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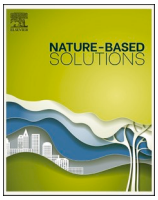

# Mob grazing: A nature-based solution for British farms producing pasture-fed livestock

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ABSTRACT

Mob grazing is a nature-based solution to boost sustainable livestock productivity by optimising pasture management. It is already used widely in North America, and is now also receiving increased attention in the United Kingdom. In spite of this, its implementation by British farmers has so far remained largely unexplored. To close this gap, we studied how and why mob grazing is being adopted by British pasture-fed beef farmers. Field-level grazing management information was collected on 15 farms and analysed using cluster analysis and ordination analysis, showing the diversity of practices and establishing a gradient of mob grazing implementation. Farmer interviews explored general farming context, and rationale and motivations underpinning each farmer's grazing approach. Four main rotational approaches were identified at the field level: (1) conventional non-mob stocking by farmers still in the initial stages of discovering mob grazing; (2) mob stocking, involving reduced grazing duration at increased stocking densities, with pasture rest periods similar to those used in rotational non-mob stocking; (3) mob grazing, involving similar stocking densities as in mob stocking, but allowing for longer rest periods; and based on one early adopter of mob grazing practices in our sample (4) intensive mob grazing using very high stocking densities and frequent cattle movement, allowing for even longer rest periods. Interviews revealed the shift to mob grazing as a gradual process of farmer adaptation, involving the need to overcome constraints such as fencing and water access. Some early adopters amongst our sample of farmers observed various benefits to sustainability of livestock production, soil and ecosystem health, and animal health. We found much variation across farms, partly due to farmers adopting mob grazing gradually. Also, many farmers in our sample, in varying degree, were influenced by holistic grazing approaches. The 'systems' basis underlying such approaches, and variation in mob grazing implementation, mean that interdisciplinary and longer-term investigations may be most appropriate for exploring mob grazing effects. This is also illustrated by a case study involving long-term data from one intensively mob grazed farm.

## 1. Introduction

Mob grazing as a component of regenerative farming [1] has received much attention in the last couple of decades in livestock systems, first in North America [2–4], and increasingly also in Europe [5,6]. Both mob grazing and related adaptive multi-paddock (AMP) grazing techniques are advocated as a nature-based solution that, by simulating natural herd grazing strategies, can be used to optimize grass and livestock production both in the short term and, through improving soil quality, also in the long term [7,8]. In recent years, mob grazing practices have also found their way into the United Kingdom [9,10]. Because of their claimed benefits and other potential impacts, and because over one fifth of the UK's land cover consists of pasture [11], both British farmers and agricultural and environmental policy bodies are keen to better understand these practices and their impacts in the context of British farm systems.

Use of the term mob grazing has evolved over time [12]. Some applications have defined it as a "short-term, one-time grazing event" [13], as a grazing technique designed to repair pastures damaged by understocking [14], whereas other authors have referred to mob grazing to describe forms of intensive rotational grazing [15,16]. The International Forage and Grazing Terminology committee has more recently defined

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mob stocking as a "method of stocking at a high grazing pressure for a short time to remove forage rapidly", focusing on momentary stocking densities and making no reference to length of rest periods between grazing events [17]. In contrast to this definition of mob stocking, recent definitions of mob grazing state that the latter involves short periods of intensive grazing followed by long rest periods. In North American mob-grazed systems, these extended rest periods between grazings can be very long, with land being grazed at a maximum of 2–3 times per year, and rest periods of 140–180 d [3], and in some instances land being grazed just once annually for a short time [18]. Hence, some contemporary definitions of mob grazing specify a minimum length of the pasture rest period between successive grazings, e.g. 45 days [19] or 90 days [20]. Correspondingly, Sollenberger et al. [21] described mob stocking as "simply rotational stocking with pastures divided into a large number of paddocks", whereas mob grazing "in addition … uses long rest intervals (often 60 days or more) between grazing events". Other terms used in the literature for mob grazing include ultra-high-stocking density grazing, tall-grass grazing, and flash grazing [22]. Mob grazing also shares some characteristics with approaches such as cell grazing [23] and TechnoGrazing [24]. Some authors see mob grazing as "the grazing part of" the Holistic Management framework originated by Alan Savoury, an adaptive framework for grazing planning that, being applied at the farm level, allows for variable sward recovery periods [9]. Others consider holistic grazing more adaptive than mob grazing [25], and some advocates of holistic grazing see fundamental differences between the two approaches, and emphasize that the terms mob grazing and Holistic Planned Grazing must not be used interchangeably [26].

The argument for mob grazing as a nature-based solution for achieving higher pasture productivity builds on the premise that grasses, having evolved under similar natural grazing regimes, can maximize their photosynthesis and hence productivity under them. The characteristic short periods of intensive grazing and long rest periods of mob grazing are designed to improve pasture regrowth through leaving sufficient plant material ungrazed, thus allowing more photosynthesis and development of more extensive root systems [27]. According to mob grazing advocates, these improved conditions for pasture plant growth, and the modified interaction between livestock and grazed land under mob grazing, produce various benefits over more conventional set-stocking and rotational grazing approaches. These include:

- Increased pasture productivity as a primary benefit resulting directly from better plant growth and indirectly from (i) a gradual species compositional shift towards taller grass species that are better adapted to swards growing taller due to increased rest periods and that are characterized by a more well-developed root system enabling efficient nutrient acquisition [28], and (ii) a shift to a more diverse pasture composition [22] resulting in more even sward productivity across seasons [27]. North American mob graziers state that by implementing mob grazing practices as part of planned grazing systems, pasture and livestock productivity markedly increased [2,3,29];
- Uniform grazing and forage utilization and reduced build-up of pasture weeds avoided by livestock [5];
- Breaking of parasitic life cycles through long rest periods between grazings, leading to lower parasite burdens in livestock [30];
- Improved soil health and increased soil carbon sequestration and stocks, due to the leftover lower parts of plants being trampled in along with evenly distributed livestock faeces and urine [31].

Some of these purported benefits have been put into question [32], e.g. the ability of mob grazing practices to foster soil carbon sequestration [33,34]. The realization of other mob grazing benefits might depend on additional factors, with positive effects on productivity appearing to be more likely with higher precipitation [35]. Attempts to weigh up the potential benefits but also negative effects of mob grazing have been reported in farmer-practitioner literature [34,36,37] and in popular scientific literature [27]. Scientific studies are beginning to establish an evidence basis for whether, and if yes to what extent, mob grazing can deliver claimed benefits such as carbon sequestration [38] and forage production and nutritive value [20,39]. However, such studies usually look at very specific experimental grazing regimes which may not reflect the practical implementation of mob grazing on farms, where the realization of key elements of mob grazing such as 'short duration', 'high stocking density' etc. will depend on various factors, including individual practitioners' backgrounds [22,40].

Also, most research so far has been carried out in North America, where potential mob grazing benefits have been the subject of considerable debate [7,20,38,39,41,42]. In contrast, in the UK, aside from small-scale case studies [22,30], very little research has been carried out to understand why some farmers are implementing mob grazing approaches, how they actually go about it, and its possible impacts on livestock production and on pastures. To address this gap, this study adopts a mixed-methods, socio-ecological approach, engaging with 15 farmers who had indicated that they either already used mob grazing as a management practice or intended to do so in the 2019 season.

This study opens the black box of 'mob grazing' for British farmers and policy makers, by determining the extent of variation in mob grazing practices amongst a sample of pasture-fed beef farmers, and to understand better which stocking densities, grazing durations, and rest periods practitioners are adopting and why. In North America, four characteristics of mob grazing were regularly identified by groups of mob and non-mob graziers: increased stocking density, increased rest periods between successive grazings, shortened grazing periods, and trampled forage [12]. The same authors also explored which stocking densities and grazing periods were typically employed by their sample of mob graziers [12]. No such information has yet been collected in Britain, where, barring a few early adopters, mob grazing practices have only recently become more popular.

Below, we combine a natural science approach with qualitative social science interviews to explore mob grazing practices in Britain. Bringing together quantitative data on grazing management, soils and vegetation, and qualitative farmer interview data, we capture the complexities involved in shifting a grassland-herbivore agroecosystem towards a mob grazing management approach, in line with similar socio-ecological approaches [43–46]. We are interested in the practical experiences of British farmers taking up mob grazing and how these connect to a wider framework of motivations, actions and consequences that are relevant to our sample of farmers. Qualitative research on 'cell graziers' in Australia, for example, has found some livestock farmers to be seeking a middle way between a "productivist paradigm" and an "ecologically integrated paradigm" [47]. Such insights indicate that a shift to mob grazing may be part of an attempt, by some farmers, to position themselves in relation to the future sustainability of livestock systems. This evidently speaks to the wider context of global ecosystem health and climate change [28,48,49]. We therefore explore what farmers think they are doing by adopting new mob grazing approaches.

## 2. Materials and methods

### 2.1. Farm selection

In summer 2019, we surveyed 15 British farms run by farmer members of the Pasture-Fed Livestock Association (PFLA), and located across all the major regions of England (13 farms) and in south-east Scotland (2 farms). Of these, thirteen comprised a sub-sample of the 56 farms previously surveyed in 2018 to explore public goods delivery from pasture-based livestock farming [50,51]. Two additional PFLA farms managed by farmers implementing mob grazing practices were included in 2019. Farms were selected according to whether the farmer had indicated that they either already used mob grazing as a management practice or intended to do so in 2019. Starting points varied amongst our sample of farmers, and those who were already adopting

mob grazing practices had done so after previously implementing either set stocking or conventional rotational grazing approaches on their farms. The sample focused on farmers producing beef animals at scale, with one exception made for a small-scale beef producer who is strong proponent of mob grazing approaches.

