigated meadow in the Nebraska. They found that there was no difference in plant species composition, aboveground production and root growth using mob grazing compared to low stocking densities. Similarly, in two experiments on North Island, New Zealand, Radcliffe (1973) found that the effects of mob-stocking on the botanical composition of hill sheep pastures was no different to those of set-stocking. Tracy and Bauer (2019) found that mob stocking with cattle, with extra-long rest periods allowed grasses to grow tall and over-mature but did not affect herbage mass or forage nutritive values compared to rotational and continuous stocking. They also found that mob stocking favoured establishment of red clover (*Trifolium pretense* L.) but did not affect the abundance of weeds. However, Graham and others (2000) found, as part of the

Temperate Pasture Sustainability Key Program study, that mob stocking by sheep increased the ryegrass content in pasture.

Impacts on pasture – invasive species

Mob grazing maybe a useful management tool for controlling some invasive species but not others.

Although there were no studies from the UK on invasive species, there are examples of invasive species suppression from mob grazing on that may be applicable to the UK. For example, De Bruijn and Bork (2006) found that Canada thistle (*Cirsium arvense*) (known as creeping thistle in the UK, and a problem weed with a creeping root system), increased in perennial pasture under continuous grazing, but that high intensity-low frequency rotational grazing reduced shoot density and biomass. This is due to cattle grazing on more palatable herbs in the continuous grazing systems. avoiding Canada thistle plants. But the mob grazing system, with two defoliations annually for 2-3 years eliminated almost all Canada thistle. The authors recommended that high intensity-low frequency rotational grazing be used as a biological control for Canada thistle, especially where the use of herbicides is not desirable. Similar impacts may be found on selected UK pest plants but is likely to be species specific and so would need further research.

In contrast, a study at the Ballantrae Hill Country Research Station in New Zealand by Betteridge and others (2000) found that the use of set stocked sheep was better than mob stocked sheep to control ragwort (*Senecio jacobacea*) in beef pastures. They used two stocking densities in both treatments i.e. 1.5 or 3.0 stock units/ha. Set stocking resulted in higher ragwort mortality than mob stocking with 72% of ragwort dying (set stocked 3.0 stock units/ha) within 12 months without flowering. The ragwort population declined from 9.2 plants/m^2 to 0.2 plants/m^2 in the mob-stocked (3.0 stock units/ha) after 12 months, while under set-stocking ragwort densities increased ($p<0.05$). Mob stocking reduced flowering but induced multi-stem development in the second year. Set stocked hoggets reached 63 kg liveweight at 20 months. There was no sign of liver damage in mob or set stocked sheep, but the authors cautioned that if one mob of sheep is continually used to control ragwort then their intake of toxin would be much higher than for the sheep in their experiment. The authors concluded that set stocking cattle-pastures with 3 sheep stock units/ha can give good control of ragwort and the potential for marketing good sized lambs.

Other global studies tend to show variable impacts of mob grazing on invasive species, although there appears to be a general trend towards favouring invasive species control. This may be influenced by both the invasive species studied, and the livestock that are used. A few examples are shown below.

A French study (Mesléard and others, 2017), found that mob grazing may be a suitable method for meeting conservation goals such as maintaining open habitats in grasslands. They found that mob grazing was effective both in controlling the establishment and increasing the mortality of *Phillyrea angustifolia*. The authors concluded that mob grazing

may be used as a stocking method, alternating or not with low grazing pressure, to control of bush encroachment. Similarly, a study on naturalised grassland in Chile by Domínguez Díaz and others (2018) found that holistic grazing significantly increased some more palatable species for livestock from holistic grazing. This was thought to be due to decreased competition in the canopy favouring naturalised exotic species such as white clover (*Trifolium repens*) which had previously been unable to compete with invasive weeds such as *Achillea millefolium* and *Hieracium prealtum* under semi-intensive grazing. These changes may also benefit native grass species. A study by Henneman, Seavy and Gardali (2014) evaluated the ability of a planned grazing program to restore California grassland. The change from continuous grazing to planned grazing with high cattle density and long rest periods restored native perennial grasses by reducing the competitive advantage of the invasive grasses. More resources were available to the native grass species promoting tiller formation. The periods of no grazing allowed perennial regrowth and seed production resulting in increased plant numbers and increased plant size and vigour.

Diversifying the livestock grazed within mob grazing systems can also help control invasive grassland species. Luginbuhl and others (2021) evaluated the effectiveness of mob grazing with cattle, goats, or goats and cattle to renovate hill-land pastures overgrown with brush and woody species in North Carolina, USA. They found that various shrubs were better controlled in combined goat and cattle systems and concluded that integrating goats with cattle is an environmentally friendly management tool to keep pastures open for production.

Native tree restoration

There was little evidence regarding the benefit of mob grazing to trees, however one study showed how mob stocking could be used to restore native trees from seeding.

Dodd and Power (2007) examined the applicability of mob grazing to restore native tree restoration in New Zealand hill pasture by trampling seed into soil. In spring and autumn, hand sown seeds of native tree and shrub species were trampled with a mob of 80 ewes for 2 hours. They found that mob stocking was successful for two shrub species and was effective in spring but not autumn sowing, suggesting that soil moisture content as an important factor in successful germination. The sown species also needed have sufficient early growth rates to be able to compete with recovering resident pasture species in the absence of post-sowing vegetation suppression. They concluded that treading by mob stocking is an effective technique to provide good seed-soil contact in conditions of unreliable soil moisture and is a cost-effective approach to native plant restoration.

Animal health and production

A fifth of the studies (n=18) measured outcomes regarding animal health. These tended to be around livestock production but also included effects on animal parasites.

There is some overall indication from studies that individual animal weights are reduced under mob grazing, but that that overall productivity per hectare can be increased as less

land is needed or stocking rates can be higher. Short term impacts suggest that animals cannot select most nutritious food, but over time pasture quality may improve so grazing becomes more efficient. More long-term studies are needed to test this.

In a study conducted in the UK, Zaralis and Padel (2019) reported that mob grazed biodiverse pastures serve as a viable alternative to conventional pastures as they can maintain animal productivity at high levels. However, it should be noted that the authors stated that the grazing rotation applied in the farm during the study year was rather short to fulfil the expectations of a mob-grazing system, but stocking density was high (115 t LW /ha).

Other studies indicate that mob grazing may have negative impacts on animal health. For example, Oliva and others (2021) compared vegetation and sheep responses to holistic grazing management and continuous grazing on degraded rangelands in Patagonia. They found an improvement in cover and key forage species, with a decrease in bare soil and standing dead vegetation in both systems, but holistic grazing management reduced sheep weight, and ewes had lower lambing rates. The authors also thought that lambs may have died after becoming detached from their mothers during stock movements under holistic grazing management). The authors suggested that although holistic grazing management is a good option to regenerate rangelands, the process of pasture improvement may not be a quick process especially in severely restricted habitats. This may result in at least short-term animal health impacts, and it may take up to three years for animals to adapt (Oliva and others, 2021).

Other authors have found similar reductions in livestock weight in mob grazing systems. Andrade and others (2022) found a reduced daily gain of steers in a mob grazing system when compared with a 4-pasture rotation with two grazing cycles pastures. They thought this was likely due to the low harvest efficiency and the relatively low forage quality of the standing vegetation in the mob pastures. Some authors, (e.g. Tracy and Bauer, 2019) who found that cow weight was lower going into winter under mob stocking compared with continuous stocking have suggested there are few reasons why mob stocking should be used for livestock production over other stocking methods. However, Cowley *and others* (2018) found that the lower weight gain per head associated with cell grazing can be compensated for by the increased production (kilograms of meat per hectare) due to the increased stocking that can be achieved.

Badgery (2017) theorised that dry matter may influence the success of mob grazing systems for animal performance. Their sheep study in New South Wales, Australia compared three intensive rotational grazing strategies (fast rotation, 57-day rest; slow rotation, 114-day rest; and flexible grazing, based on availability of green herbage mass) with continuous grazing to determine the effect upon vegetation and diet quality. All of the intensive rotational grazing treatments had greater ground cover and herbage mass than continuous grazing. Diet quality was found to be lowest in the slow rotation system. Badgery (2017) advised that in order to maintain a higher quality diet, green dry matter needs to be >0.5 t DM /ha after grazing. The author considered that using fast or flexible intensive rotational grazing can achieve per head animal performance comparable to

continuous grazing that also provides higher herbage mass and cover with a preferable pasture composition.

