**Title**: Regenerative Rangeland Management farmers in Spain: enthusiastic among a great diversity in farming conditions

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## Abstract

Regenerative Rangeland Management (RRM) is emerging as one of the most promising approaches to achieving sustainability of animal production at economic, social and environmental levels. The current bottleneck in RRM is a slow adoption rate, as the farmers' views are still poorly studied and considered. We conducted individual surveys with 33 Spanish RRM farmers that collected multiple variables regarding general characteristics of farms, productive parameters, rangeland management and opinions around perceptions. We performed associative tests in order to detect the most important drivers of economic profitability and personal satisfaction. Among a wide diversity of farms, we found no features or management types associated with higher profitability, but rather a link to the level of intensification and degree of experience. About 93% of the farmers were mostly satisfied with RRM, even though they face difficulties – highlighting bureaucratic ones. To overcome such hurdles, we encourage improving the dialogue between farmers, researchers and institutions. This is the first state-level study on RRM in Spain, and one of the first analyses collecting farmers' perceptions on this topic.

**Keywords:** Animal productivity, Livestock grazing, Adaptive management, Inputs, Socio-ecological systems, Sustainable food systems.

## 1. Introduction

Within the food systems debate, livestock management is invariably receiving most attention, given its close and broad links with environmental impacts (Gerber et al., 2013). Increasing demand for animal products is translated into important pressures on the food supply chain (Godfray et al., 2010). A large amount of anthropogenic GHG emissions (14.5%) are attributed to livestock farming (Gerber et al., 2013) and current livestock production systems are considered to trigger land degradation, air and water pollution, and biodiversity loss (Steinfeld et al., 2009). Such impacts backlash on this system by increasing competition for resources, animal diseases, thermal stress and, once more, biodiversity loss (Rojas-Downing et al., 2017). This is a general trend of the global livestock system, happening in the overwhelmingly industrial sector of most high-income countries, but also in low-income ones where it is undergoing industrialization processes (del Prado et al., 2021; Molina-Flores et al., 2020).

In Spain, grazing systems have traditionally been very relevant (Manzano & Casas, 2010; San Miguel et al., 2017). Beyond the valuable animal products that grazing systems used to produce from low-value resources (Mottet et al., 2017), rangelands are important providers of ecosystem services (Schils et al., 2022) and social well-being (van den Pol-van Dasselaar et al., 2018). intensification, coupled with rural abandonment, have been the main drivers of rangeland management in the last decades (Pulido-Fernández et al., 2018). These drivers add an important pressure, leading to higher dependence on inputs like feed or fossil fuels in both the global and the Spanish livestock systems (Bajan et al., 2021; Gaspar et al., 2009; Lassaletta et al., 2016; Wang et al., 2018). Such dependence makes it difficult to reach a sustainable biochemical or energetical balance (Guzmán & González de Molina, 2015; Mogollón et al., 2018). Producers must cope with the double challenge of responding to increased resource needs, like land, water and energy needs, while reaching sustainability (Godfray et al., 2010).

To face such challenges, in the last century there has been a worldwide interest in optimized rangeland management that can have a net beneficial effect. Regenerative Rangeland Management (RRM) or adaptive managements, mimicking wild herbivory dynamics through continuous mobility, have been prominent in rangeland research (di Virgilio et al., 2019; Savory and Butterfield, 2016). There are plenty of variations around the biophysical basis of RRM (di Virgilio et al., 2019): Holistic Planned Grazing, High-Intensity Low-Frequency, Cell Grazing, Short Duration Grazing, Adapted Multi-Paddock Grazing... RRM is considered to be triple bottom line technique (Gosnell et al., 2020b), i.e., it is supposed to deliver positive impacts along social, economic and environmental dimensions. Despite the ongoing debate on different RRM variants, there is considerable consensus on the usefulness of management types that include an adaptive framework (di Virgilio et al., 2019; Mann and Sherren, 2018).

The first element of RRM is mobility, particularly relevant in Spain and other arid, rugged, cold and swampy areas worldwide for tracing temporarily available resources (FAO, 2020; Manzano and Casas, 2010). Hurdles to pastoral mobility and ensuing sedentarization lower the productivity of grazing livestock (Manzano et al., 2020; Scoones, 1995). When compared to the industrial model, mobile grazing is less profitable in immediate economic terms, due to higher manpower needs and current hurdles for commercialization but environmentally rewarding, due to considerably less dependence on resources, e.g., fossil energy and water and comparable levels of GHG emissions (Casas Nogales and Manzano, 2010; Pardo et al. 2023).