### 2.2. Field methods

The 15 farms were visited both by an ecologist to record management and carry out soil and vegetation sampling, and by a sociologist to conduct two semi-structured interviews, including a farm walk and a kitchen table interview with the farmer(s) on each farm.

### 2.3. Management, soil and vegetation data collection

For collection of management, soil and vegetation data, each farm was visited by an ecologist during the period between 4 June 2019 and 2 August 2019. Farmers helped the ecologist to identify pairs of fields for grazing management evaluations for which detailed management information was recorded, and on which samples were taken. The intended purpose was to compare fields within a single farm that were either mob grazed or set stocked. However, in many instances, this proved difficult; e.g. farms that had implemented a holistic grazing approach did so on all their grazed land, which meant that all fields were mob grazed. In some instances, controls were recorded that were rotationally grazed. In other instances, controls were recorded that were not primarily managed by grazing, as suitable grazed fields did not exist. On the two farms surveyed first, two pairs of fields were recorded, but subsequently, recording was only carried out on one pair of fields per farm. In instances where control fields were not primarily managed by grazing, only one of the pair of fields was carried forward for analysis, resulting in six fields being discarded from analyses. As a result, the final sample consisted of 28 fields from 15 different farms. Of these 28 fields, 24 were permanent pasture, including one that was relatively recently reseeded. Four fields were mob grazed arable leys.

We recorded vegetation composition in each field as percent cover for all species present in three randomly placed 4m$^2$ quadrats per field. Following the protocol used in the UK Countryside Survey [52], in one of the quadrats, a single soil core (7 cm diameter, 15 cm depth) was sampled and analysed for bulk density and loss-on-ignition. This sampling approach has previously been found to produce consistently reliable bulk density measurements [53]. In the same quadrat, a single measurement was taken of the thickness of thatch (if any) accumulated on the ground, using a metre stick and taking a reading of thatch thickness to the nearest 0.5 cm. In addition, in each field we measured sward height at 10 points along a W-shaped transect, again using a metre stick placed vertically through the sward canopy until it touched the ground, and at each point taking a reading of sward height to the nearest 1 cm. For each of the recorded fields on a farm, we also recorded information provided by the farmers on grassland type (permanent vs ley), field size, number of grazings and type and average group size of grazing livestock and average duration of grazings during the grazing season, other management practices such as cutting, and in the case of fields being partitioned for rotational/mob grazing also the number of partitions in the field. Average duration of grazings was recorded for the smallest grazing unit, typically a paddock or grazing cell in rotationally grazed land, or in some instances, the whole field when not subdivided for grazing.

### 2.4. Farmer interviews

We conducted two semi-structured interviews with the farmer(s) on each farm. The first semi-structured interview, usually carried out in the farm kitchen, was followed by a 'walking interview' across the farm. The latter was designed to give free rein to the farmer to show, and discuss further, the farming and grazing practices that had been mentioned in the earlier semi-structured interview. Both interviews were around one hour long, and were recorded on a digital ZOOM recorder. Later, they were transcribed verbatim. NVivo qualitative data analysis software, version 12, was used for coding and interpretation of transcripts.

### 2.5. Data analysis

To capture the variation in short-term grazing pressure, we calculated stocking densities for each field at the level of the smallest grazing subunit (see above). For this, we calculated livestock units (LUs) on a per hectare basis [54], using information provided by the farmers on type (species, breed, age) and average numbers of grazing livestock per grazing, as well as field size and partition during grazing. One livestock unit corresponds to a cow of 650 kg body weight [54], and we used this value as a conversion factor when comparing stocking densities on our farms with those typically listed as kg live weight per hectare in other (e.g., North American) mob grazing studies.

Focused on a subset of 19 fields in our sample that were rotationally (at least twice consecutively in a single grazing season) cattle-grazed in 2019, including some fields originally recorded as controls on farms in the initial stages of adopting mob grazing practices, we carried out a cluster analysis to identify variation in rotational non-mob and mob grazing practices – that is, the different types of rotational cattle grazing actually implemented. Nine other fields that were either set-stocked, one-off mob-stocked, or on which the grazing rotation alternated between sheep and cattle, were discarded. A resemblance matrix between the 19 fields was calculated using Gower's similarity measure [55], and the input parameters average stocking density, average rest period between successive cattle grazings during the growing season, and average duration of grazing per subunit. This matrix was used in hierarchical agglomerative clustering of the 19 fields using group average linkage via the UPGMA algorithm [56]. Due to the relatively small sample size, the optimal number of groupings could not be numerically validated. Instead, and to visually explore and interpret possible groupings, we ran an ordination analysis using two-dimensional Metric Dimensional Scaling (NMS), with the final model based on 100 random starting configurations and a minimum stress threshold of 0.01. To illustrate relationships between cluster groups and grazing management parameters, we produced an NMS ordination biplot also including a vector overlay indicating Pearson correlations of grazing parameters in ordination space. Both the cluster analysis and ordination analysis were carried out using PRIMER vs. 7.0 statistical software [57]. After visual determination of the most meaningful number of groupings, we constructed box and whisker plots to illustrate the spread of the three input parameters across the resulting groupings. This was done using the R 'gplots' package, version 3.1.3 [58].

To provide further context for all 28 fields, we calculated weighted means of Ellenberg N values [59] for each vegetation quadrat and averaged across the three quadrats recorded per field, to characterize potential sward productivity [60,61]. For each field, we also calculated average plant species richness per 4 m$^2$, and average sward height. Results of these calculations for each field, along with information on management and dominant species, are provided in Supplementary Material, Appendix A.

## 3. Results and discussion

Of the 15 farmers whose farms we visited, 13 stated that they had their cattle graze at mob stocking densities. Eleven farmers did so in the context of rotational approaches, and two had their cattle graze fields just once during the growing season at such elevated stocking densities. The other two farmers used rotational approaches but still did so using conventional lower stocking densities. Some fields in our sample were managed not just by cattle grazing, but also by sheep grazing or by cutting to produce silage or haylage for consumption by cattle overwintering indoors. Supplementary Material, Appendix A illustrates the

diversity and complexity of the systems and practices involved, providing detailed management information for all 28 fields including the 19 rotationally managed fields, alongside 3 fields that were mob-stocked just once during the 2019 growing season, 4 fields managed by set stocking, and 2 fields managed by alternating sheep and cattle grazing. With a few exceptions (notably farms 1 and 4), rotational mob grazing practices recorded on the farms visited by us only date back a few years or were only initiated for the first time in the year of our visit (see management information in Supplementary Material, Appendix A).

### 3.1. Categorization of rotational mob grazing practices

The cluster dendrogram indicates four principal groups (Fig. 1a). These groups reflect the different approaches to rotational cattle grazing taken up in practice by farmers, and as illustrated by the NMS ordination plot with vector overlay of grazing management parameters (Fig. 1b), differ from each other systematically with respect to stocking density, grazing duration, and length of the typical rest period between grazings. The full range for each of these management parameters for each cluster group is shown in Fig. 2. Group 1 ('rotational non-mob stocking') corresponds to conventional rotational grazing prior to adoption of mob grazing elements. Group 2 ('rotational mob stocking') represents rotational grazing with adoption of more frequent livestock movement (Fig. 2a) and of increased stocking densities (Fig. 2b), with rest periods remaining unchanged from conventional rotational grazing (Fig. 2c). Group 3 ('mob grazing') differs from group 2 by additional adoption of

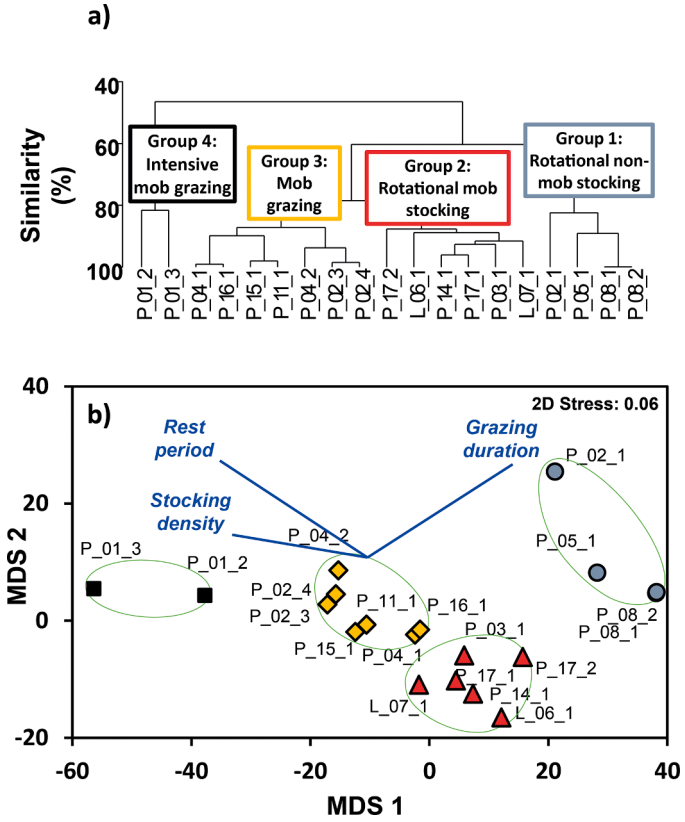


**Fig. 1.** Types of rotational grazing management derived by cluster analysis of 19 rotationally grazed fields using three grazing parameters as input variables. (a) Cluster dendrogram of the 19 fields rotationally cattle grazed in 2019. (b) Ordination biplot of the final 2D Metric Multidimensional Scaling model. Also indicated in this biplot are the cluster memberships of individual fields and Pearson correlations with the grazing parameters used as input in the cluster analysis in the form of vector overlays. Field codes indicate whether a field was managed as ley (L) or as permanent pasture (P), followed by the farm number and field number within a given farm.