There may be other impacts of mob grazing on animal health. There is some indication, for example that mob grazing can have a positive impact on reducing animal parasites by interrupting the life cycle of the parasite.

In a study conducted in the UK, Cook (2017) reported parasite faecal egg counts were lower on mob-grazing farms than on the conventionally grazed farms. The length of the rotation cycles (60-90 days) meant that cattle are not on the pasture during times of peak infectivity (typically 1-3 weeks). The authors hypothesised that it is this 'breaking' of the gastrointestinal nematode life cycle that may in part be why low egg counts were observed. This has been backed up in other global studies. For example, Rapiya and others (2019) compared the effect of holistic planned grazing and four-camp rotational grazing on cattle parasite counts with continuous season-long grazing in South Africa. Mean counts for ticks and faecal worm eggs from fresh faecal samples of cattle were highest in the hot wet season in the continuous season-long grazing system compared to the two rotational systems ($P \leq 0.05$). The study suggested that rotational grazing has the potential to reduce livestock production losses caused by high tick and worm loads in cattle, especially in the hot wet season.

Similar impacts have been found on sheep in Australia. Healey and others (2004) compared the effect of intensive rotational grazing system (involving extended rest periods) with typical grazing methods (high or moderate stocking flexible grazing, on nematode faecal egg counts taken from ewes, hoggets and lambs over four years. Animals in the intensive rotational grazing system had lower mean faecal egg counts over all sampling periods than the other two systems. This was particularly pronounced in lambs. It is thought that this was due to the sheep being removed before nematode eggs develop into infective larvae and the long rest periods probably resulted in the death of most of the infective larvae contributing to low larval availability and reduced infection rates. The authors warned that there is a need to interpret these results with contrasting data on animal liveweight change and wool growth which tend to be higher on the two flexible grazing systems.

Gastrointestinal nematode infection is a major health issue for sheep worldwide. In temperate Western Europe, three nematode species dominate the digestive helminthofauna of sheep: *Teladorsagia circumcincta*, *Haemonchus contortus* and *Trichostrongylus colubriformis*. These can cause growth reduction and milk production losses and *H. contortus* infections can lead to high mortality rates in lambs and ewes (Ruiz-Huidobro and others, 2019). A two-year experiment was conducted in Western France by Ruiz-Huidobro and others (2019) that compared the effect of intensive cell grazing with conventional rotational grazing on the intensities of gastrointestinal nematode infection egg excretions and the frequencies and intensities of *H. contortus* infections. Contrary to findings from Australia, the authors found that cell grazing was unable to decrease the intensity of gastrointestinal nematode infection egg excretions from grazing ewes in the temperate conditions of Western France. However, it could be used as a tool

to limit *H. contortus* infections which is an issue for sheep farm sustainability due to increasing resistance to anthelmintics.

Animal behaviour

There were two studies found that reported on animal behaviour. Holistic grazing can affect animal behaviour by reducing their selectivity of vegetation.

Holistic planned grazing did not affect cattle herding proximities, time spent grazing, forage utilisation, forage species selection, or dung trampling in the study located in Eastern Cape, South Africa undertaken by Venter, Hawkins and Cramer (2019). They also found that the use of electric fencing did not cause cattle to concentrate more tightly relative to cattle that are allowed to range freely. They noticed that increasing animal densities reduced the selection for palatable vegetation patches which can reduce the spatial heterogeneity in vegetation vigour over time. Crawford and others (2019) similarly found that, under planned grazing management, restricting cattle movements reduced selectivity by causing cattle to walk more slowly while grazing and to take more bites per step. Using bites per step ratios as a measure of grazing selectivity (high values indicates less selectivity), planned grazing cattle took 5.25 bites per step compared to 2.65 bites per step for continuous grazing cattle ($P<0.001$). Cattle in the planned grazing treatment ate significantly ($P<0.001$) more *Pennisetum* grasses which are typically avoided because of their unpalatability. Planned grazing cattle spent significantly ($P<0.001$) less time walking (3.48%) than continuous grazing cattle (7.60%). Continuous grazing cattle walked significantly ($P<0.001$) farther each day (5.01 km) than planned grazing cattle (3.59 km).

Effects on wildlife

Eleven studies investigated impact on wildlife. None of the studies were carried out in the UK or Europe. Some of the literature captured had no relevance to British wildlife (e.g. Sharp and others 2010; Lalampaa and others 2016), these studies were recorded in the database for general interest. Although the species investigated in the remaining studies were not directly relevant to the UK some lessons could be learnt. These studies indicated that mob/holistic grazing can have a positive effect on the abundance and diversity of invertebrates in terms of ecological functioning, and the grazing systems may be useful for controlling some invertebrate pests. Impact on bird abundance was mixed and dependent on species habitat requirements.

Many wildlife species require periodic environmental disturbance to maintain heterogeneity in vegetation patterns. Behney (2021) studied the effect of high-intensity short-duration grazing on Northern Bobwhite (*Colinus virginianus*) habitat in Colorado. Although grazing had no effect on their nest or brood survival or brood habitat selection, Northern Bobwhites selected against nesting in grazed areas.

In another study, Davis and others (2020) evaluated how continuous, season-long grazing and adaptive, rest-rotational grazing affected abundance of five species of grassland bird on shortgrass steppe in Colorado, USA. The authors recommended that soil and vegetation characteristics should be used to inform how adaptive management is applied

to benefit grassland birds, including species that have contrasting habitat needs. For example, resting pastures for one year could generate grassbanks for birds that prefer a taller/denser vegetation structure, and that intensive, short duration grazing on less productive soils may benefit species preferring shorter/sparser vegetation.

Terrestrial invertebrates, in forest and grassland ecosystems, that fall into streams can be important prey for fish, providing about 50% of their energy requirement. Saunders and Fausch (2012) compared the effects of three grazing systems (season-long grazing, simple rotational grazing, intensive rotational grazing) and wildlife only areas (control) on terrestrial invertebrate inputs to streams in northern Colorado, USA and their use by trout. Rotational grazing management (simple and intensive) resulted in more riparian vegetation, greater inputs of terrestrial invertebrates and a greater biomass of terrestrial invertebrate prey in trout diets than season-long grazing but of similar values found in sites managed for wildlife grazing only. High variability, especially for trout diets and biomass, meant that differences were often not statistically significant. The authors concluded that rotational grazing systems can be effective for maintaining levels of terrestrial invertebrate subsidies to streams necessary to support robust trout populations.

In an Australian study, Lawrence, Reid and Rader (2015) compared, unimproved pastures managed using high intensity, short duration grazing or conventional grazing (year-long continuous or long duration rotation) systems. Parasitoid hymenopteran richness was significantly greater (P=0.034) for high intensity, short duration grazing properties, but abundance differences were not significant. The authors concluded that their research suggests that high intensity, short duration grazing improves ecological functions which may benefit production and the conservation of native fauna.

Four studies from New Zealand investigated the impact of grazing systems on invertebrate pasture pests (French, 1973; Holmes, French and Savage 1981; Goldson and Wynn-Williams 1984; Stewart and Archibald, 1987). For control of porina moth larvae (*Wiseana* spp) timing of mob grazing is critical. Mob stocking of pastures by sheep in February caused up to 75% mortality of larvae of *Wiseana* spp. but mob stocking in March was less effective (Stewart and Archibald, 1987). The authors hypothesised that this was probably a result of the relative proportions in each month of small porina living on the soil surface, rather than in burrows where they are less at risk of desiccation or trampling by sheep.

In contrast to the study on porina, Goldson and Wynn-Williams (1984), found that winter (June-July) mob stocking with sheep (500 sheep/ha) was not effective for controlling the root damaging spring larval populations of *Sitona discoideus* in Lucerne pasture in Christchurch, New Zealand.

Soil health

Fourteen studies measured outcomes regarding soil health. These can be broken down in terms of soil physical, chemical, and biological properties as follows:

- soil physical: Bulk density, penetrometer readings, infiltration rates, saturated hydraulic conductivities, water stable aggregates, soil stability, soil-water content.

- soil chemical: soil organic matter, soil organic carbon (SOC), soil TOC and TON, C:N ratio, available nitrogen and phosphorus, soil CO_2, CH_4 and N_2O.
- soil biological: soil microbial community, microbial biomass and respiration, sampling of earthworms and arthropod biological diversity.