Mobility hence needs adaptability to be beneficial. For example, planned or strict mobility is not effective because the climatic regime is highly variable in most rangelands of the world, needing appropriate adaptive practices for its optimization (Briske et al., 2008; Hawkins et al. 2022) With a focus on long-term objectives, monitoring, analysis, and constant improvement, RRM aims to adapt to present circumstances (Teague & Kreuter, 2020). It allows adjusting the stocking rate to the available ecological opportunities: increasing animal density when the system allows for it and decreasing it in stressful situations such as droughts (Gosnell et al., 2020b). With the resulting economic discontinuity, this may seem counterintuitive, but the capacity of transformation and adaptation is as essential as the economic robustness of farms (Meuwissen et al., 2019; Roe et al. 1998). Other adaptive key elements in RRM are grazing duration and frequency, spatial distribution, and grazing selectivity (Grissom & Steffens, 2013). Indicators used in adaptive decision making are probably overlapping with those forged by traditional pastoralists (Sharifian et al., 2023), and the use of local breeds is also a valuable strategy in both (Ligda & Casabianca, 2013).

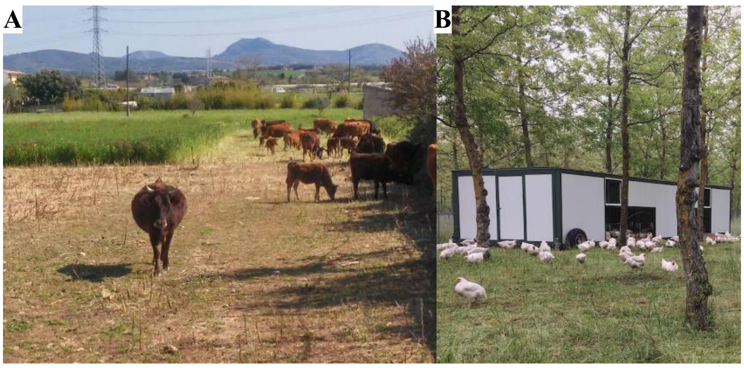


**Figure 1.** Examples of Spanish RRM farms. A) RRM using cattle in Girona. B) Grazing of chicken in adaptive silvopastoralism.

With many influencing variables, the complexity of grazing systems further confounds the choice of the most appropriate management (Sharifian et al., 2023). RRM demands ecological knowledge at all levels, demanding effort, know-how and will, which are not always available (Gosnell et al., 2020a; Teague et al., 2013). Expansion of RRM is therefore not easy to achieve, and adoption rate is still slow in Spain (Figure 1). Moreover, the diversity in management required by the necessary adaptability can complicate the identification of RRM itself (Mann & Sherren, 2018). It has therefore been claimed that wide management variables must be considered and compared, such as livestock type, grazing and rest periods, or time after the onset of this management type (di Virgilio et al., 2019).

In addition, environmental topics predominate in RRM research e.g., carbon fluxes, and socio-economic studies are scarce (di Virgilio et al., 2019). Climate change mitigation or adaptation seems, however, a secondary incentive for ranchers to implement RRM (Gosnell et al., 2020a). RRM research requires a socio-ecologic approach that also addresses the concerns of farmers (Gosnell et al., 2020a; Sherren et al., 2022). To progress in the knowledge of grazing systems, it is also necessary to enlarge the data currently available at a broader scale, by collecting experimental information on management at all levels (Manzano et al., 2021; Teague et al., 2016).

Responding to such needs, we characterised the main features of RRM in Spain as of 2021 through a series of surveys with farmers. We collected diverse farm information and personal thoughts. We analysed the relation of economic aspects with farm features and management decisions . Our main objectives were to identify key parameters for level of success and to delve into the point of view of current practitioners.

## 2. Materials and Methods

### 2.1 Survey description

The survey comprised 5 sections: (i) "Characterization of the farm": collecting characteristics external to the animal management: identification data, product commercialization, farm area, input consumption and economic data, (ii) "Production": asking about the identification of the animals: productive and reproductive parameters, (iii) "Supplementary feeding": characterizing all feed not directly grazed: on the one hand, the farm's crops and forages, and on the other, purchased ones, (iv) "Animal management": checking on parameters related to directed grazing: animal movement, plot design, grazing time and pasture recovery time and (v) "Pasture management": asking for techniques not related to animal management, such as irrigation, grass re-seeding, and any other specified by the farmers. Additionally, we asked three open questions for the analysis of personal perceptions of RRM.