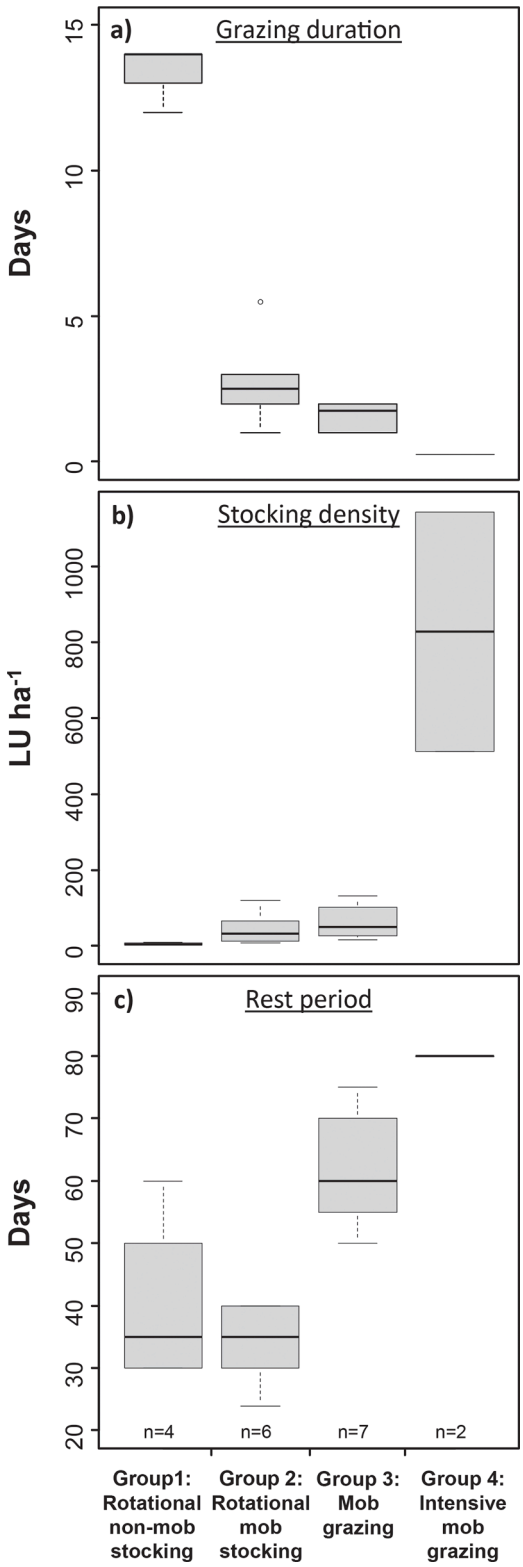


**Fig. 2.** Box and whisker plots of grazing parameters for the fields assigned to four types of non-mob and mob grazing management derived by cluster analysis. (a) grazing duration for the smallest grazing unit, (b) stocking density, (c) rest period between grazings. Sample sizes for each category are indicated in the bottom graph.

longer rest periods between grazings, and a tendency to move livestock even more frequently between grazing units. Group 4 ('intensive mob grazing') is characterized by much higher stocking densities compared to the other groups and by even more frequent livestock movement, as well as a further increase in rest periods between grazings (Fig. 2). As discussed below in Section 3.5, the use of stocking densities such as those employed in this latter group of fields is not considered out of the ordinary by North American mob graziers, but since such high stocking densities appear to be exceptionally high amongst our sample of British mob graziers, we decided to refer to this in the British context as 'intensive mob grazing'. Splits in the cluster analyses occurred in the order of group 4 being split off at 46% Gower similarity, group 1 being split off at a Gower similarity level of 60%, and the remaining set of 13 fields being split into groups 2 and 3 at 78% Gower similarity. The small set of four permanent pastures in the 'rotational non-mob stocking' group 1 were managed by grazing over longer time periods (12–14 days) at comparatively low stocking densities (2.6 to 10.3 LU $ha^{-1}$). Four permanent pastures and two leys making up group 2 were characterized by shorter grazing duration of between 1 day and 5–6 days, and generally higher stocking densities, ranging between 9.6 and 121 LU $ha^{-1}$. Rest periods were relatively short at between 24 days and 40 days, and similar to those used in rotational non-mob stocking. Reflecting a distinction between mob stocking and mob grazing based on rest periods [21], we labelled group 2 the 'rotational mob stocking' group. The most obvious difference between fields in this group and those in group 3, consisting of seven permanent grassland fields, was that fields in group 3 were characterized by longer average rest periods between grazings, ranging between 50 days and 75 days (Fig. 2). Hence, in line with [21], we labelled group 3 the 'mob grazing' group. However, grazing durations of 1–2 days and stocking densities of 17.1 and 132 LU $ha^{-1}$ applied to the fields in group 3 are similar to those applied to group 2. As a result, in terms of overall grazing management, fields in these groups are more similar to those in the respective other group than they are to fields within groups 1 and 4, with groups 2 and 3 almost representing some kind of continuum along a main axis reflecting differences in the length of rest periods (Fig. 1b). Two permanent pastures in group 4, split off at high level from the remaining sample in the cluster analysis, were characterized by a very short average grazing duration per subunit, with animals being moved on average 4 times per day. This frequent movement was combined with very high stocking densities exceeding 500 LU $ha^{-1}$, and the longest average rest periods of all groups at 80 days. Accordingly, we labelled this group the 'intensive mob grazing' group.

The observed continuum of grazing practices in our sample reflects individual interpretations of mob grazing. Fourteen of the 15 fields in groups 2, 3, and 4 were referred to by farmers as being 'mob grazed', with the exception of one permanent pasture (P_17_2) described by the farmer as being 'rotationally grazed'.

Below, we explore how choice of rotational mob grazing practices is affected by constraints and by influences on each farmer, and by where the farmer is positioned on what we have termed the 'mob grazing journey'. We also briefly outline the reasons for farmers in our wider sample having used 'one-off' mob stocking. However, to start with, it is important to acknowledge the most important commonality across all farms. All farmers involved in this study have embarked on a system-level transition in their agricultural practices in becoming members of the PFLA, and are therefore part of a community of practitioners committed to feed their beef cattle entirely on grass and forage crops [62]. Fully certified PFLA farmer members can sell meat under the Pasture for Life brand. This means that all of these farmers have a keen interest in learning how to "utilize our grass better" (Farmer 06 Interview). All of them rely on the productivity of pasture as the single most important input in a more "closed system" (Farmer 10 Interview), with mob grazing practices representing a nature-based solution to realize such a closed system. Baselines varied, with some farmers having previously set-stocked their land, and others having previously used conventional rotational grazing, but all of them having already undergone a conversion to the pasture-fed approach prior to taking up mob grazing. Farmers across our sample discussed the promise of greater grass growth and a longer season in which to feed cattle as one of the reasons that they are adapting their grazing system: "What we're trying to achieve is quality grass that we can go round reasonably quickly, not take too much; keep coming round it because the more we can go round it and round it, the longer the cows can be out here for" (Farmer 15 Interview). This simple motivation - to maximize grass use efficiency – is however underlain by several factors driving the observed broad differentiation in grazing practices (Fig. 1). Multiple issues relating to a complex mix of personal, biographical, socio-cultural, economic, biophysical, and historical factors shape the way that farmers choose to take up innovations in farm practices [63]. Using data from our qualitative interviews, we can explore how farmers are adapting grazing regimes to their own particular and wider circumstances, and with what kind of results.

#### 3.1.1. *Rotational non-mob stocking (Group 1)*

Our interviews with the three farmers managing these four pastures (farmer 02, 05 and 08) indicate a range of different factors - some technical, others more social, ethical or organisational - coming together differently on each farm to influence their grazing practices.

Farmer 05, for example, keeps his cattle, with calves and followers, outside all year round in large areas of pasture at a stocking density of around 5 LU $ha^{-1}$. He is keen to experiment in order to sustain the cattle outdoors year-round. He has tried bale grazing as well as using smaller paddocks in the winter months. He labels his loosely contained grazing groups as mobs, acknowledging however: "I have much bigger mobs than everybody else really…". He suggested, "the trouble with …the small paddocks is, animals can't necessarily, you know, express their total behaviour as well as [they can] in bigger mobs" (Farmer 05 Walking Interview). Hence, his choices about grazing practices focus, at least partly, on consideration of animal behaviour and welfare.

Farmer 05 is only mildly tinkering with his system and does not show any signs of moving towards more stringent mob grazing practices. Farmer 08, however, indicates that he may soon 'move along' the dendrogram in Fig. 1a, into group 2 or group 3. He is on a learning and experimenting journey, picking up ideas, reading, and aiming to try more innovations in time: "I'm now more interested in taking a slightly more active approach to grassland, particularly just doing this rotation thing… …ideally, and maybe in the future, I'm going to start subdividing those [fields] with electric and doing more of this mob grazing system" (Farmer 08 Interview).