Evidence about the impact of mob/holistic grazing on soil health is often conflicting. Moreover, although improvements in some areas of soil health may be realised, other aspects of soil health may not be improved and may even be negatively impacted. This is illustrated in the examples provided below.

Soil heath – soil physical properties

A study of intensive, short duration grazing by cattle with three intensities (light, moderate and heavy) was undertaken by Seitlheko, Allen and Wester (1993) in Texas. Heavily grazed areas had significantly lower infiltration rates, saturated hydraulic conductivities and water stable aggregates, whereas lightly grazed areas had significantly less bulk density and greater total porosity (this study also reported no significant differences in organic carbon levels under the three grazing intensities).

Conversely, an Australian study, by Lawrence, Reid and Rader (2015) found that soil stability and water infiltration, (and nutrient cycling capacity) were significantly higher in the high intensity, short duration grazing pastures compared to conventional grazing. High water infiltration also occurred on adaptive multi-paddocks grazing except those with a high clay content, compared to continuous grazing, in an experiment on the Northern Great Plains of South Dakota, USA (Hillenbrand and others 2019).

Soil heath – soil chemical properties

Two studies conducted in the UK, both investigated soil organic matter. Cook (2017) found that soil organic matter was improved on mob grazed farms compared to a conventionally grazed farm. The author hypothesised that the higher forage biomass of the mob grazed farms compared to the conventional grazed farm, may promote soil organic matter content due to the more extensive and diverse root systems required to support this flora. Zaralis and Padel (2019) found that high stocking grazing density (115 t LW /ha) of biodiverse pastures had a positive effect on the build-up of the soil organic matter. However, Zaralis and Padel (2019) cautioned that the grazing rotation applied was rather short to fulfil the expectations of a mob-grazing system.

Contrary to these findings, in a study in Nebraska USA, Guretzky and others (2020), found that mob grazing (high stocky densities over short grazing periods) compared to a four-paddock system (longer grazing periods and low stocking densities) increased trampling but did not increase litter deposition or accumulation. The authors concluded that the notion that more trampling equates to more litter and therefore soil organic matter appears to be a misconception. The authors cautioned, however, that the study was carried out on a high producing sub-irrigated meadow with little variation in species composition, production and availability of minerals and water and that results may be different on other grasslands.

Studies from elsewhere in the world have shown that although mob grazing may improve soil organic matter, there may be no improvement in total soil carbon. For example, Roberts and Johnson (2021) reported that mob grazing increased soil organic matter, but not total soil carbon, compared to traditionally grazed pasture or un-grazed pasture (for 18 years) in a semiarid grassland study in Arizona, USA. This study also showed that mob grazing, negatively impacted soil structure (increased soil compaction and decreased soil aggregate stability and soil moisture) and vegetation composition (increase in abundance of two invasive species). Furthermore, Hillenbrand and others (2019) found that total carbon stocks, summing organic carbon and inorganic carbon, were not found to be different between the adaptive multi-paddocks grazing and light set stocked continuous grazing soils but both had higher total carbon than heavy set stocked continuous grazing soils. In this study adaptive multi-paddocks grazing also increased fine litter cover, forage biomass and improved plant composition and the amount of bare ground was decreased as well as the number of invasive plants.

Dowhower and others (2020) investigated greenhouse gas dynamics on a Texas tallgrass prairie subjected to adaptive multi-paddock grazing or continuous (moderate and heavy) grazing management. Adaptive multi-paddock grazing had the highest CO_2 emissions but lowest N_2O emissions. Methane (CH_4) emissions were generally negative but became elevated when soils became saturated. Adaptive multi-paddock grazing was the strongest methane sink. Removal of green material had no influence on CH_4 oxidation. Emissions of CO_2 and N_2O decreased with removal of canopy indicating a positive response could be achieved by adjusting grazing management. Adaptive multi-paddock grazing can be adjusted to maintain higher proportions of green material to benefit energy capture by photosynthesis and livestock diet quality, resulting in multiple benefits from this type of management. The authors highlighted that previous field work had shown that adaptive multi-paddock grazing produced higher levels of soil organic carbon, and this provided a greater greenhouse gas sink because CO_2 emissions are higher and N_2O emissions are lower from soils with higher levels of soil carbon.

Soil health – soil biological properties

The effects on arthropod biological diversity and soil respiration were compared between time-controlled grazing and set-stocked grazing in Australia by Moulin and others (2012). These parameters were considered by the authors as reliable indicators of soil health. In autumn the time-controlled grazing areas had increased arthropod abundance, diversity in the soil and surface litter and soil respiration in the topsoil compared to set-stocked grazing areas. However, in the spring the differences were not significant. The authors suggested that the benefits of time-controlled grazing are seasonally dependent, with rainfall and temperature mediating the effects. The authors concluded that short-duration rotational grazing can be beneficial to soil biological health in the longer term.

Sediment loss and water runoff and quality

No studies about sediment loss and water runoff and quality were found from the UK or Europe. Studies conducted in Australia and the USA suggest that mob/holistic grazing

may reduce sediment loss and water runoff but a study from Zimbabwe cautioned that intensively managed livestock can have a negative impact on water quality during drought.

A six-year catchment scale experiment was carried out by Sanjari and others (2009) in Queensland, Australia, to compare runoff and sediment loss from Eucalypt open woodland with a native and naturalised perennial grass species understory, subjected to time-controlled rotational grazing or continuous grazing by sheep (both systems used the 1.6 Dry Sheep Equivalent/ha grazing intensity considered normal in the region). Time-controlled grazing reduced runoff during small rainfall events and sediment loss was reduced significantly irrespective of the size of runoff events. Ground cover was considered the key factor for reducing sediment loss. The long rest periods in time-controlled grazing enabled soil and pasture recovery after intensive defoliation by grazing animals resulting in higher levels of ground cover (up to 90%) compared to continuous grazing (up to 65%). A minimum of 70% ground cover was needed to effectively protect the soil surface from the erosive forces of rain and runoff.

A study in Texas, USA by Park and others (2017) suggested that adaptive multipaddock grazing could reduce the risk of flooding downstream by reducing maximum streamflow. The authors used a Soil and Water Assessment Tool (SWAT) to assess the impacts of alternate grazing management practices, in rangeland watershed, on hydrological processes. The SWAT model was calibrated using measured standing crop biomass and soil moisture and streamflow data over the period from 1980 to 2013. A change from heavy continuous grazing to adaptive multipaddock grazing decreased surface runoff by 47%, increased infiltration by 5%, and decreased streamflow by 29.5%. The simulated highest annual streamflow over the 23-year period decreased from 8.3 $m^3 s^{-1}$ to 6.2 $m^3 s^{-1}$ by adopting adaptive multipaddock grazing. The authors concluded that adaptive multipaddock grazing was the best grazing management practice in terms of water conservation, vegetation regrowth, and the potential to reduce flood risk.

A community-based conservation program was established in Northwest Zimbabwe that uses Holistic Management Planned Grazing to restore lost habitat and re-establish natural vegetation. Strauch, Kapust and Jost (2009) examined riparian ecosystem structure and water quality to compare the environmental impact of this management to nearby communal grazing lands during a drought using low (small groups of free-roaming livestock) and high (75 cattle and goats/day - active herding of livestock along streams using HMPG) livestock treatments. They found that concentrating livestock on the ephemeral stream standing pools resulted in a reduction in water quality (higher salinity, conductivity and phosphate) and altered riparian ecosystem structure (lower vegetation cover and higher proportion of bare ground). Strauch, Kapust and Jost (2009) concluded that more research is needed to consider the short-term reductions in water quality compared to long term regional benefits of Holistic Management Planned Grazing.

Economics

Four studies considered productivity or profitability outcomes of mob/holistic grazing. Although conversion to mob/holistic grazing can be profitable but requires large set up

investment and cashflow. One study found that grazing management can have a beneficial impact on wool production.

Economics – profitability and associated costs

Leung and Smith (1984) used partial budgeting to analyse the profitability of changing from conventional grazing to the Savory Grazing Method (intensive grazing) for a cattle operation in Hawaii. The change increased production (250lbs to 725lbs/beef acre^{-1}) and set up costs could be paid back in just over one year and assuming the life of the enterprise is 10 years (internal rate of return 90%). The authors, however, warned that the large cash outlay required careful cash flow planning and budgeting and the large increase in stock needed careful management.