A preliminary version was reviewed by BC3 researchers and by staff from the Iberian Regenerative Agriculture Association and was tested with a first farmer who suggested adaptations of the survey, according to his day-to-day reality. The format of the responses was dependent on the format of the questions: quantifiable questions required either continuous values (economic or productive data), or discrete values (number of animals, or year starting RRM), while qualitative questions were also asked for topics that could not be measured (commercialization, breeds or perceptions). The detailed survey template is included in Supplementary Material 1.

### 2.2 Participants

47 Spanish practitioners were surveyed, representing 50% of Spanish provinces (25 of 50; Supplementary Figure 2.1). Participants were contacted through the mailing list of the Iberian Regenerative Agriculture Association ("Asociación de Agricultura Regenerativa Ibérica"). In this list there were farmers that were not affiliated to the association. Other external RRM practitioners were invited to take part in the survey through direct farmer-to-farmer contact.

The surveys were conducted by phone between February 21 and April 7, 2021, lasting between 40 and 90 minutes. We later excluded from the analysis those farmers who earned less than 5,000€ per year, as they were considered not to derive a significant portion of their income from RRM livestock, as well as those who had had RRM for less than 2 years, due to the distortion that immature farms could bring in. The final sample analysed was thus 33 farms.

The survey was conducted as a conversation to achieve homogeneity and comparability of the answers. However, it was not possible to prevent many cases of unanswered questions. This was especially the case for highly variable data, such as plot resting time or electricity and water consumption, even within the farm.

### 2.3 Data treatment

We filtered, transformed and grouped the information, to reduce the number of variables without losing their value. For example, open-ended qualitative questions were transformed into limited classes. To calculate the expenses, an economic conversion value was allocated to each input, described in Supplementary Table 2.1.

8 farms declared to have insignificant electricity expenses and 1 declared insignificant fuels input. As insignificant consumption must be distinguished from no expense, we assigned a value of 50€/year for each of these inputs. For the case of 4 further energetically self-sufficient farms, we assigned a value of 25€/year. The installation of renewable energy sources is considered an investment and is not included in the analysis, but some farmers declared further energy-related expenses due to problems in infrastructures, such as deteriorating cables or thefts. Feed was split into forages and compound feed, according to the criteria of the Spanish Ministry of Agriculture (MAPA, 2021). Compound feed was assumed to be considered an equal mixture of corn and soy flour.

Regarding statistical analyses, tests and sample sizes as well as additional information on the collected variables are available at Supplementary Table 2.2. We chose annual net profits as a dependent variable, excluding subsidies or investment expenses, to compare the farms under the same conditions. Subsidies conform around 30,1 ± 23.8% (mean ± standard deviation-SD) of annual earnings. With such variation, subsidies can distort the real benefits, as they depend on factors chosen by the public administration system applying criteria that are in constant change (age of the manager, ecological certification, other activities besides grazing…). Profits were measured in €/year (sampling year was 2020), with 26 farms providing this information. Only ruminant farms were included in this analysis, due to their comparable use of the forage and other resources such as inputs. For data protection reasons, we have omitted all absolute data about the economic benefits of farms. Only comparisons between farms are shown. Quantitative variables were tested against economic profits using Pearson's correlations. Regarding the qualitative characteristics, differences for binomial variables were tested with a Student's t-test for comparison of means, while variables with more than two classes were analysed using a one-way ANOVA. Once the necessary parametric assumptions were verified, statistical tests were carried out in R (version 4.0.3).

Three open-ended questions were related to the subjective experience of the farmers along this management: appreciable changes since the implementation of RRM; difficulties in management and satisfaction so far with RRM. Answers were transformed into classes. To know if experience impacts on the experience of farmers, we also performed a comparison test of the mean time since the implementation of RRM of those who stated the changes and difficulties and those who did not. We must acknowledge that surveyed farms belonging to the mailing list of the Iberian Regenerative Agriculture Association may be an unquantifiable bias regarding the perception of this type management, even though not necessarily was there a relation between farmers and the association.

In light of the results, we added some more analyses to explain the characteristics and relations observed. Firstly, we performed a correlation matrix among some parameters we considered strategic: total livestock abundance, rangeland area, total livestock density, profits, profitability and intensity of feed expenses. We then compared the sampled total livestock abundances and rangeland areas with those from literature on conventional rangeland management in Spain (Batalla, 2015; Díaz-Gaona et al., 2019; Escribano et al., 2016; Lavín et al., 2016; Pardos et al., 2008; Serrano Martínez et al., 2004; Toro-Mujica et al., 2011). This was done to identify features of RRM that could be characteristic and therefore, explanatory of the behaviour of the farmers.