Farmer 02, on the other hand, straddles two categories: some of his stock is grazed in a non-mob rotation, but he does implement mob grazing on parts of the farm where he has managed to install the required infrastructure – electric fencing and water supply. He is in the midst of a steep learning curve, reading, meeting up with other farmers and absorbing as much information as possible from those that know more about changing grazing regimes. Farmer 02 is partly drawing on models from the past, "Grandad used to run rotational systems apparently" (Farmer 02 Interview). Also, since he manages parcels of land that are not all contained within one site, he is currently engaged in something that several other farmers talked about: how to implement a mob grazing regime that will work across the disparate areas of the land that he farms.

Only one farmer in this non-mob stocking category has found his ideal rotational grazing method for the time being (farmer 05). However, even this farmer suggested, "I don't think I'd ever rest on my laurels and say I'm doing it perfectly" (Farmer 05 Interview). The other two farmers (02 and 08) seem to be on a 'mob grazing journey' towards adoption of more intensive mob grazing techniques and infrastructures. Their current practices may therefore be a staging post on their journey, whilst they gather the knowledge and resources to move towards a mob grazing technique suiting the particularities of their farm operation.

*3.1.2. Rotational mob stocking (Group 2)*

Like two of the farmers in Group 1, four farmers in group 2 (farmers 03, 17, 07, and 14) also feel that they are on a steep learning curve. As farmer 03 put it: "Mob grazing is a new idea which we're looking at … There's various ways of looking at it. I think the proper term is holistic planned grazing… I don't know anything about it but that's something I'd like to learn about…I'm very much on the bottom rung" (Farmer 03 Interview).

Farmers in group 2 are observing carefully what the effects of their relatively recent experiments are. Farmer 07, who started mob grazing the year before we interviewed, for example, spoke how, in his second year, he was observing and changing his practices "a little bit as you go along": "Even on the same field…you can see there's certain bits come back quicker, and it's doing better than the bit a bit lower down, where you might have grazed a touch longer or gone a bit shorter" (Farmer 07 Interview).

The quality of the land and the soil were key concerns for these farmers: "Obviously I mean it's all about trying to improve the soil as well, you know, trying to improve the soil structure and the water retention and all that" (Farmer 07 Interview): "hoping for maximum production as well as improving the quality of the land at the same time" (Farmer 17 Interview).

For some farmers in this category, including farmer 06 and farmer 14, the decision to change the grazing regime towards a mob stocking methodology, was based on a stark assessment of farm finances: "Under the old system we weren't making any money.... We weren't making any money and we still weren't making any money, like, over a long period. So I looked at it, and I thought, hang on a second, what are we doing? We're running around to stand still". (Farmer 14 Interview).

Different kinds of challenges accompany this shift. Farmer 14, for example, is striving to implement a form of mob grazing in a large and complex farm business. One real constraint was the difficulty of bringing his stockman and farm manager along with him. He has plans for bigger mobs and is excited about extending the rest period: "If you leave that for two months, it's going to be rocket fuel. It's just going to, POUF!" (Farmer 14 Walking Interview). But the transition to a system that he can imagine is slow: what was really important for this farmer was a social issue - to be able to make sure his staff are "able to see some sort of change" from the work that they had put in (Farm 14 Walking Interview). Constraints slowing down the mob grazing journey in this case are social/cultural as well as technical.

*3.1.3. Mob grazing (Group 3)*

All farmers in this category share a strong concern for soil health and an interest in holistic management of farmed land. Farmer 11, for example, has redefined himself as a "soil farmer" who sees a key role for cattle in a mixed farm system. Farmer 02 describes a "growing awareness" of what he understands to be going on in the topsoil and farmer 15 was motivated to try mob grazing, as "our soils weren't improving". The soils on this farm were, he observed, "depleted in organic matter", and lacking resilience to the stresses farms are experiencing under climate change.

Mob grazing seems to be working well for the six farmers in this group. Some of them have recently (since 2017) dipped their toe in the waters through gradual introduction of the mob grazing method. So far, they seem pleased with the results: "we are now increasing the number [of fields] that we're using the mob grazing on, and next year, everything will go mob grazing" (Farmer 15 Interview). Farmer 04 had been mob grazing for around 7 years and saw it as part of a wider move towards Holistic Planned Grazing, as promoted globally by the Savory Institute. Farmer 04's main interest was in the potential of holistic grazing without chemical fertilizer or pesticide inputs to facilitate stocking rates equivalent to those on conventional farms with such inputs. Farmer 02 drew inspiration from TechnoGrazing: "I measure the grass, each field, and then when I come back it's all on the computer in a nice graph form showing me what grass I've got where and how many days ahead with grazing I've got". (Farmer 02 Interview). This farmer is keen to imagine a time when "you've got your biometrics stuff and your cows, you know where they are, what they're doing, body temperature, movement, everything that's going on, electric fences will be virtual, er, and then you will be able to move your cows" (Farmer 02 Interview).

Mob grazing is clearly not an end-point in itself: it can give farmers the scope and ability to refine their businesses further. As discussed, a perceived benefit of mob grazing is that the method itself facilitates grass use efficiency, meaning that cattle can stay out for longer. Both partial and full outwintering reduce costs of housing, labour and feed and avoid costs of associated accumulation of farmyard manure. The grazing season for farmer 15, for example, has extended from 6 months to 10 months. Other farmers in the mob grazing category leave the cattle out all year round (farmer 04), with open barn space for cattle to occupy in harsh weather (farmer 16), or are transitioning to overwintering all cattle outside (farmer 11). Farmer 11 stated that overwintering in the fields would mean that he might be able to increase his herd from previously 50 cows/150 animals to 150 cows/400 animals within a period of approximately 5 years, increasing the productivity of his pastures and shifting considerably the ratio of arable to livestock on his farm.

*3.1.4. Intensive mob grazing (Group 4): a case study*

The two fields in this cluster group were both on farm 01. Farmer 01 is an interesting case due to the intensity with which he has applied the mob grazing philosophy, setting up small paddocks within his grass pastures and using extremely high stocking rates (Fig. 2b). Having grown up with an industrial agricultural model in dairying, this farmer initially applied the same model when he started farming in 1996. However, by 2004 he had reached a point at which his farm was unworkable, and seeing no future in dairy farming he decided to take some time out. After a year in New Zealand and several years back at the farm with no cattle, he began to raise small numbers of beef cattle across the whole farm in 2009, but this time without chemical inputs. He applied intensive mob-grazing practices from 2013. He describes how he learnt by doing and how, by applying rotational grazing, he could keep the cows out longer in the autumn, while also starting to get "interesting grassland" (Farmer 01 Interview). He suggests that part of what motivates him is the continual learning that he is engaging in - with other farmers globally, via the internet, via Youtube, and locally, through farmer networks. He is currently mentoring three other farmers with whom he set up an informal group. The farmers visit each other, "chat, and see what each other are doing" (Farmer 01 Interview). They advise each other and learn together.

Farmer 01 is intensely interested in seeing how much he can produce on his small (40 ha) farm and is keen to fine-tune his system further to increase the amount of stock the land is able to support: "I'm still focused on maximum production, it comes back way back to the sixties with my parents and my brother, I still want to produce the maximum amount off this ground, but I realize you can do it without using inputs" (Farmer 01 Interview).

Thus, farmer 01 wants to produce the maximum possible from his land. He is using mob grazing to do this in a way that he feels is sustainable - for his own wellbeing, in terms of the viability of the farm business, for the health of his soils and for wildlife. He relayed to the interviewer how much he was enjoying his new method of farming.

"In spring turnout…the cows skip when they first leave the sheds. My animals do it four times a day, every day, as they go to the new paddock… Honestly, I just love it. I set my automatic latches up but if I'm not busy I'll go down just to watch them go through" (Farmer 01 Walking Interview).

Farmer 01 is satisfied with the condition and growth of his cattle, and delighted by the wider ecological changes he is witnessing on the farm. He described sightings of birds of prey - buzzards, sparrow-hawks and red kites - possibly hunting on increased numbers of small mammals: "we get these little holes which are vole holes I think, we get loads of them, I never saw them before" (Farmer 01 Walking Interview). On the

other hand, sward species richness appears to be low in his intensively mob-grazed fields (Supplementary Material, Appendix A).

Coincidentally, soil and vegetation samples were also gathered from another field on farm 01 one year earlier in 2018 for another part of our project, and this was a field for which we also have directly comparable long-term monitoring data involving identical plot types and soil cores from the UK Countryside Survey [52,53]. As this field was also under mob grazing management, additional information is presented in Supplementary Material, Appendix B, on how on this farm, historical and present management, which has for some years included intensive mob grazing practices, relates to changes in vegetation and soil characteristics over time.

### 3.2. Insights from the categorization

Farm transitions to fully grass-fed systems, exemplified by the farmers in our study of which many were already fully certified by the Pasture for Life Association, are connected to a wider farmer commitment towards more sustainable and resilient farming. Farmers apply mob grazing practices as a nature-based solution, helping them to gain more from their pastures. The majority of farmers in our sample are influenced by the principles of holistic grazing, and in accordance with its guidelines, these farmers implement shorter grazing durations and longer rest periods.

Our data reveal that the move towards mob grazing involves a marked learning process, with highly active self-learning, reading articles, watching Youtube videos, and taking part in discussions on Twitter and Facebook. A main inspiration of the burgeoning mob grazing movement in UK livestock farming are influential pioneers of mob grazing and related grazing approaches primarily in North America. Those mentioned by farmers in our interview included the originator of Holistic Management Allan savoury (Zimbabwe and USA), Gabe Brown from North Dakota, Greg Judy from Missouri, Joel Salatin from Virginia, Allen Williams from Mississippi (all USA), and Neil Dennis from Saskatchewan (Canada). There is also an active exchange amongst UK mob graziers of ideas and farming experiences. Farmers create discussion groups, visit each other, share discoveries on the PFLA Google group, and hold demonstration days on their farms. Many farmers in this study felt that they were on the bottom rung of a ladder of learning that they imagined would carry on further into the future.