Conversely, a three year in an experimental trial in a mesic grassland of South Africa by Venter, Hawkins and Cramer (2019) found that rotational grazing and high-density grazing did not increase animal productivity relative to season-long continuous grazing in the short term. However, the authors warned that, over the longer term, continued season-long grazing can lead to rangeland degradation and declines in animal production. The authors suggested there are significant economic consequences when adopting high density grazing due to the capital investment required in setting up electric fencing and watering infrastructure. They reported that holistic planned grazing will take around four years to offset the higher setup and maintenance costs whereas season-long grazing and four-camp grazing will become profitable after one to two years. They suggested that managers who wanted to adopt rotational grazing could reduce infrastructure costs by replacing the function of fencing with traditional active herding.

Collaborative adaptive management is a resource management approach that seeks to increase provision of ecosystem services by engaging multiple stakeholders with diverse interests and knowledge to understand the complex ecosystem dynamics and responses to management actions (Derner and others, 2021).

The ability of collaborative adaptive management to negate the negative effects of increased stocking density on yearling cattle weight gains in semiarid short grassland in Colorado, USA was assessed by Derner and others (2021). They evaluated the average daily weight gain of cattle (kg steer^{-1} d^{-1}) in a multipaddock rotational grazing system by using nonadaptive grazing management (with different stocking densities) and collaborative adaptive management (highest stocking density). Collaborative adaptive management increased absolute livestock production (0.13 to 0.19 kg steer^{-1} d^{-1}) in non-drought years (23−25%) compared to nonadaptive grazing management. This resulted in an estimated additional gross revenue return of $48.16 to $55.54 per steer. The authors suggested that the benefits of collaborative adaptive management when applied to multipaddock rotational grazing were from the stakeholder group being able to incorporate adaptive movements of livestock across a spatially and temporally variable landscape, rather than just alternating between grazing and rest. The authors concluded, however, that in this particular experiment the economic benefits of the increased livestock production associated with collaborative adaptive management were unlikely to be

sufficient to offset the substantial costs associated with this approach (i.e extensive monitoring, analysis and summarization of data, and the collaborative decision making processes).Furthermore, as individual livestock weight gains were consistently higher in traditional season-long grazing treatment, adaptive multipaddock rotational systems become more difficult to justify. This is especially true when the inherent cost (e.g. water and fencing, reduced livestock weight gains, time and resources needed for animal movement) of these systems is added to the cost of collaborative adaptive management.

The authors stated that the critical question regarding the benefits of collaborative adaptive management in multipaddock grazing hinges on whether it can enhance attainment of multiple management objectives in a way that offsets additional implementation costs. They highlighted that to date experimental evidence has shown only benefits for enhanced grassland bird habitat in multipaddock rotation systems supported with collaborative adaptive management (Davis and others 2020), and it is unclear whether these benefits are enough to offset added costs.

Economics – wool production

A six-year experiment was conducted by Cottle and others (2013), in New South Wales, Australia showed the significant influence that pasture, soil inputs and grazing management have on wool production and quality. The average gross wool income per ha was $303 in flexible rotational grazing with high soil fertility, $215 flexible rotational grazing with moderate soil fertility and $180 in intensive rotational grazing with moderate soil fertility.

Review papers

A total of nine review papers relevant to this project were found from the bibliographic database searches. They are summarised below.

High-density grazing

Franke and Kotzé (2022) state that high-density grazing management aims to mimic the ways grasslands are utilized by natural grazers improving soil, vegetation productivity and diversity to regenerate grasslands. It is also promoted as a way to mitigate climate change by increasing the carbon sequestration in grassland soils. In their article Franke and Kotzé (2022) describe:

- the historical background of grazing and rangeland degradation in southern Africa
- the principles of high-density grazing, and the problems it seeks to address.

They also discuss:

- the evidence of the potential benefits of high-density grazing
- to what extent high-density grazing can be regarded as representative of grazing in natural ecosystems.

The authors conclude that high-density grazing may be a form of sustainable rangeland management, but it is attractive to farmers for its potential to increase livestock densities and associated productivity per unit area. They question if high-density grazing systems are more representative of natural ecosystems than other grazing management systems and warn that the theoretical relationship between nature and high-density grazing may lead to its embrace by policy makers without sufficient empirical basis.

Rotational grazing systems

Rotational grazing systems rely on resting paddocks after grazing for sustaining rangeland productivity and desired species composition. However, the forage loses digestibility and nutrient concentration during these rest periods. Frequently rotating large numbers of cattle through small paddocks can also compromise nutrition by increasing competition for forage and reducing adaptive foraging movements. The economic viability of ranches can be compromised by the installation and maintenance costs of fencing (Fynn and Jackson, 2022). Using foraging ecology principles to highlight how intensive multipaddock grazing systems can compromise cattle production while their infrastructure requirements increase overhead costs of management, thereby minimizing profits. Whilst highlighting how intensive multipaddock grazing systems can compromise cattle production and increasing overhead costs and minimizing profits, Fynn and Jackson (2022) provided working examples of how to overcome these problems whilst also maintaining ecological sustainability.

A meta-analysis using experimental publications, by di Virgilio, Lambertucci and Morales (2019), assessed the performance of grazing strategies on sustainability indicators worldwide, considering rangeland type (i.e., grasslands, shrublands, woodlands and forests) and other management variables (e.g., livestock type, grazing level, paddock sizes, precipitation). Their results showed that:

- complete destocking does not improve soil or vegetation in comparison to grazed systems
- continuous grazing was detrimental to vegetation, on woodlands or under heavy grazing levels
- rotational grazing is less likely to impact negatively on vegetation under moderate grazing levels
- the Savory grazing method is more likely to have negative impacts on livestock productivity (especially over short time periods)
- grazing schemes effects can be very different in different range types can have negative, positive or neutral outcomes on rangelands
- management decisions (e.g. grazing intensity, livestock type, application period) and environmental factors (e.g. precipitation level) are key to prevent negative impacts of grazing schemes on rangeland sustainability.

They conclude that the grazing application period was very influential for grazing schemes suggesting flexible decisions are required in the form of adaptive grazing strategies to

increase sustainability. They recommended that more research was needed around the potential interactions with livestock type, alternative rest periods length in rotational schemes and about socio-economic factors.

Adaptive multi-paddock grazing

According to Gomez-Casanovas and others (2021) grasslands can significantly contribute to climate mitigation but management intensification and land conversion has led to them having a net warming effect. They examined the potential of four innovative strategies to slow climate change:

1. Adaptive multi-paddock grazing (mimicking how ancestral herds roamed the Earth)
2. Agrivoltaics that consists of simultaneously producing food and energy from solar panels on the same land area
3. Agroforestry with a reverse phenology tree species
4. Enhanced Weathering, a negative emission technology that removes atmospheric CO_2 from the atmosphere.

They found that these strategies could promote benefits of grasslands from CO_2 sequestration, non-CO_2 GHG mitigation, productivity, resilience to climate change, and an efficient use of natural resources. However, they state that it requires urgent assessment of the ecological, environmental, and socio-economic consequences of adopting these strategies to fully assess the potential of grasslands to provide food, energy and environmental security.

Holistic planned grazing

Three quantitative meta-analysis models were used by Hawkins (2017) to assess data sets from literature between 1972 and 2016 that compared season-long continuous grazing holistic planned grazing alone to explore the evidence for animal impact. The analysis, using weighted mean differences, showed that there was no difference in plant basal cover, plant biomass and animal gain responses. Those studies with positive effect sizes tended to have higher precipitation ($p<0.05$) which suggests that only some rangelands have the resources to support holistic planned grazing.

Hawkins, Short and Kirkman (2017) compiled research and reviews of aspects of holistic planned grazing in a Special Issue paper. They evaluated existing and new evidence in the hope of improving consensus among scientists, conservationists and land-users of the positive and negative aspects of the use of intensive grazing approaches on rangelands under threat. They identified several research gaps and recommended that simulation modelling should be further developed to understand the efficacy of anyone grazing approach from the:

- impact of site history (grazing, temperature and rainfall)
- the impact of management factors (herd size, animal density, camp size and recovery periods)

- biotic factors (browsers, grazers, and large and small stock)
- abiotic factors (climate and lithology)

They recognise that poor or no replication on working farms, natural experiments and long-term trials is a common obstacle and encourage further research on working farms, by partnering with innovative land managers on real operations, applying adaptive treatments and combining field studies with modelling. They concluded that they could neither dismiss Holistic Planned Grazing out of hand nor claim that it will work anywhere. Land-users and scientists should consider the existing evidence together with their management goals (production, conservation or restoration) before deciding what livestock management approach to use.