## 3. Results

### 3.1 Characterization of RRM farms

Surveyed farms were very diverse despite their convergence on fast, adaptative grazing followed by long recovery periods – in line with the definition of RRM. This diversity was remarkably high in variables such as the size of the farms, with mean and Standard Deviation (SD) of 107.7 ± 127.7 ha of rangeland area, or 176.1 ± 221.4 ha when considering the total farm area (including other land uses such as crops). Similarly, the time since the adoption of RRM was very variable (6.5 ± 5.8 years). The type of pasture was also diverse, with a predominance of meadows (present in 52% of farms), sparse woodland (30%) and *dehesas* (15%).

Table 1 shows some characteristics of the animal species on the farms. Cattle and sheep were the most common ones, with a significant presence of local breeds for the case of sheep, and less for cattle. Herd size, measured as the number of adult females, was also highly variable: a higher SD than the mean for the case of cows and sheep suggests complexity within Spanish RRM farms.

**Table 1:** Summary of the characteristics of the main grazing livestock species. Adult females are those older than 12 months. The number of sold calves has been estimated only among those that sell.

| | Cattle | Sheep | Goat | Chicken |
|---|---|---|---|---|
| Number of farms | 18 | 13 | 3 | 8 |
| Farms selling meat | 13 | 11 | 2 | 4 |
| Farms selling milk / eggs | 4 | 1 | 1 | 3 |
| Local breeds (% farms) | 11% | 69% | 33% | 13% |
| Endangered breeds (% farms) | 0% | 8% | 0% | 13% |
| Adult weight (kg) | 524 ± 111 | 53 ± 8 | 55 ± 14 | |
| Adult females (mean + SD) | 54 ± 45 | 321 ± 301 | 114 ± 12 | |
| Annually sold calves | 21 ± 15 | 287 ± 314 | 6 ± 0.0 | 2853 ± 4917 |

Similarly, for the rest variables collected (Supplementary Table 2.3), SD was often larger than the mean, namely for daily grazing density, grazing and recovery time, or paddock and herd size. In addition, a minority of big farms disproportionately increased mean values, compared to median values.

There are also differences among the binomial variables. For example, 60.6% of those surveyed produced their own feed, compared to 39.4% who did not. Up to 53.1% of participants did some kind of re-seeding, especially grass and legumes. Most commonly, both plant families were combined. More than half of the farms doing re-seeding seems a high value for the context of Spanish farmers where such practice is less common (Javier García Lacal, personal communication).

## 3.2 Impact of different parameters and management on economics

Except for inputs, the economic net profit of the farms showed no significant relationship with the different farm variables (Table 2), i.e. stocking density, grazing time, the recovery time of the pasture, paddock size, herd number and size, or the annual number of grazing turns per paddock. Nor were there when analysing decisions other than grazing management: own fodder production, pasture species diversity, the use of local breeds, or the diversity of income sources – not influencing the profits of the farms. Surprisingly, animal density was more related to economic profits than the total livestock abundance, which was not an important parameter for predicting economic performance. But farm profitability, measured in terms of € $LSU^{-1} year^{-1}$ and € $ha^{-1}$ $year^{-1}$, was correlated with a few variables. Among animal and farm management options, only forage productivity was moderately correlated with profitability per area, which could be related to the economic boost by the agronomic land use. Time since RRM adoption seems to be one of the most important variables correlated with profitability in general. Productivity seems to be enhanced by farm maturation, even if all farms analysed had been at RRM already for more than 2 years. A higher livestock density (more intensive farms) was correlated with profitability per area, but not profitability per livestock biomass. This means that animal density increases profitability due to higher animal stocks, but not due to an increase in productivity. Previous land use also seems relevant, with higher profitability per livestock biomass unit for the case of previous pastoral land use, while agro-pastoral having lower profitability. This could be attributed to previous loss of nutrients due to plowing, but the sample size for different land uses was not large enough to prove it.