At the same time, farmers are actively applying what they are learning. As part of what we call the 'mob grazing journey', they are experimenting and tinkering – with paddock sizes, with fencing and water supply infrastructure, with rest periods and with stocking densities. Our analysis suggests that farmers in group 1 may well increasingly adopt elements of mob grazing as they figure out how to get around the initial constraints that initially face them on this journey. As discussed below, other farmers may equally find that constraints associated with mob grazing such as the time and labour requirements in moving fences and water, and the challenges of keeping cattle outside throughout the year, cannot by fully implemented in their system. It is also possible that farmers may shift out of mob stocking/grazing altogether. Farmers' positions may continue to shift as they work out their own version of mob grazing, also depending on practical constraints and the extent to which these can be accommodated or removed. This journey is an adaptive process. Farmers are engaged in learning through doing, and are excited by the challenge of finding a better way to rear livestock [64] which works for their system. This excitement also seems to be partly due to this very much being a "bottom-up" process. As one farmer put it: "I don't think there needs to be experts. Like, everyone's the expert on their own farm, and you can just take, like a magpie, off everyone and apply it to whatever works for you" (Farmer 04 Interview).

### 3.3. Perceived practical benefits of mob grazing practices

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.

All farmers in our sample who practiced forms of rotational mob grazing mentioned benefits for boosting sustainable livestock productivity, building productive farming operations that require only few inputs, thus as much as possible approximating "a closed loop system" (Farmer 02, 10, 16 Interviews). The majority wanted to manage their land for better sward growth without inputs such as fertilizer, reducing costs to maximize productivity rather than production, and ensuring that their land can maintain its productive capacity. Farmers expected better plant growth in mob grazed pastures compared to the same pastures as previously managed by them using either continuous grazing (e.g., farmer 17) or conventional rotational grazing (e.g., farmer 16). They expected that such increased productivity would enable them to extend the grazing season, thereby reducing or eliminating the requirement for indoor housing and feed over winter. Some wanted to fit mob grazing around management to produce preserved forages on farms where stock overwinter indoors. For example, on farm 12, a field was cut for haylage, and subsequently mob-stocked late in the season (Supplementary Material, Appendix A). Some farmers emphasized that mob grazing approaches would facilitate stocking rates similar to those on conventional farms, or otherwise help increase stocking rates over current rates of stocking.

The input of labour, as a cost, is a very interesting aspect of the mob-grazing journey for farmers. As we have seen from the case study of farmer 01, watching the cattle go through from one paddock to the next is a real pleasure for him, clearly affirming his mob-grazing practice and philosophy. Other farmers have described how this routine gives them a regular insight into the health and welfare of their animals in ways not possible under a set-stocking regime. Thus, the labour requirement in 'being there' to move fences saves time and costs in other ways. All the farmers in our sample were aware of changes in labour dynamics. However, their comments mostly referred to observed trade-offs rather than to increases. Farmer 14, for example, described how his gradual shift to mob grazing was, perhaps counter-intuitively: "not more work, it's less work, cause we're not spending any time mixing feeding …That frees up a lot of time to open an electric fence and turn a water supply on" (Farmer 14 Interview).

Benefits to soil and ecosystem health and weed management were mentioned by the majority of interviewed farmers. Whilst linked to sustainable livestock production, these benefits were seen in a longer-term perspective, as a nature-based solution for ensuring the continued existence of healthy and sustainable ecosystems. Farmers specifically alluded to aspects of soil fertility, soil carbon, water infiltration capacity, and soil biodiversity. An important practical benefit that several farmers associated with mob grazing was weed management (Farms 01, 04, 05, 09, 10 and 17). Farmer 17 mentioned that set stocking with just a few animals continuously from spring to autumn had resulted in undesirable species such as thistles, Yorkshire fog and buttercups taking over because of selective grazing, whereas now, with mob grazing, "the thistles have gone and the nettles have disappeared" (Farmer 17 Walking Interview). Other studies have shown that one-off grazing at mob stocking densities outside of a rotation can manage weeds successfully [5,65], alleviating the need for non-nature-based interventions such as herbicide application. However, while this may help against weed species that become problematic due to their low palatability, some opportunistic weeds may potentially benefit from mob grazing [33].

One interviewed farmer used cattle mob grazing once annually for conservation management of species-rich grassland. Farmer 10 employed annual one-off cattle mob stocking in the late summer, supplemented by short-duration intensive sheep grazing once in the winter

to one field since 1982 with very good results. This grassland is characterized by high species richness (24 species per 4 $m^{-2}$) and low potential sward productivity (Ellenberg N mean = 4.1). Farmer 10 does not categorically rule out that rotational forms of mob grazing, "long pastures and… moving them every day" (Farmer 10 Interview), can also be beneficial to biodiversity: "quite possibly [pastures] would have more insect life, and the soil, more going on beneath because of that, and more birds." (Farmer 10 Interview). In his case, a main reason not to implement rotational forms of mob grazing is that he keeps both cattle and sheep. The late one-off mob grazing in the summer on his species-rich grassland permits many of the plants, including orchids, to set seed and to persist. Such carefully timed one-off mob grazing is more akin to a mowing regime [66], also avoiding disturbance to wildlife such as ground-nesting birds earlier in the season. Thus, one-off mob stocking could be a viable strategy for maintaining species-rich grassland of conservation value [67]. As discussed below, one-off mob stocking was also implemented in a different context on farm 12.

Several farmers referred to practical benefits of rotational mob grazing for animal health. Farmers specifically alluded to two such benefits. The first was an expectation that longer rest periods would result in a much lower parasite burden of grazing cattle. The other was that mob grazing would be associated with an improved nutritional quality of forage. Farmers suggested that mob-grazed grasses would develop deeper root systems, and as a result would contain more calcium. Another farmer stated that with mob grazing, "the animals stop being interested in mineral licks" (Farmer 16 Interview). Importantly, animal health connects to the viability of the livestock enterprise: "I mean pleasingly, you know, when we sell stores [i.e. young cattle not yet ready for slaughter] at the market, they tend to sell slightly better than the average…they look well and they sell well and they are healthy" (Farmer 17 Interview).

### 3.4. Perceived constraints for implementing mob grazing

Mob grazing is a relative novelty amongst British farmers and the interviewed farmers displayed some excitement, but also drew attention to some limitations and constraints linked to rotational mob grazing practices. Key requirements for their implementation are adequate fencing and water supply infrastructures. Farmers may need to invest in mobile electric fencing and optional self-releasing gates or may invest in fence/hedge infrastructures to create fixed smaller paddocks within pre-existing fields, all of which also require some form of water provision [34]. Farmer 12 stated: "One problem is the water, water facilities. Am I going to have water in every little cell? Am I going to then go and put up bank fences everywhere, or am I going to fence the entire area and have everything pre-fenced already?" (Farmer 12 Interview). Farmer 6 suggested that he was intending to plant hedges in order to move cattle in a permanent pattern as moving fences had proved time consuming. Another farmer indicated that their attempts to implement mob grazing using one large mob were constrained by inadequate water supplies, particularly in hot weather (Farmer 17 Interview).

Farmer 14 highlighted the fact that all farm workers and stockmen on the farm involved in the grazing management need to adapt to the new mind-set associated with mob grazing. The ability to implement mob grazing also depends on having sufficient time available to implement the required frequent movement of animals. In the words of farmer 5 who decided against rotational mob grazing: "I keep an eye on it but and there's a few of us who think, oh well it's just too extreme if we move them every week, um we're doing well enough, you know. If I had to start moving all this lot every three hours, I would never go to bed, would I?" (Farmer 5 Walking Interview). As highlighted above, this farmer also considered that high stocking densities may be detrimental to the welfare of his livestock. Other considerations played a role in farmer 10′s decision not to go down the route of rotational mob grazing. His-farming system was more complex, involving both cattle and sheep: "Cattle only, is a lot simpler than both cattle and sheep" (Farmer 10 Interview). He felt that sufficient build-up of tall grass swards through rotational mob grazing to enable out-wintering of cattle was not possible with sheep on the farm as well, as "sheep do need the short sweet leafy grass" (Farmer 10 Interview).

### 3.5. How does mob grazing in our sample of British farmers differ from North American mob grazing?

Stocking densities tended to be lower in our sample of UK farms than in North America [12]. Minimum stocking density thresholds in North America have been suggested as equivalent to 77 LU $ha^{-1}$ combined with rest periods exceeding 90 days [20], 172 LU $ha^{-1}$ combined with short grazing durations of one day or less, and rest periods of at least 45 days [19], or 308 LU $ha^{-1}$ [68]. In a survey of 58 beef and dairy farms practicing mob grazing in the Upper Midwest of the United States, stocking densities ranged from 86 LU $ha^{-1}$ to 1723 LU $ha^{-1}$, with 40% of farmers using stocking densities higher than 431 LU $ha^{-1}$ [12]. 84% of mob graziers moved their cattle between one and three times a day, with an unspecified additional percentage moving them 4-5 times a day, meaning that only a small percentage of mob graziers (fewer than 16%) moved their mobs less often than daily [12].