Cell grazing

The paper by McCosker (2000) tracks the progress of Cell Grazing in Australia from its introduction in 1990 to where its principles are considered 'normal science' after 10 years. Its perspective is industry-oriented, with results obtained from properties throughout eastern Australia, illustrating the impact that cell grazing can have on business profitability (up to 2-3 times higher profit), soil improvement that has doubled the available soil P on some properties, rainfall use efficiency (50-100% above previous levels), increases in biodiversity and variable animal performance. By its holistic nature, cell grazing is very difficult to research using traditional statistical models. This may be partially overcome if more effort is expended on understanding biological processes rather than attempting to measure outcomes. Cell grazing is described as a high-level, time-control grazing method and is different from continuous grazing, rotational resting, rotational grazing and multi-camp rotational grazing systems. Comprehensive definitions of the different systems are used by McCosker (2000) to illustrate why the scientific literature differs from industry results.

Richards and Lawrence (2009) questioned whether the cost-price squeeze associated with primary production, restrict the choices of Australian cattle graziers in moving to more sustainable practices. They highlight how cell grazing moves from the traditional aspects of grazing which can be described as productivist, to an ecologically integrated paradigm approach. It requires an ideological and cultural shift, as well as an investment in new infrastructure but has the potential to be economically and environmentally sustainable for beef grazing.

Regenerative grazing management

Morris (2021) states that regenerative grazing management (including holistic planned grazing and related methods) seeks to mimic natural grazing dynamics to restore degraded soils and the ecological processes underpinning sustainable livestock production while enhancing biodiversity. The evidence, from 58 studies of benefits to biodiversity from regenerative grazing management is reviewed by Morris (2021). The evidence includes:

- Soils have increased microbial bioactivity, higher fungal/bacteria biomass, greater functional diversity, and richer microarthropods and macrofauna communities
- Vegetation responds inconsistently, with increased, neutral, or decreased plant diversity
- Trampling reduces numerous arthropods by altering vegetation structure, but creates favourable habitat and food for other taxa e.g. dung beetles
- Structural changes benefit some birds (for foraging, nest sites) while heavy stocking during winter and droughts reduces food for seedeaters and songbirds
- With herding and no fences, wildlife thrives on nutritious regrowth while having access to large undisturbed areas.

Morris (2021) concluded that regenerative grazing management does not universally promote biodiversity but can be adapted to provide better landscape habitat heterogeneity suitable to a wider range of biota.

Interviews

Eight interviews were conducted with industry practitioners and influencers, as detailed in Table 5, which also gives details of their associated farms attributes. Three of the interviewees (all farmers), have adopted mob grazing. One of the researchers interviewed who has their own farm, stated they are going to adopt mob grazing, with their decision based on the results of their research. Interviewee's anonymised answers to the interview questions are detailed below.

Table 5. Interviewee occupation and farm attributes

No	Occupation	Farm location	Farm size	Farm Type	Landscape type	archaeological site/feature
1	Farmer	Hertfordshire	1000ha	Mixed (arable with beef cattle)	Lowland	Bronze age henges, roman villa (remains), historical agricultural buildings
2	Researcher (environmental management) and Farmer	NW Wales	20ha	Livestock (sheep and cattle)	Lowland	Historical and archaeological remains
3	Researcher (animal production)	Devon	350ha	Trial farm (mixed arable and cattle)	Lowland	Interviewee not aware of any sites/features

No	Occupation	Farm location	Farm size	Farm Type	Landscape type	archaeological site/feature
4	Researcher (grazing systems) and Farmer	North Wales	20ha	Trial Farm (sheep and cattle)	Lowland	Ancient mausoleum adjacent to trials
5	Researcher (landscape ecology)	England (various sites)	Range of sizes < 120ha	Trial farms (various)	Various	Interviewee not aware of any sites/features
6	Soil Scientist & consultant	England and North Wales	Range of sizes	Trial farms (various)	Various	Interviewee not aware of any sites/features
7	Farmer	Aberdeenshire	50 & 120 ha	Cattle	Upland	Hill forts
8	Farmer	Scottish Borders	250ha	Livestock	Upland	SSSI, river of palaeontological importance, special area of conservation, species rich grasslands, evidence of cultivation terraces

Farmer understanding and use of mob grazing

All of the interviewees regarded mob grazing as the practice of using a large density of livestock grazing pasture area intensively for a short duration and then leaving the pasture for a long rest period (typically 60 days) between grazing events. However, one of the researchers highlighted that there is no single recognised definition and there are a range of definitions of the practice of mob grazing in the UK. Some interviewees saw mob grazing more as how the land is used i.e. a farm management tool (how many cows per unit area and how long they stay on a paddock, what length of grass they are fed on and how many times). Holistic planned grazing was seen as an entire framework for a wider management practice that has the ability to adapt to the needs of the environment, animals and habitat i.e. adaptive multi-paddock grazing. Holistic grazing is thinking about whole farm investments (economics, social and environmental aspects). Mob and holistic grazing are two terms meaning slightly different practices under the same umbrella.

Goals associated with mob/holistic grazing practices

Where interviewees had goals for mob grazing, they were different depending on whether they were farmers or academics. Their identified goals were:

Farmers

- Finding the right animals for the system
- Finding the right rotations that work
- Improving pasture and arable rotation
- Improving soil health
- Improving biodiversity (abundance & diversity) on farm (seeing the change in the landscape and improvement in animal and plant abundance is a key motivating factor)
- Reducing inputs
- Animal health improvement
- Extend grazing season and carrying capacity
- Improve social aspects (e.g. experimenting with mob/holistic grazing, collaborating with like-minded farmers and discovering different ways of livestock farming)
- Money and profitability (e.g. improved output and profitability)
- Optimise stocking levels and freeing up land for other uses such as more environmentally friendly practices

Researchers

- Impacts on soil health, including soil structure and nutrient cycling potential
- Impact on vegetation
- Impacts on GHG, leaching and biodiversity
- Improving grass utilisation, increasing stocking density, freeing land for other uses i.e. biodiversity afforestation, etc.
- Impacts on stock performance
- Optimising land performance and fertiliser use, and maximising grass production and utilisation
- Farmer motivations for practicing mob/holistic grazing, what they consider the constraints are and how they learn about the practice
- Impacts of mob grazing and what the environmental, economic and animal health and welfare implications are of mob grazing are compared to conventional grazing systems

What have been/are the main barriers/issues/challenges to adopting mob/holistic grazing?

Details of the answers given by interviewees to this question are in the section ‘Barriers to mob/holistic grazing’.

Benefits

The interviewees identified a variety of perceived benefits from mob grazing as follows:

Wildlife and biodiversity

The farmers interviewed noticed improvements in the amount of wildlife returning following the introduction of mob grazing practices and improved biodiversity.

Pasture health

A researcher stated that their research showed that mob grazing has led to an increase in the proportion of sown species in trial pastures such as clovers, and reductions in the number of weed species.

Production and profitability

Following conversion to mob grazing practices several of the interviewees have experienced increased livestock yield with reduced inputs. They have increased stocking and carrying capacity/ha. This has translated into increased production/ha and increased profits. One farmer reported that stock has risen by 30% and total output by 50%. This has led to increased profitability resulting from the more efficient land use and reduced production costs. This farmer also reported that the mob grazing integrates well with stewardship schemes.

Animal health

Mob grazing fosters a greater interest in animal health. The researchers highlighted that moving and increased handling of animals more often means health problems can be identified quicker as there is a better understanding of the animals. It is also easier to check the animals more frequently when opening the fence and letting them run through rather than needing to drive around a larger paddock to inspect them. One farmer also said that there is a better understanding of the animals and learning their behaviours and mannerisms makes it easier to adjust nutritional requirements by inspecting more regularly.

Social benefits

Farmers appear to enjoy doing the practice, experimenting with it and collaborating with like-minded farmers and discovering different ways of livestock farming.

These benefits were also reflected in the study by Wagner, Waterton and Norton (2023) who found that ‘farmers perceived mob-grazing to be a nature-based solution with associated practical benefits for three main aspects of their farming: sustainable livestock productivity, soil and ecosystem health including weed management, and animal health’. However, they also concluded that ‘mob grazing practices are still in their infancy in Britain, and it may be too early to evaluate their environmental benefits and constraints.’