**Table 2.** Statistical tests on three economic variables of farms (profits, profitability per animal abundance and profitability per area), based on different parameters of management, general characteristics and inputs. Statistical significance: ns, not significant; *, significant at 0.05 level; **, significant at 0.025 level; ***, significant at 0.01 level. Tests and sample sizes as well as definitions on the collected variables are available in Supplementary Table 2.2.

| | Profits (€*yr$^{-1}$) | | | Profitability (€*LSU$^{-1}$*year$^{-1}$) | | | Profitability (€*ha$^{-1}$*year$^{-1}$) | | |
|---|---|---|---|---|---|---|---|---|---|
| | R² | p | Sig. | R² | p | Sig. | R² | p | Sig. |
| **Animal management** | | | | | | | | | |
| Daily grazing density | 0.128 | 0.623 | ns | 0.116 | 0.657 | ns | 0.083 | 0.753 | ns |
| Grazing time | 0.025 | 0.923 | ns | -0.160 | 0.540 | ns | -0.108 | 0.681 | ns |
| Recovery time | 0.227 | 0.502 | ns | 0.577 | 0.104 | ns | 0.222 | 0.565 | ns |
| Paddock size | 0.088 | 0.705 | ns | 0.000 | 0.999 | ns | -0.052 | 0.833 | ns |
| Herd number | 0.191 | 0.394 | ns | -0.072 | 0.755 | ns | 0.181 | 0.432 | ns |
| Paddock format | - | 0.164 | ns | - | 0.168 | ns | - | 0.080 | ns |
| Herd size | 0.169 | 0.451 | ns | -0.107 | 0.645 | ns | -0.016 | 0.945 | ns |
| Grazing turns | 0.231 | 0.341 | ns | 0.061 | 0.817 | ns | 0.297 | 0.247 | ns |
| **Farm management** | | | | | | | | | |
| Forage | - | 0.531 | ns | - | 0.692 | ns | - | 0.987 | ns |
| Forage production | 0.336 | 0.343 | ns | 0.342 | 0.368 | ns | 0.671 | 0.048 | * |
| Animal diversity | -0.085 | 0.699 | ns | -0.137 | 0.554 | ns | -0.165 | 0.474 | ns |
| Income diversity | -0.025 | 0.922 | ns | -0.028 | 0.916 | ns | -0.263 | 0.308 | ns |
| Re-seeding | - | 0.482 | ns | - | 0.770 | ns | - | 0.488 | ns |
| Native breeds | - | 0.621 | ns | - | 0.548 | ns | - | 0.163 | ns |
| **Other characteristics** | | | | | | | | | |
| Total livestock abundance | 0.334 | 0.140 | ns | -0.112 | 0.630 | ns | 0.193 | 0.403 | ns |
| Total livestock density | 0.426 | 0.054 | ns | -0.032 | 0.890 | ns | 0.465 | 0.034 | * |
| Time | 0.391 | 0.072 | ns | 0.467 | 0.038 | * | 0.576 | 0.008 | *** |
| Rangeland area | -0.200 | 0.386 | ns | -0.060 | 0.796 | ns | -0.242 | 0.290 | ns |
| Previous land use | - | 0.242 | ns | - | 0.017 | ** | - | 0.072 | ns |
| **Inputs** | | | | | | | | | |
| Water | 0.521 | 0.123 | ns | 0.510 | 0.160 | ns | 0.458 | 0.215 | ns |
| Electricity | 0.580 | 0.015 | ** | 0.339 | 0.217 | ns | 0.530 | 0.042 | * |
| Fuel | 0.138 | 0.542 | ns | -0.001 | 0.998 | ns | 0.073 | 0.759 | ns |
| Feed | 0.651 | 0.009 | *** | 0.537 | 0.048 | * | 0.692 | 0.006 | *** |

Some types of inputs could be a key factor for predicting both profits and profitability. In general, farms with the highest consumption rates of electricity and feed presented higher benefits. This is important, considering that feed is the most relevant input in terms of expenses, even if the variability among farms is rather large (Supplementary Figure 2.2). However, these correlations are based on the yearly expenses from inputs. When applying an adjustment to both variables based on the animal density and area (Table 3), the correlation with electricity waned to insignificance, while for water consumption, a strong correlation appeared. Econometrics on water may not be solid because non-monetized water sources, such as wells, lakes or rainwater collection, were not included. Similarly, electricity consumption is not represented in 24% of farms with own self-supply. Fuel consumption did not show any correlation neither with profits nor with profitability. Feed was thus the most important input as a profitability predictor. It seems that productivity is influenced by parameters such as intensification and the quantity of consumed feed (forage production was also an indicator of profitability per area). Thus, more productive farms generate more income per production unit. This relation was weaker (but still significant) between the feed expense intensity and net benefits. Overall, it seems that, except feed, inputs are not clearly related to the economic profit of farms.