While several farmers in our study implemented mob grazing at stocking densities higher than the minimum of 77 LU $ha^{-1}$ suggested [20], only farmer 01 applied stocking densities exceeding the 308 LU $ha^{-1}$ indicated by [68]. Relatively recent uptake of mob stocking practices, and the substantial shift in practices required to move to ultra-high stocking densities, may be the reason for lower stocking densities in Britain. Notably, farmer 01, the only farmer practicing intensive rotational mob grazing, began his 'mob grazing journey' earlier than the other farmers in our study. His-farm is also in one of the driest parts of England and might be climatically a bit closer to North American mob graziers' experience. However, the whole of the UK is generally characterized by a more humid temperate oceanic climate with no dry season [69], whereas in North America, mob grazing is very often implemented in regions that are comparatively dry and even semi-arid [41,42].

More research is needed to explore what such differences in climate between the UK and North America and the somewhat lower stocking densities as employed by UK-based mob graziers compared to North American mob graziers might mean for the realization of postulated mob grazing benefits and how exactly the adoption of mob grazing practices by UK graziers will affect pasture soils and vegetation (see below in Section 3.6). However, the farmers in our study are closely observing the effects of mob grazing on their farms on soil condition and swards. For example, farmer 01 pointed out the need to be wary of too much trampling on his heavy clay pastures "you can really do harm in this system", but also described the benefits he had witnessed where intense trampling had taken place: "it's the best bit of grass on the farm!" (Farmer 01 Walking Interview). Several farmers across our sample expressed the motivation not only to grow more grass via mob grazing techniques but to do this in order to stock higher numbers of cattle (Farmers 01, 02, 07, 11, 14, 15, and 16).

The farmers in our study specified a wide range of rest periods for mob grazed pastures with average rest periods of between 24 and 80 days in Britain, being similar to a range of between 20 and >80 days reported for a North American sample [12]. Interestingly, in [12], 76% of mob graziers identified an increased pasture rest period as a characteristic of mob grazing, whilst only 55% of conventional rotational graziers did so. According to the authors, this element of mob-grazed systems is often overlooked [12]. The same may initially apply to UK farmers implementing mob stocking. The five mob graziers in our rotational mob stocking group 2 applied rest periods of similar lengths to those used by conventional rotational graziers, although two planned to increase rest periods in line with holistic grazing principles.

Differences in the realization of mob grazing practices by UK pasture-fed cattle farmers compared to their North American counterparts might

be expected. The more humid British climate [69] means swards tend to be more productive, which may in turn support relatively large numbers of livestock. This might make it more difficult to implement very long rest periods, whereas on larger North American farms, these can be up to a year in length [22].

### 3.6. Impacts of mob grazing approaches

The relatively recent move to mob grazing approaches on the majority of farms included in our study, and pre-existing differences between farms in terms of management history, soils, and climate, rule out a systematic investigation of the potential effects of mob grazing approaches. It is too early to draw any conclusions about whether mob grazing practices might help these farmers to sustainably raise livestock productivity on their farms, as claimed by North American mob grazing advocates [2,3,29].

With respect to the soil and vegetation field survey data summarized in Supplementary Material, Appendix A, for the same reasons, no clear patterns related to practice were yet evident. For example, we found no consistent differences regarding the identity of dominant species between different types of grazing. This suggests that any expected species compositional shift towards taller grasses in response to the introduction of rotational mob grazing practices by farmers may require some time, if such a marked shift will occur at all. At the time of our farm visits, low-statured grasses such as *Agrostis stolonifera* L. and *Lolium perenne* L. were still dominant even in those fields where this shift in management had taken place the earliest (Supplementary Material, Appendix A). We did also find little evidence for thatch accumulation to be more substantial in mob-grazed fields than in set-stocked fields (Supplementary Material, Appendix A). However, it should be noted that our farm visits were not timed to coincide with mob grazing events in the recorded fields. Also, the humid British climate might lead to faster decomposition, compared to drier North American climates.

Challenges in relation to carrying out systematic investigations in managed grazing systems, like the ones studied by us are acknowledged elsewhere [7,43,70] and reflect differences in terms of adaptive practices as well as underlying differences between farms and the longevity of practice. The example of farmer 01 (Section 3.1.4 and Supplementary Material, Appendix B) demonstrates the value of long-term datasets [52] and associated long-term management information, as opposed to short-term experiments, for tracking the impacts of grazing management over time.

## 4. Conclusion

Uptake of mob grazing practices by PFLA members reflects a more general recent interest amongst the British livestock farming community. Key individuals strongly influenced by trailblazers, mostly from North America, are driving practices forward. Our study provides a snapshot of the evolution of mob grazing practices as currently implemented by British PFLA farmers.

The interviewed farmers overwhelmingly perceived mob grazing as an important element of a wider (holistic or regenerative) farming approach, often learning about and adopting planned grazing approaches such as e.g., Holistic Planned Grazing [71] within wider framings of their businesses. Thus, they are likely to develop new perspectives on issues important to them within their farm operations [43,45]. Examples include issues of time (they may well take a longer view), issues of risk (they may be more open to experimentation), and issues of agency in relation to wider social problems (they may take a more proactive rather than a reactive stance).

As illustrated by our interviews, the mob grazing movement in Britain (and worldwide) represents a bottom-up innovation by practitioners. Notably, in contrast to top-down innovations driven by agribusiness, this innovation is not primarily aimed at increasing the overall outputs of the farming operation, but constitutes a nature-based solution for improving the balance between inputs and outputs, thus ensuring an economically viable bottom line and long-term environmental sustainability.

As mob grazing practices are very different from conventional continuous and rotational practices, the transition towards them is gradual. Farmers initially try them out at a small scale, and over time create the infrastructure to integrate mob grazing across their farming operations. Notably, only one farmer in our sample has moved to ultra-high stocking densities and grazing periods of less than one day across all his grazed land, as implemented by experienced North American mob graziers.

Mob grazing practices are still in their infancy in Britain, and it may be too early to evaluate their environmental benefits and constraints. However, it is already clear that in terms of social impacts, farmers are generating new social dynamics and social capital, by engaging and by supporting each other in a journey of learning. The move towards mob grazing represents a dynamic journey, marked by experimentation and exploration. The potential for tinkering, and for working out what works best where, is a key part of the appeal of mob grazing. However, the effects of mob grazing practices can be challenging to explore by means of reductionist natural science approaches because of the complexity of operation, the general flexibility of the concept and its application by individual farmers. From our interviews, it is clear that farmers themselves see a variety of benefits already in the first few years of mob grazing.

In a nutshell, mob grazing is not just adopted as a nature-based solution for growing more grass and for producing high quality beef but is seen by farmers themselves within a wider context that also involves ambitions to sustain a complex interdependent system, and to manage it for social, environmental and economic benefits.

## NBS impacts and implications

Environmental: Many farmers in our sample have observed or expect environmental benefits from adopting mob grazing practices. These include benefits to soil health, such as improved soil carbon accumulation, water infiltration, and soil biodiversity, but also more effective control of weed species known to become problematic with more conventional grazing approaches.

Economic: All farmers in our sample implementing rotational mob grazing practices have observed or expect economic benefits from their application. These benefits can be characterized as boosting sustainable livestock productivity, achieving high productivity with lower external inputs, as a result of implementing grazing management designed to maximize sward regrowth between grazings.

Social: With mob grazing practices in British farming still being in their infancy, their implementation involves farmers engaging with and supporting each other, thus creating a new social dynamic. While doing so, they are building a knowledge base from which other farmers following in their footsteps will be able to benefit.

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## CRediT authorship contribution statement

**Markus Wagner:** Data curation-Equal, Formal analysis-Equal, Investigation-Equal, Validation-Equal, Visualization-Lead, Writing – original draft-Lead, Writing – review & editing-Lead. **Claire Waterton:** Conceptualization-Supporting, Data curation-Equal, Formal analysis-Equal, Funding acquisition-Supporting, Investigation-Equal, Methodology-Equal, Validation-Equal, Writing – original draft-Supporting, Writing – review & editing-Supporting. **Lisa Norton:** Conceptualization-Lead, Funding acquisition-Lead, Investigation-Equal, Methodology-

Equal, Project administration-Lead, Writing – original draft-Supporting, Writing – review & editing-Supporting.

## Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## Data availability

Quantitative soil, vegetation, and management data are available in Table S1 within Supporting Information. Qualitative interview data that support the findings of this study are not publicly available due to reasons of confidentiality.

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## Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.nbsj.2023.100054.