How the farmer/practitioner thinks mob grazing practices could secure the archaeological resource better if there are heritage assets

None of the interviewees had used mob grazing to specifically protect archaeological or heritage sites. However, they were asked if they could see how mob grazing practices could reduce negative impacts on these types of sites. The interviewees identified the following:

- Reduction in heavy grazing could reduce erosion
- May reduce compaction from animals on historical assets due to increased rest period. With the increased rest period, swards can grow and root deeper and therefore reduce water infiltration into historical/archaeological assets
- Requires less use of the land so can potentially free up land with archaeological or historical assets (allows better management grazing around rather than on them). This could lead to increased protection of these sites
- May improve recovery time of sites and enable impact to be monitored more easily. Can be more responsive to needs of the land
- Limits exposure to the animals, however it requires delicate management to get right and to benefit sites of importance
- For species rich grassland – can help to keep these sites species rich and biodiverse without overgrazing these areas as it limits their exposure to the animals whilst also maintaining dominant species

Barriers to mob/holistic grazing (primary research studies and interviews)

Seven of the studies identified potential barriers to adopting mob or holistic grazing practices. All project interviewees gave answers to the question: ‘What have been/are the main barriers/issues/challenges to adopting mob/holistic grazing?’ These suggested barriers, issues and challenges can be broken down into:

- Set up costs and provision of necessary infrastructure
- change in type of management
- extra labour and time constraints.

Set up costs and provision of necessary infrastructure

Tracy and Bauer (2019) suggested that it was unwise to invest in extra management, infrastructure, and potential land resources required to carry out mob stocking on temperate grassland in Virginia, USA considering its limited benefit to livestock production. Similarly, Venter, Hawkins and Cramer (2019) indicated that there were significant economic consequences when adopting high density grazing due to the capital investment required in setting up electric fencing and watering infrastructure considering there was no increase in animal production compared to season-long continuous grazing. However, this

investment could be reduced by using traditional active herding rather than the use of fencing.

Leung and Smith (1984) warn that careful cash flow planning is required to successfully changeover from conventional grazing to intensive grazing. The planned grazing system set up by Immekus (1977) in Arizona, USA required 8.5 miles of fence to be constructed or repaired and required the existing herd of cattle to be reduced until new water facilities (stock water systems and 20,000-gallon water storage tank) could be developed. The planned grazing system set up dramatically affected farm finances for the following two years especially as finding financial help was difficult.

One of the interviewees, a researcher and part time farmer, said that many UK farmers are interested in the practice of mob grazing, but they need investment (e.g. more water troughs) and time to implement the new system. This reflects the findings of a recently published study about adoption of mob grazing in the UK by Wagner, Waterton and Norton (2023) who reported that the shift to mob grazing by UK farmers is a gradual process of farmer adaptation, involving the need to overcome constraints such as fencing and water access. Water provision is important for production and animal welfare, Hart and others (1993) found that the provision of additional water sources is necessary to produce higher livestock gains and greater stocking rates. Two researchers interviewed highlighted that animal welfare could be compromised during inclement weather conditions, in mob grazing systems. For example, livestock access to water and shade during periods of extreme heat. They also identified that, in the terms of sheep production, if lambing was earlier in the year, there could be difficulty getting access to shelter.

Change in type of management

Leung and Smith (1984) warn that careful cash flow planning is required to successfully changeover from conventional grazing to intensive grazing. The Savory Grazing Method (intensive grazing) affects pasture carrying capacity and animal management and therefore requires careful farm management and planning to be successfully implemented. This includes planning in terms of time, livestock, pasture, finance, marketing and economics. Additionally, the flow of animals requires a high level of operational management skill.

The researchers interviewed identified challenges relating to the change in management required to implement a mob grazing system:

- The steep learning curve for anyone taking up the practice for the first time
- Limited access to clear guidance, knowledge and support in the transition to the new systems and practices. Lack of clear guidance of how to do the practice well and what the benefits of adopting the practice are
- Farmers lack of confidence in the outcomes/potential benefits of mob/holistic grazing, and suitability to their own farm (e.g. will it work in their situation, how it will affect their animals and the grass and long-term sustainability, does it improve the

soil and nutritional content of pasture for their animals and is there a positive impact on biodiversity)
- Practical implications of adopting mob grazing (i.e. have they got the right equipment, the correct infrastructure such as water provision and fencing, is there adequate shade)
- UK farmers are influenced by anecdotal data from farming systems from other countries that may not be representative of conditions in or even across the UK

All three farmers interviewed identified that adopting mob grazing required a change in mind set from the practice of set stocking, as initially it seems to go against normal practice. For example, one farmer stated that having to handle the livestock more due to short rotations in pastures seems costly, even though in the longer term it can reduce actual costs of inputs and potentially improve profit. Another farmer suggested the challenge was to become comfortable with adopting the new practice and the change from set stocking whilst having the skillset to achieve it.

Several interviewees highlighted the need for peer support when adopting mob grazing. One researcher said that the change to mob grazing required farmer's family and peers support to be successful. A farmer stated that when there is a lack of confidence at the beginning of the change in practice, any negative views from peers could be a big barrier. Another farmer pointed out that there are negative views from peers around mob grazed calves growing slower and it taking longer to achieve the required outputs and reach profits.

Extra labour and time constraints

Crawford and others (2019) did not use fencing for their planned grazing study on East African Savanna. Cattle were rotated to a different 1 ha plot each day and kept bunched together (<1m apart), by four herders, whilst grazing. Only two herders were required for their continuous grazing treatment. The authors concluded that to encourage cattle ranch owners to adopt planned grazing instead of the conventional continuous grazing, the financial benefits from improved rangeland health and sustainability and cattle weight gain needed to outweigh the cost of hiring more herders.

Phillips and others (1991) indicated that operating a cell grazing management system was labour intensive. This was a view shared by several of the project interviewees, who identified higher labour costs, from the extra time needed to plan and move animals more often, as an issue to adopting mob grazing.

On-going projects

Defra have commissioned an ADAS led consortium (Newcastle University, AFBI, Bangor University, Liz Genever Consulting and LLM Farm Vets) to look at the environmental and productivity benefits of mob grazing systems. The project was initiated in 2021 will run for

3.5 years. It will compare mob grazing and conventional grazing systems at nine farm sites across the country. Measurements will include livestock performance, soil quality, biodiversity, and diffuse pollution (nitrate leaching, ammonia and nitrous oxide emissions).

Limitations of the review

- Searches for literature were only carried out in English language and therefore some relevant articles may have been missed.
- Articles may have been missed in the searches due to the wide variety of terms used by authors to describe mob and holistic grazing.
- Where full text was not available meta-data were extracted using abstracts.
- Unpublished research may be under-represented, particularly where it is not available online.
- No formal critical appraisal of studies or quantitative analyses has been carried out.
- Any conclusions drawn by study authors, come with the caveat that risk of bias has not been assessed.

Key findings and knowledge gaps

- There is no single definition of mob or holistic grazing, and a wide variety of terms are used by authors, to describe keeping large numbers of grazing animals on small areas of pasture and moving them frequently.
- Very little primary research has been conducted in the UK on mob/holistic grazing. Most of the available research to date is from overseas where soil, climatic, social and economic conditions may be very different to the UK.
- Research evidence was often conflicting in terms of the impact and potential benefits of mob/holistic grazing (e.g. for pasture productivity, biodiversity and water infiltration).
- The research collated suggested that over time mob grazed pasture quality may improve so that grazing becomes more efficient. However, more long-term studies are needed to test this especially within the context of the UK.
- There is little evidence regarding the benefit of mob grazing to trees
- No research studies were found that investigated the effect of mob grazing on the historic environment
- Although evidence suggests that there are benefits in terms of productivity of adopting mob/holistic grazing, the system requires significant investment in infrastructure and time/labour inputs
- First time adopters in the UK face a steep learning curve, and clear guidance is lacking about the practice and what the benefits are. This is compounded by the often-conflicting evidence of the potential impacts of mob/holistic grazing on the wider environment

Implications and recommendations for policy, practice and research

- Clear definition and consistent use of terminology by researchers investigating mob or holistic grazing is needed
- This review highlights the need to fund long-term experiments in the UK to investigate and fully understand the potential benefits of mob grazing and to identify what goods and natural capital are delivered. Once this is known clear guidance about practicing mob/holistic grazing and what the benefits are needs to be developed and disseminated to stakeholders.
- Further research is required to investigate the potential for blended finance and carbon trading from the use of mob grazing.
- Research is required to investigate the effect of mob grazing on the historic environment including trees.
- The authors of this review are aware of an on-going research project funded by Defra that is comparing mob grazing and conventional grazing systems at nine farm sites across the country, in terms of livestock performance, soil quality, biodiversity, and diffuse pollution (nitrate leaching, ammonia and nitrous oxide emissions). It is expected that the results of the project will contribute significantly towards the evidence base in the UK.