**Table 3.** Correlations tests between inputs and net profits. Statistical significance: ns, not significant; *, significant at 0.05 level; **, significant at 0.025 level; ***, significant at 0.01 level.

| | | Profits (€·yr$^{-1}$) | | | Profitability (€·LSU$^{-1}$·ha$^{-1}$·year$^{-1}$) | | |
|---|---|---|---|---|---|---|---|
| | | $R^2$ | p | Sig. | $R^2$ | p | Sig. |
| | **Inputs** | | | | | | |
| Expenses (€·yr$^{-1}$) | Water | 0,5210 | 0,1225 | ns | 0,5575 | 0,1189 | ns |
| | Electricity | 0,5795 | 0,0148 | ** | 0,2890 | 0,2961 | ns |
| | Fuel | 0,1375 | 0,5417 | ns | -0,0787 | 0,7417 | ns |
| | Feed | 0,6512 | 0,0086 | *** | 0,4978 | 0,0701 | ns |
| Expense intensity (€·LSU$^{-1}$·ha$^{-1}$·year$^{-1}$) | Water | 0,1959 | 0,6135 | ns | 0,9077 | 0,0007 | *** |
| | Electricity | 0,1867 | 0,5053 | ns | 0,1685 | 0,5484 | ns |
| | Fuel | -0,0516 | 0,8291 | ns | 0,1797 | 0,4484 | ns |
| | Feed | 0,5867 | 0,0274 | * | 0,5977 | 0,0240 | ** |

We performed correlation analysis to check the interaction of feed with other main features that could be relevant, such as animal density or grazed area (Figure 2). This also shows other relationships that could be relevant to understand farm typologies. Feed expenditure intensity was strongly correlated with animal density ($R^2$= 0.584, p=0.009) and both features were negatively correlated with rangeland area ($R^2$= -0.481, p=0.037 and $R^2$= -0.515, p=0.005, respectively). This shows significant differences in intensification levels among RRM farms, with a somehow uniform gradient between intensive and extensive farms. Meanwhile, the correlation between these expenses and total livestock abundance (LSU) was not significant ($R^2$ = -0.2808, p- value = 0.244), and there was a strong negative correlation between rangeland area and expenses in feed per stocking rate ($R^2$ = -0.4813, p = 0.0369). This suggests that farms with lower options for grazing tend to outsource feed supply.

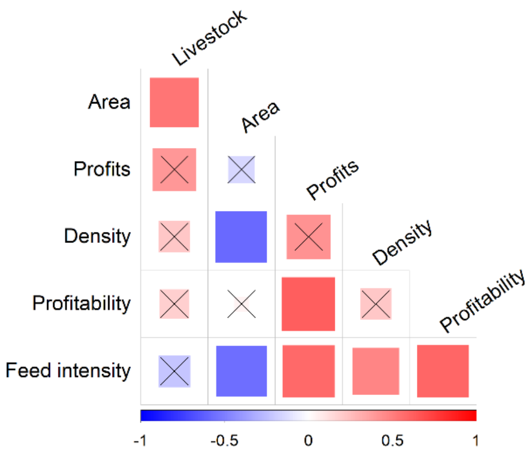


**Figure 2.** Correlations between different parameters: total livestock abundance (LSU), rangeland area (ha), total livestock density (LSU/ha), profits (€*yr$^{-1}$), profitability (€·LSU$^{-1}$·ha$^{-1}$·yr$^{-1}$), and feed expense intensity (€*LSU$^{-1}$*ha$^{-1}$*yr$^{-1}$). Pearson correlation index is expressed as colour and shape size, non-significance at <0.05 level is expressed with a cross.

We also compared RRM farms with conventional grazing-based farms for cattle and small ruminants (sheep and goats) in Spain (Batalla, 2015; Díaz-Gaona et al., 2019; Escribano et al., 2016; Lavín et al., 2016; Pardos et al., 2008; Serrano Martínez et al., 2004; Toro-Mujica et al., 2011). We found that RRM occupies significantly smaller land plots ($W = 254$; $p = 0.014$; Figure 3), in contrast to total livestock abundance, which did not differ ($W = 212$; $p = 0.247$). This shows a higher animal density than conventional grazing-based farms in Spain, even though diversity is large.