## References

[1] A. Kassam, L. Kassam, Paradigms of agriculture, in: A. Kassam, L. Kassam (Eds.), Rethinking Food and Agriculture: New Ways Forward, Woodhead Publishing, Cambridge, 2020, pp. 181–218.
[2] K. Gordon, Mastering mob grazing, Angus J. (August 2010) 80-81http://www.angusjournal.com/ArticlePDF/Mob%20Grazing%2008.10.pdf (accessed 08 November 2021).
[3] B. Kidwell, Mob Grazing: High-Density Stocking Builds Profits Back Into the Cattle Business, Angus Beef Bulletin (March2010) 28-29 http://www.angusbeefbulletin.com/ArticlePDF/MobGrazing%2003_10%20ABB.pdf (accessed 08 November 2021).
[4] H.S. Thomas, Ranchers sing the praises of mob grazing of cattle, Beef Mag. (2012). https://www..beefmagazine.com/pasture-range/ranchers-sing-praises-mob-grazing-cattle (accessed 08 November 2021).
[5] F. Mesléard, N. Yavercovski, G. Lefebvre, L. Willm, A. Bonis, High stocking density controls *Phillyrea angustifolia* in Mediterranean grasslands, Environ. Manag. 59 (2017) 455–463, https://doi.org/10.1007/s00267-016-0808-x.
[6] M. Winter, W. Starz, Mob Grazing - ein Ausweg aus dem Trockenheits-Dilemma? Landwirtschaftliche Zeitschrift Rheinland 45/2021 47-49. https://raumberg-gumpenstein.at/component/rsfiles/download.html?path=Allgemein%252FBiologische_Landwirtschaft_und_Biodiversitaet_der_Nutztiere%252F41_2021_hof_und_feld_mob_grazing.pdf, 2021 (accessed 08 November 2021).
[7] R. Teague, F. Provenza, U. Kreuter, T. Steffens, M. Barnes, Multi-paddock grazing on rangelands: why the perpetual dichotomy between research results and rancher experience? J. Environ. Manag. 128 (2013) 699–717, https://doi.org/10.1016/j.jenvman.2013.05.064.
[8] R. Teague, U. Kreuter, Managing grazing to restore soil health, ecosystem function, and ecosystem services, Front. Sustain. Food Syst. 4 (2020), 534187, https://doi.org/10.3389/fsufs.2020.534187.
[9] P. Brown, The importance of how we graze our cattle and sheep - a look at mob grazing, Star Furrow 127 (2017) 16–19. https://www.biodynamic.org.uk/wp-content/uploads/2017/08/Mob-grazing-article-by-Peter-Brown-Summer-17-SF-.pdf (accessed 08 November 2021).
[10] R. Wills, A guide to mob grazing livestock. *Farmers Weekly*. https://www.fwi.co.uk/livestock/grassland-management/a-guide-to-mob-grazing-livestock, 2020 (accessed 08 November 2021).
[11] V. Nafilyan, Office for National Statistics, UK natural capital – Land cover in the UK. https://www.ons.gov.uk/economy/environmentalaccounts/articles/uknaturalcapitallandcoverintheuk/2015-03-17, 2015 (accessed 08 November 2021).
[12] A.M. Gurda, M.J. Renz, G.E. Brink, Defining mob grazing in the Upper Midwestern United States, J. Ext. 56 (2018) #4RIB2. https://tigerprints.clemson.edu/joe/vol56/iss4/11 (accessed 08 November 2021).
[13] J.D. Volesky, W.H. Schacht, S.S. Waller, G80-504 Proper livestock grazing distribution on rangeland (Revised February 1996). https://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=2313&context=extensionhist, 1996 (accessed 08 November 2021).
[14] W. Schacht, J. Volesky, A. Shropshire, T. Lindsey, M. Redden, B. Beckman, J. Johnson, A. Wingeuer, M. Mamo, Mob grazing on Nebraska Sandhills meadow, in: Proceedings of the 19th Annual Nebraska Grazing Conference, University of Nebraska-Lincoln, Lincoln, 2019, in: https://grassland.unl.edu/documents/NGCProceedings/NGCProceedings2019.pdf, pp. 34-40. (accessed 08 November 2021).
[15] J.B. Fergusson, Preliminary investigations on introductions of species of the genus *Poa* L. in New Zealand, Proc. New Zealand Grassl. Assoc. 35 (1973) 240–248, https://doi.org/10.33584/jnzg.1973.35.1384.
[16] P. Mislevy, G.O. Mott, F.G. Martin, Screening perennial forages by mob-grazing technique, in: J.A. Smith, V.W. Hays (Eds.), Proceedings of the XIV International Grassland Congress, Westview Press, Boulder, 1983, pp. 516–519.
[17] V.G. Allen, C. Batello, E.J. Berretta, J. Hodgson, M. Kothmann, X. Li, J. McIvor, J. Milne, C. Morris, A. Peeters, M. Sanderson, An international terminology for grazing lands and grazing animals, Grass Forage Sci. 66 (2011) 2–29, https://doi.org/10.1111/j.1365-2494.2010.00780.x.
[18] L. Janssen, B. McMurtry, M. Stockton, A. Smart, S. Clay, An economic analysis of high-intensity, short-duration grazing systems in South Dakota and Nebraska. https://openprairie.sdstate.edu/plant_faculty_pubs/5, 2015 (accessed 08 November 2021).
[19] D. Hancock, Is mob grazing as effective as we thought? https://onpasture.com/2017/11/06/is-mob-grazing-as-effective-as-we-thought, 2017 (accessed 08 November 2021).
[20] B.F. Tracy, R.B. Bauer, Evaluating mob stocking for beef cattle in a temperate grassland, PLoS One 14 (2019), e0226360, https://doi.org/10.1371/journal.pone.0226360.
[21] L.E. Sollenberger, G.E. Aiken, M.O. Wallau, Managing grazing in forage - livestock systems, in: M. Rouquette Jr, G.E. Aiken (Eds.), Management Strategies For Sustainable Cattle Production in Southern Pastures, Academic Press, Cambridge, 2020, pp. 77–100.
[22] K. Zaralis, S. Padel, Effects of high stocking grazing density of diverse swards on forage production, animal performance and soil organic matter: a case study, in: A. Theodoridis, A. Ragkos, M. Salampasis (Eds.), Innovative Approaches and Applications For Sustainable Rural Development, Springer Nature, Cham, 2019, pp. 131–146.
[23] J.M. Earl, C.E. Jones, The need for a new approach to grazing management - is cell grazing the answer? Rangel. J. 18 (1996) 327–350, https://doi.org/10.1071/RJ9960327.
[24] J.F.L. Charlton, J.H. Wier, TechnoGrazingTM - a new grazing concept, Proc. New Zealand Grassl. Assoc. 63 (2001) 33–36, https://doi.org/10.33584/jnzg.2001.63.2428.
[25] H. Gosnell, S. Charnley, P. Stanley, Climate change mitigation as a co-benefit of regenerative ranching: insights from Australia and the United States, Interface Focus 10 (2020), 20200027, https://doi.org/10.1098/rsfs.2020.0027.
[26] A. Smith, Holistic Planned Grazing is not rotational or mob grazing. https://jeffersonhub.com/holistic-planned-grazing-is-not-rotational-or-mob-grazing/, 2015 (accessed 08 November 2021).
[27] S. Flack, The Art and Science of Grazing, Chelsea Green Publishing, White River Junction, 2016.
[28] N.H. Zahn, C. Ertel, R. Hener, S. Franke, A. Beck, J. Westphal, I. Schleip, Mob Grazing als Weidestrategie im Grünland und Ackerfutter bei zunehmenden Trockenheiten in Nordostdeutschland, in: M. Wolf (Ed.), Grünland Im Spannungsfeld Forschung, Wissenstransfer und öffentliche Wahrnehmung. Arbeitsgemeinschaft Grünland Und Futterbau der Gesellschaft für Pflanzenbauwissenschaften e.V, Soest, 2022, pp. 46–49.
[29] A. Adams, Keen on grass and dollars, Land Livest. 110 (2006) 3–6. https://effertzeranch.com/pdfs/2016/Keen_on_Grass.pdf (accessed 08 November 2021).
[30] A. Cooke, The Management of UK Pasture-Fed Beef Production Systems and Impacts on Dung and Disease, University of Bristol, Bristol, 2018. PhD Thesis.
[31] S. Schwarzer, Putting carbon back where it belongs - the potential of carbon sequestration in the soil. https://wedocs.unep.org/bitstream/handle/20.500.11822/28453/Foresight013.pdf, 2019 (accessed 08 November 2021).
[32] D.D. Briske, A.J. Ash, J.D. Derner, L. Huntsinger, Commentary: a critical assessment of the policy endorsement for holistic management, Agric. Syst. 125 (2014) 50–53, https://doi.org/10.1016/j.agsy.2013.12.001.
[33] C. Helzer, A skeptical look at mob grazing. prairieecologist.com/2011/11/28/a-skeptical-look-at-mob-grazing, 2011 (accessed 08 November 2021).
[34] R. Lemus, What is mob grazing and does it really provide grazing advantages? http://extension.msstate.edu/newsletters/forage-news/2011/what-mob-grazing-does-it-really-provides-grazing-advantages, 2011 (accessed 08 November 2021).
[35] H.-J. Hawkins, A global assessment of Holistic Planned Grazing™ compared with season-long, continuous grazing: meta-analysis findings, Afr. J. Range Forage Sci. 34 (2017) 65–75, https://doi.org/10.2989/10220119.2017.1358213.
[36] M. Priestley, How beef herd is delivering £350/cow net profit with deferred, mob grazing. *Farmers Weekly*. https://www.fwi.co.uk/livestock/grassland-management/how-beef-herd-is-delivering-350-cow-net-profit-with-deferred-mob-grazing, 2019 (accessed 08 November 2021).
[37] M. Priestley, Organic mob grazing system cuts £380/livestock unit on estate. *Farmers Weekly*. https://www.fwi.co.uk/livestock/beef/organic-mob-grazing-system-cuts-380-livestock-unit-on-estate, 2020 (accessed 08 November 2021).
[38] J.A. Guretzky, M. Mamo, W.H. Schacht, J.D. Volesky, A.B. Wingeyer, Mob grazing increases trampling but not litter deposition on a Nebraska Sandhills subirrigated meadow, Crop Forage Turfgrass Manag. 6 (2020) e20047, https://doi.org/10.1002/cft2.20047.