Conclusions

To date very little research into the impacts of mob/holistic grazing on productivity and the environment has been carried out in the UK. Much of the available research has been carried out in countries where soil, climatic, social and economic conditions may be different to those in the UK. As suggested by Wagner, Waterton and Norton (2023), more research is needed to investigate whether mob grazing, under the UK climate, with lower stocking rates (compared with North America), will provide real benefits to UK farmers and whether there will be resulting positive effects upon vegetation and soils. The evidence suggests that although there are benefits in terms of productivity of adopting mob/holistic grazing, the system requires significant investment in infrastructure and time/labour inputs. First time adopters in the UK face a steep learning curve, and clear guidance is lacking about the practice and what the benefits are. This is compounded by the often-conflicting evidence of the potential impacts of mob/holistic grazing on the wider environment. For example, studies on water infiltration and farmland birds. Moreover, research about the impact of mob/holistic grazing on the historic assets is non-existent. This review highlights the need to fund long-term experiments in the UK to investigate and fully understand the potential wider benefits of mob grazing and to identify what goods and natural capital are delivered. The authors of this review are aware of an on-going research project funded by Defra that is comparing mob grazing and conventional grazing systems at nine farm sites across the country, in terms of livestock performance, soil quality, biodiversity, and diffuse

pollution (nitrate leaching, ammonia and nitrous oxide emissions). It is expected that the results of the project will contribute significantly towards the evidence base in the UK.

The majority of primary research studies looked at impacts on pasture, measuring a variety of vegetation responses to the mob grazing system practices. These included species composition, richness and persistence, plant/ground cover, pasture establishment, herbage/root mass, vegetation height and density and pasture diet quality. The impacts of these practices appear to vary between studies when compared with more conventional grazing. Some studies indicate little impact on plant diversity or productivity. In other studies, mob grazing appears to have some benefits when aiming to control invasive species.

The effect of mob/holistic grazing practices on animal productivity often found that individual animal weights are reduced that can lead to increased mortality in some cases. Overall productivity per hectare can be increased as less land is needed, or stocking rates can be higher. In the short-term, holistic grazing can affect animal behaviour by reducing their selectivity of vegetation, such that the animals cannot select the most nutritious food, but over time pasture quality may improve so grazing becomes more efficient. More long-term studies are needed to test this. Mob grazing can have a positive impact on reducing animal parasites by interrupting the life cycle of the parasite.

There is evidence that pasture is improved by holistic grazing making it more desirable for wildlife grazing and provision of food in the form of insects. However, holistic grazing can positively or negatively affect habit of birds depending on their requirements. Similarly, mob grazing can have a positive effect on insect diversity but can also be used as a control of pasture pest larvae.

Some studies suggest that mob grazing can have a positive effect on soil organic matter but not necessarily soil carbon content. Some researchers have found that trampling increases bulk density and reduces water infiltration. However, others have found that mob grazing can reduce soil runoff and increase infiltration.

Conversion to intensive rotational grazing can be profitable but requires large set up investment and cashflow. It can be difficult to find sources of funding when wishing to adopt mob grazing.

Barriers to adopting mob grazing are set up costs and provision of necessary infrastructure, the ability to change in type of management and the extra labour and time constraints involved.

The interviews found that potential mob grazing adopters may have limited access to clear guidance, knowledge and support in the transition to the new systems and practices and found that there was a lack of clear guidance of how to do the practice well and what the benefits of adopting the practice are.

Further research is needed on the outcomes of mob grazing practice from long term trials especially in the UK. Studies are required to investigate the benefits of mob grazing to trees and the effect that the practices have on the historic environment.

References

Andrade, B.O., Shropshire, A., Johnson, J.R., Redden, M.D., Semerad, T., Soper, J.M., Beckman, B., Milby, J., Eskridge, K.M., Volesky, J.D. and Schacht, W.H. 2022. Vegetation and animal performance responses to stocking density grazing systems in Nebraska Sandhills Meadows. *Rangeland Ecology & Management*, 82, 86-96.

Badgery, W.B. 2017. Longer rest periods for intensive rotational grazing limit diet quality of sheep without enhancing environmental benefits. *African Journal of Range & Forage Science*, 34(2), 99-109.

Behney, A.C. 2021. High-intensity short-duration grazing during spring is not an effective habitat management tool for Northern Bobwhites in Colorado. *Ornithological Applications*, 123(3), 1-17.

Chapman, T. 2012. Are mob grazed cattle the perfect arable break. A Nuffield Farming Scholarships Trust report. John Oldacre Foundation, UK.

Cottle, D., Gaden, C.A., Hoad, J., Lance, D., Smith, J. and Scott, J.M. 2013. The effects of pasture inputs and intensive rotational grazing on superfine wool production, quality and income. *Animal Production Science*, 53(8), 750-764.

Cowley, R., Scott, K., Krafft, P. and Hearnden, M. 2018. Newcastle Waters cell grazing trial: comparing cell grazing systems with traditional practice in the north-western Barkly region. *Technical Bulletin-Northern Territory Government*, No 357.

Crawford, C.L., Volenec, Z.M., Sisanya, M., Kibet, R. and Rubenstein, D.I. 2019. Behavioral and ecological implications of bunched, rotational cattle grazing in East African Savanna ecosystem. *Rangeland Ecology & Management*, 72(1), 204-209.

Davis, K.P., Augustine, D.J., Monroe, A.P., Derner, J.D. and Aldridge, C.L. 2020. Adaptive rangeland management benefits grassland birds utilizing opposing vegetation structure in the shortgrass steppe. *Ecological Applications*, 30(1), e02020.

De Bruijn, S.L. and Bork, E.W. 2006. Biological control of Canada thistle in temperate pastures using high density rotational cattle grazing. *Biological Control*, 36(3), 305-315.

Di Virgilio, A., Lambertucci, S.A. and Morales, J.M. 2019. Sustainable grazing management in rangelands: Over a century searching for a silver bullet. *Agriculture, Ecosystems & Environment*, 283, 106561.

Derner, J.D., Augustine, D.J., Briske, D.D., Wilmer, H., Porensky, L.M., Fernández-Giménez, M.E., Peck, D.E. and Ritten, J.P. 2021. Can collaborative adaptive management improve cattle production in multipaddock grazing systems? *Rangeland Ecology & Management*, 75, 1-8.

Dodd, M.B. and Power, I.L. 2007. Direct seeding of indigenous tree and shrub species into New Zealand hill country pasture. *Ecological Management & Restoration*, 8(1), 49-55.

Domínguez Díaz, E., Esteban Oliva, G., Báez Madariaga, J., Suárez Navarro, Á. and Pérez Castillo, C. 2018. Effects of holistic grazing on structure and composition of naturalized prairies under livestock grazing, provincia de Última Esperanza, Magellan region, Chile. *Anales del Instituto de la Patagonia*, 46(3),17-28.

Dowhower, S.L., Teague, W.R., Casey, K.D. and Daniel, R. 2020. Soil greenhouse gas emissions as impacted by soil moisture and temperature under continuous and holistic planned grazing in native tallgrass prairie. *Agriculture, Ecosystems & Environment*, 287, 106647.

Fynn, R. and Jackson, J. 2022. Grazing management on commercial cattle ranches: Incorporating foraging ecology and biodiversity conservation principles. *Rangelands*, 44(2), 136-147.

Franke, A.C. and Kotzé, E. 2022. High-density grazing in southern Africa: Inspiration by nature leads to conservation? *Outlook on Agriculture*, 51(1), 67-74.

French, R. A. 1973. Mob stocking to beat porina. *New Zealand Journal of Agriculture*, 126 (2), 21-23.

Goldson, S.L. and Wynn-Williams, R.B. 1984. effect of winter mob-stocking on *sitona* larval populations in lucerne. *Proceedings of the Thirty-Seventh New Zealand Weed and Pest Control Conference. Russley Hotel, Christchurch, August 14th to 16th, 1984*, 110-112.

Gomez-Casanovas, N., Blanc-Betes, E., Moore, C.E., Bernacchi, C.J., Kantola, I. and DeLucia, E.H. 2021. A review of transformative strategies for climate mitigation by grasslands. *Science of the Total Environment*, 799, 149466.