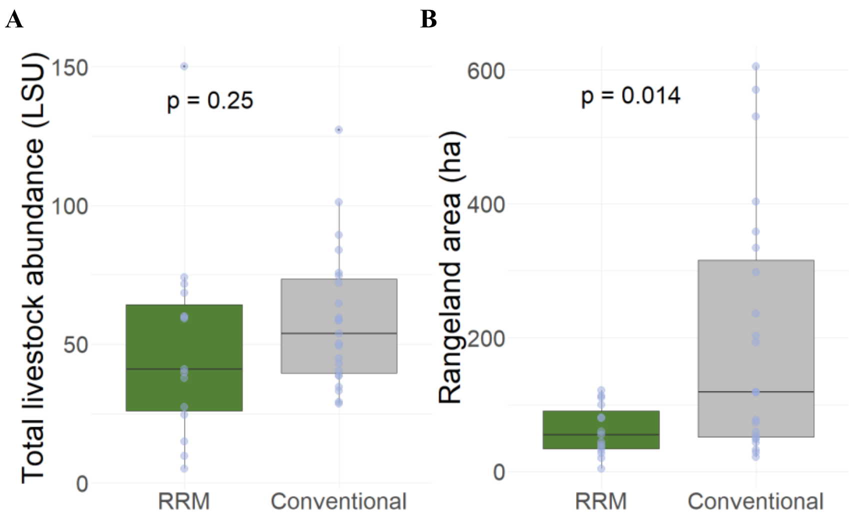


**Figure 3.** Total livestock abundance and rangeland area of the surveyed RRM farms and conventional grazing-based farms from literature, with a Wilcoxon test of means.

### 3.3 Perceptions regarding RRM

A vast majority of farmers (88%) reported positive changes in their farms since the implementation of RRM. Almost two-thirds of the farms (62%) declared more than one improvement. The most reported positive change was perceiving an improvement in primary production, which was mentioned by more than half (51.5%) of the farmers. Here, the emphasis of many ranchers on having reached a permanent cover in areas where it did not exist before stands out, while many others highlighted an improvement of their grass in comparison with nearby rangelands. Improved plant composition and biodiversity (45.5%) were also underlined, with the appearance of new species, a greater presence of legumes and more wildlife activity (especially invertebrates). Perceived changes in soil quality diverged, but were always positive (36.4%): they included increase in soil carbon stock, and less erosion and water runoff. Additionally, one in six farmers (18.2%) mentioned an apparently better condition of the animals, as they showed less selectivity in grazing, or lower levels of stress. Fewer input needs were mentioned by 9.1% of farmers. Finally, two farmers declared less impacts from pests otherwise affecting their region, and a further one mentioned the reduction of an invasive species. However, 12% had not observed major changes, and one (3%) reported lower plant production since the implementation of the management.

Farmers tended to rather highlight the positive aspects than the difficulties experienced, since almost 18% did not report any notable difficulties, compared to 12% who did not report positive changes. Among difficulties, administrative issues and bureaucracy stand out (36,4%). One of the great problems perceived is indeed the current lack of support from the administrations, as the policy framework does not consider the existence of RRM. To be eligible for some subsidies requires, e.g., certain investments such as machinery that are hardly compatible with the RRM view on minimizing inputs. In addition, economic barriers are positioned among the top rank of perceived difficulties (18,2%), showing problems to achieve financial stability, and great pressure to keep cash flow. Regarding the management, the organization of paddocks and fencing were commonly mentioned as difficulties (24.2%), followed by water management and the difficulty to transport it to each plot (15.2%). Problems related to biological agents, such as wildlife and pests, were also important for ranchers (18.2%). Pressure towards discouragement induced by their social environment mentioned by 4 of the farmers (12.1%).

As the time since RRM adoption was an important variable for farm profitability, it may also be a driver for perceptions. This variable was thus compared to the statement and the absence of positive changes and difficulties through U Mann-Whitney tests (Figure 4). Overall, there were no significant differences in the time since for those who stated positive changes and those who did not. This could be expected from a small sample size, but there were some trends that can shed some clarity. In most cases, median farm age was higher among those declaring positive changes, compared to those who did not declare (4 of 5 classes). The only exception was livestock well-being, which seems logical since time for results in livestock behaviour can be shorter than changes in sustainability or econometrics. Similarly, no significance was generally found when comparing statements around difficulties perceived. The only statistically significant difficulty was regarding the design of paddocks, stated solely by young farms. It was also interesting to observe that younger farmers were particularly worried about farm economy.