[39] E.D. Billman, E. D, J.A. Williamson, K.J. Soder, D.M. Andreen, R.H. Skinner, Mob and rotational grazing influence pasture biomass, nutritive value, and species composition, Agron. J. 112 (2020) 2866–2878, https://doi.org/10.1002/agj2.20215.
[40] B. Anderson, When mob grazing is not mob grazing, https://www.progressiveforage.com/forage-types/grasses-and-grazing/when-mob-grazing-is-not-mob-grazing, 2015 (accessed 08 November 2021).
[41] B.O. Andrade, A. Shropshire, J.R. Johnson, M.D. Redden, T. Semerad, J.M. Soper, B. Beckman, J. Milby, K.M. Eskridge, J.D. Volesky, W.H. Schacht, Vegetation and animal performance responses to stocking density grazing systems in Nebraska Sandhills meadows, Rangel. Ecol. Manag. 82 (2022) 86–96, https://doi.org/10.1016/j.rama.2022.02.006.
[42] A.J. Roberts, N.C. Johnson, Effects of mob-grazing on soil and range quality vary with plant species and season in a semiarid grassland, Rangel. Ecol. Manag. 79 (2021) 139–149, https://doi.org/10.1016/j.rama.2021.04.0088.
[43] H. Gosnell, K. Grimm, B.E. Goldstein, A half century of Holistic Management: what does the evidence reveal? Agric. Hum. Values 37 (2020) 849–867, https://doi.org/10.1007/s10460-020-10016-w.
[44] K. Sherren, I. Darnhofer, Precondition for integration: in support of stand-alone social science in rangeland and silvopastoral research, Rangel. Ecol. Manag. 71 (2018) 545–548, https://doi.org/10.1016/j.rama.2017.08.003.
[45] D.H. Stinner, B.R. Stinner, E. Martsolf, Biodiversity as an organizing principle in agroecosystem management: case studies of holistic resource management practitioners in the USA, Agric. Ecosyst. Environ. 62 (1997) 199–213, https://doi.org/10.1016/S0167-8809(96)01135-8.
[46] R. Teague, M. Barnes, Grazing management that regenerates ecosystem function and grazingland livelihoods, Afr. J. Range Forage Sci. 34 (2017) 77–86, https://doi.org/10.2989/10220119.2017.1334706.
[47] C. Richards, G. Lawrence, Adaptation and change in Queensland's rangelands: cell grazing as an emerging ideology of pastoral-ecology, Land Use Policy 26 (2009) 630–639, https://doi.org/10.1016/j.landusepol.2008.08.016.
[48] Food, Farming & Countryside Commission (FFCC), Farming For Change. Mapping a Route to 2030, FFCC, London, 2021. https://ffcc.co.uk/assets/downloads/FFCC_Farming-for-Change_January21-FINAL.pdf (accessed 08 November 2021).
[49] H.C.J. Godfray, P. Aveyard, T. Gernett, J.W. Hall, T.J. Key, J. Lorimer, R. T. Pierrehumbert, P. Scarborough, M. Springmann, S.A. Jebb, Meat consumption, health, and the environment, Science 361 (2018) eaam5324, https://doi.org/10.1126/science.aam5324.
[50] L.R. Norton, L.C. Maskell, M. Wagner, C.M. Wood, A.P. Pinder, M. Brentegani, Can pasture-fed livestock farming practives improve the ecological condition of grassland in Great Britain? Ecol. Solut. Evid. 3 (2022) e12191, https://doi.org/10.1002/2688-8319-12191.
[51] L. Norton, L. Maskell, A. McVittie, L. Smith, M. Wagner, C. Waterton, C. Watson, Learning from innovative practitioners: evidence for the sustainability and resilience of pasture fed livestock systems, Front. Sustain. Food Syst. 6 (2022), 1012691, https://doi.org/10.3389/fsufs.2022.1012691.
[52] C.M. Wood, S.M. Smart, R.G.H. Bunce, L.R. Norton, L.C. Maskell, D.C. Howard, W. A. Scott, P.A. Henrys, Long-term vegetation monitoring in Great Britain – the Countryside Survey 1978-2007 and beyond, Earth Syst. Sci. Data 9 (2017) 445–459, https://doi.org/10.5194/essd-9-445-2017.
[53] B.A. Emmett, B. Reynolds, P.M. Chamberlain, E. Rowe, D. Spurgeon, S.A. Brittain, Z. Frogbrook, S. Hughes, A.J. Lawlor, J. Poskitt, E. Potter, D.A. Robinson, A. Scott, C. Wood, C. Woods, Countryside Survey: soils report from 2007, Centre for Ecology & Hydrology (2010). https://countrysidesurvey.org.uk/sites/default/files/CS_UK_2007_TR9-revised%20-%20Soils%20Report.pdf (accessed 08 November 2021).
[54] C. Chesterton, Technical Advice Note 33,, 2nd edition, DEFRA Rural Development Service, London, 2006. https://web.archive.org/web/20070626001539/http://www.defra.gov.uk/rds/publications/technical/tan_33.pdf (accessed 08 November 2021).
[55] J.C. Gower, A general coefficient of similarity and some of its properties, Biometrics 27 (1971) 857–872, https://doi.org/10.2307/2528823.
[56] B.S. Everitt, S. Landau, M. Leese, D. Stahl, Cluster Analysis, 2nd ed, Wiley, Chichester, 2011.
[57] K.R. Clarke, R.N. Gorley, PRIMER V7: User Manual/Tutorial, PRIMER-E Ltd., Plymouth, 2015.
[58] G.R. Warnes, B. Bolker, L. Bonebakker, R. Gentleman, W. Huber, W. Liaw, T. Lumley, M. Maechler, A. Magnusson, S. Moeller, M. Schwartz, B. Venables, T. Galili, Package 'gplots', version 3.1.3. https://cran.r-project.org/, 2022 (accessed 23 November 2022).
[59] M.O. Hill, C.D. Preston, D.B. Roy, PLANTATT – Attributes of British and Irish Plants: Status, Size, Life History, Geography and Habitats, Centre for Ecology & Hydrology, Huntingdon, 2004.
[60] M.O. Hill, P.D. Carey, Prediction of yield in the Rothamsted Park Grass Experiment by Ellenberg indicator values, J. Veg. Sci. 8 (1997) 579–586, https://doi.org/10.2307/3237210.
[61] M. Wagner, A. Kahmen, H. Schlumprecht, V. Audorff, J. Perner, N. Buchmann, W. W. Weisser, Prediction of herbage yield in grassland: how well do Ellenberg N-values perform? Appl. Veg. Sci. 10 (2007) 15–24, https://doi.org/10.1111/j.1654-109X.2007.tb00499.x.
[62] Pasture-Fed Livestock Association (PFLA), Certification Standards for Ruminant Livestock. Version 4.0, May 2020. https://www.pastureforlife.org/media/2020/08/PfL-Standards-Update-Version-4.0-FINAL-v2.pdf, 2020 (accessed 08 November 2021).
[63] J. Tsouvalis-Gerber, R. Little, Factors influencing farmer participation in agri-environment schemes (AES) – evidence from the social sciences. Report to Defra. https://figshare.shef.ac.uk/ndownloader/files/21843777, 2019 (accessed 08 November 2021).
[64] C.A. Kennedy, M.W. Brunson, Creating a culture of innovation in ranching: a study of outreach and cooperation in west-central Colorado, Rangelands 29 (2007) 35–40, https://doi.org/10.2111/1551-501X(2007)29 [35:CACOII]2.0.CO;2.
[65] H. Reed, A. Smart, D.E. Clay, M. Ohrtman, S.A. Clay, Mob vs. rotational grazing: impact on forage use and *Artemisia absinthium*, in: R.L. Edvan, E.M. Santos (Eds.), Forage Groups, IntechOpen, London, 2018, pp. 53–70.
[66] D. Ash, P. Toynton, S. Davis, Management of Chalk Grassland on Salisbury Plain Military Training Area. Tilshead, UK: Salisbury Plain Life Project, https://webgate.ec.europa.eu/life/publicWebsite/project/details/1624, not dated (accessed 08 November 2021).
[67] B.A. Woodcock, R.F. Pywell, D.B. Roy, R.J. Rose, D. Bell, Grazing management of calcareous grasslands and its implications for the conservation of beetle communities, Biol. Conserv. 125 (2005) 193–202, https://doi.org/10.1016/j.biocon.2005.03.017.
[68] J.D. Volesky, W.H. Schacht, M.D. Redden, T. Lindsey, J. Johnson, Grazing strategy effects on herbage utilization, production, and animal performance on Nebraska Sandhills meadow, in: A. Iwaasa, H.A. Lardner, M. Chellenberg, W. Willms, K. Larson (Eds.), Proceedings of the 10th International Rangelands Congress: The Future Management of Grazing and Wild Lands in A High-Tech World, The International Rangeland Conference, Saskatoon, 2016, pp. 192–193.
[69] H.E. Beck, N.E. Zimmermann, T.R. McVicar, N. Vergopolan, A. Berg, E.F. Wood, Present and future Köppen-Geiger climate classification maps at 1-km resolution, Sci. Data 5 (2018), 180214, https://doi.org/10.1038/sdata.2018.214.
[70] S. Mayel, M. Jarrah, K. Kuka, How does grassland management affect physical and biochemical properties of temperate grassland soils? A review study, Grass Forage Sci. 76 (2021) 215–244, https://doi.org/10.1111/gfs.12512.
[71] A. Savory, J. Butterfield, Holistic Management: a Commonsense Revolution to Restore Our Environment, Island Press, Washington DC, 2016.