Graham, J.F., Prance, T., Thompson, R.P., Borg, D., Ball, P. and Filsell, P. 2000. The effects of grazing management on perennial ryegrass (*Lolium perenne* L.) herbage mass and persistence in south-eastern Australia. *Australian Journal of Experimental Agriculture*, 40(2), 207-224.

Guretzky, J.A., Mamo, M., Schacht, W.H., Volesky, J.D. and Wingeyer, A.B. 2020. Mob grazing increases trampling but not litter deposition on a Nebraska Sandhills subirrigated meadow. Crop, Forage & Turfgrass Management, 6(1), e20047.

Haddaway NR, Macura B, Whaley P, and Pullin AS. 2017. ROSES flow diagram for systematic maps. Version 1.0. DOI: 10.6084/m9.figshare.6085940.

Hart, R.H., Bissio, J., Samuel, M.J. and Waggoner, J.W. 1993. Grazing systems, pasture size, and cattle grazing behavior, distribution and gains. *Journal of Range Management*, 46(1), 81-87.

Hawkins, H.J. 2017. A global assessment of Holistic Planned Grazing™ compared with season-long, continuous grazing: meta-analysis findings. *African Journal of Range & Forage Science*, 34(2), 65-75.

Hawkins, H.J. Short, A. and Kirkman, K.P., 2017. Does Holistic Planned Grazing™ work on native rangelands? *African Journal of Range & Forage Science*, 34(2), 59-63.

Healey, A.F., Hall, E., Walkden-Brown, S.W., Scott, J.M. and Gaden, C.A. 2004. Intensive rotational grazing reduces nematode faecal egg counts in sheep on the Cicerone Project. *Animal Production in Australia*, 25, 85-88.

Henneman, C., Seavy, N.E. and Gardali, T. 2014. Restoring native perennial grasses by changing grazing practices in central coastal California. *Ecological Restoration*, 32(4), 352-354.

Hillenbrand, M., Thompson, R., Wang, F., Apfelbaum, S. and Teague, R. 2019. Impacts of holistic planned grazing with bison compared to continuous grazing with cattle in South Dakota shortgrass prairie. *Agriculture, Ecosystems & Environment*, 279, 156-168.

Holmes N., French, R. and Savage, M. 1981. Mob stocking beats porina. *New Zealand Journal of Agriculture*, 143 (5), 38-39.

Lalampaa, P.K., Wasonga, O.V., Rubenstein, D.I. and Njoka, J.T. 2016. Effects of holistic grazing management on milk production, weight gain, and visitation to grazing areas by livestock and wildlife in Laikipia County, Kenya. *Ecological Processes*, 5, 1-12.

Lawrence, R., Reid, N. and Rader, R. 2015. High intensity, short duration livestock grazing management improves landscape function, and increases species richness and abundance of ground-layer insects on grazing properties of the northern slopes and tablelands of NSW, Australia. *Proceedings of the 17th Australian Society of Agronomy Conference: Building Productive, Diverse and Sustainable Landscapes, 20-24 September 2015, Hobart, Australia*, 191-194.

Leung, P. and Smith, B.J. 1984. Economics of intensive grazing: a case in Hawaii. *Research Extension Series, College of Tropical Agriculture and Human Resources, University of Hawaii*, No.045.

Luginbuhl, J.M., Green Jr, J.T., Poore, M.H. and Conrad, A.C. 2021. Goats to Control the Encroachment of Undesirable Brush and Woody Species in Cattle Pastures. *Proceedings of the XIX International Grassland Congress: Grassland Ecosystems: An Outlook into the 21st Century*, 949-950.

McCosker, T. 2000. Cell Grazing-the first 10 years in Australia. *Tropical grasslands*, 34(3/4), 207-218.

Morris, C.D. 2021. How Biodiversity-Friendly Is Regenerative Grazing? *Frontiers in Ecology and Evolution*, 9, 965.

Moulin, M., Lopez, J., Raman, A., Hodgkins, D., Adams, A. and Mannix, S. 2012. Measurement of biological diversity of arthropods and respiration in soils managed under time-controlled and set-stocked grazing practices in Central-West New South Wales, Australia. *Polish Journal of Soil Science*, 45(1).

Oliva, G., Ferrante, D., Cepeda, C., Humano, G. and Puig, S. 2021. Holistic versus continuous grazing in Patagonia: A station-scale case study of plant and animal production. *Rangeland Ecology & Management*, 74, 63-71.

Park, J.Y., Ale, S., Teague, W.R. and Dowhower, S.L. 2017. Simulating hydrologic responses to alternate grazing management practices at the ranch and watershed scales. *Journal of Soil and Water Conservation*, 72(2), 102-121.

Phillips, J.M., Brown Jr, A.H., Loe, W.C., Smith, R.L. and Parham, R.W. 1991. Cell grazing with steers on tall fescue and small grains overseeded into bermudagrass In Noland, P.R. (Ed.). Current topics on beef cattle research in Arkansas. Univ. of Arkansas Agricultural Exp. Sta. Spec. Rpt. 147, 5-8.

Rapiya, M., Hawkins, H.J., Muchenje, V., Mupangwa, J.F., Marufu, M.C., Dzama, K. and Mapiye, C. 2019. Rotational grazing approaches reduces external and internal parasite loads in cattle. *African Journal of Range & Forage Science*, 36(3), 151-159.

Radcliffe, J.E. 1973. Effect of different grazing systems on hill country pasture composition. *Proceedings of the New Zealand Grassland Association*, 34 (2), 212-224.

Richards, C. and Lawrence, G. 2009. Adaptation and change in Queensland's rangelands: cell grazing as an emerging ideology of pastoral-ecology. *Land Use Policy*, 26(3), 630-639.

Roberts, A.J. and Johnson, N.C. 2021. Effects of Mob-Grazing on Soil and Range Quality Vary with Plant Species and Season in a Semiarid Grassland. *Rangeland Ecology & Management*, 79, 139-149.

Ruiz-Huidobro, C., Sagot, L., Lugagne, S., Huang, Y., Milhes, M., Bordes, L., Prévot, F., Grisez, C., Gautier, D., Valadier, C. and Sautier, M. 2019. Cell grazing and Haemonchus contortus control in sheep: lessons from a two-year study in temperate Western Europe. Scientific Reports, 9(1), 1-9.

Sanjari, G., Yu, B., Ghadiri, H., Ciesiolka, C.A. and Rose, C.W. 2009. Effects of time-controlled grazing on runoff and sediment loss. *Soil Research*, 47(8), 796-808.

Saunders, W.C. and Fausch, K.D. 2012. Grazing management influences the subsidy of terrestrial prey to trout in central Rocky Mountain streams (USA). *Freshwater Biology*, 57(7), 1512-1529.

Seitlheko, E.M., Allen, B.L. and Wester, D.B. 1993. Effect of three grazing intensities on selected soil properties in semi-arid west Texas. *African Journal of Range & Forage Science*, 10(2), 82-85.

Strauch, A.M., Kapust, A.R. and Jost, C.C. 2009. Impact of livestock management on water quality and streambank structure in a semi-arid, African ecosystem. *Journal of Arid Environments*, 73(9), 795-803.

Stewart, K.M. and Archibald, R.D. 1987. The effects of pasture management on population density and diseases of porina (*Lepidoptera*: *Hepialidae*). *New Zealand Journal of Experimental Agriculture*, 15(3), 375-379.

Tracy, B.F. and Bauer, R.B. 2019. Evaluating mob stocking for beef cattle in a temperate grassland. *Plos one*, 14(12), e0226360.

Venter, Z.S., Hawkins, H.J. and Cramer, M.D. 2019. Cattle don't care: Animal behaviour is similar regardless of grazing management in grasslands. Agriculture, *Ecosystems & Environment*, 272, 175-187.

Wagner, M., Waterton, C. and Norton, L.R. 2023. Mob grazing: A nature-based solution for British farms producing pasture-fed livestock. *Nature-Based Solutions*, 3, 100054.

Zaralis, K. and Padel, S. 2017. The Effects of "Mob Grazing" on Soil Organic Matter and Dairy Cow Performance-A Case Study. *Proceedings of the 8th International Conference on Information and Communication Technologies in Agriculture, Food and Environment, Chania, Greece, 21-24 September, 2017*, 508-512.

www.gov.uk/natural-england