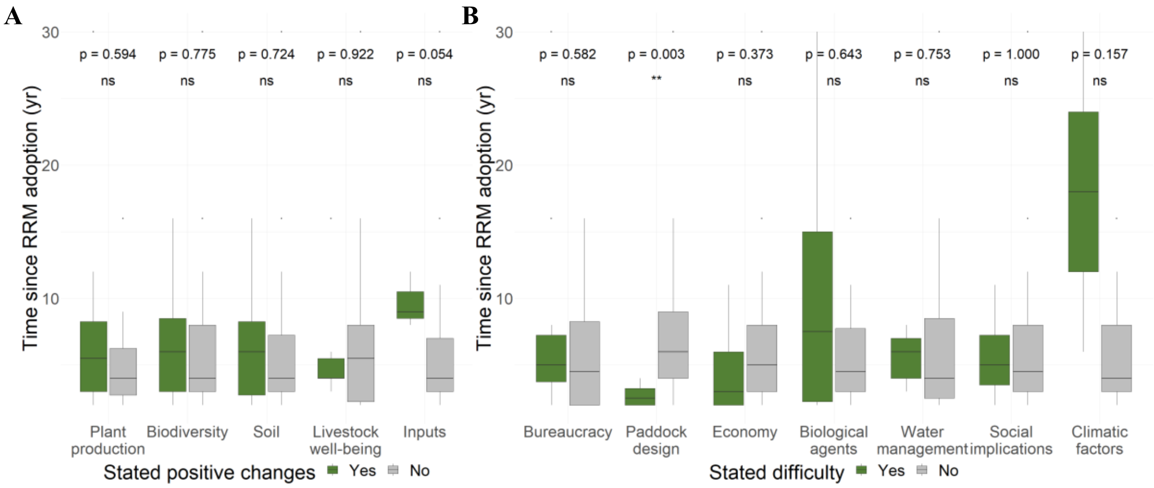


**Figure 4.** Positive changes (A) and difficulties B) stated by farmers. Time since RRM adoption is shown, comparing farmers that did and did not state the positive change or the difficulty. The colour represents whether the farmer has stated, or not, the perception displayed on the x axis. Topics are ordered by the frequency of answers.

Finally, participants gave their points of view about their experience with RRM. The trend towards a positive assessment was remarkable. With 30 respondents, 93.3% of the farmers had positive or very positive opinions, mentioning personal perceptions, which complicates a simple grouping of the answers. Almost two-thirds (60%) appealed to feelings, reporting optimism, social contribution and progress. 26% alluded to learning – mostly as a positive requirement for RRM –, highlighting a greater understanding of ecological dynamics. They also underlined the difficulty of reaching final stability, suggesting that such management requires a deep understanding of all components and their interactions, something that cannot be achieved without exhaustive learning. We did not check whether a relationship with the Association biased reporting satisfaction with the management.

## 4. Discussion

### 4.1 One model, infinite versions

One of the main reflections derived from our study is that the diversity of RRM farms to different settings is large. In light of the results, economic success relies in the ability of each farmer to interpret and respond to their particular bioclimatic and economic opportunities (Briske et al., 2008; Pinheiro, 2004; Teague et al., 2013). The importance of adaptation is reinforced, as sustainability (at all levels) of farms does not depend on simple prescribed management. For example, RRM seems to allow the use of multiple livestock species, which is positive for the multifunctionality of the system (Schils et al., 2022) and, in our analysis, did not show relation with profitability. The use of local breeds didn't lower productivity either, compared to breeds that are supposedly more productive. This is interesting since local breeds, which provide adaptability, genetic diversity and resource optimization, often need to minimize inputs to be economically sustainable, especially in unfavoured areas (Belibasaki et al., 2012; Felius et al., 2015; Ligda & Casabianca, 2013; Ripoll-Bosch et al., 2014). Overall, RRM farmers following similar biophysical bases does not prevent diversity in Spain. This is positive since diversity in farming strategies is encouraged at regional level due to increased resilience (Dumont et al., 2013; Petersen-Rockney et al., 2021).

It seems thus that RRM allows farm diversity under relative equal opportunities. Differences in opportunities can arise from characteristics inherent to the land itself (such as rainfall, soil fertility or evapotranspiration), or social aspects such as access to land (Regulation (EU) 2021/2115; Spratt et al., 2021). Such conditions influence the economic profits and also the level of inputs, especially for those directly related to animal nutrition: water and feed. For example, environmental parameters not considered in this study, such as rainfall and temperature, are essential to explain plant growth., to the point that the greatest limiting factor in semiarid rangelands of most of Spain is usually precipitation (Abdalla et al., 2018; Bailey & Brown, 2011; Briske et al., 2008 Trabucco & Zomer, 2018). Adaptability granted by RRM significantly mitigates the effects of drought in this type of rangelands (Díaz-Solís et al., 2009). That said, and based on the farmers' feedback collected in this study, understanding of the mechanisms that determine the functioning of the pasture can be a very useful tool at the farm level to optimize production, both in grazed systems in general, and in RRM in particular.

Going in depth into the characterization of RRM and livestock systems is a tool to overcome the differences in competitive opportunities that can harm the development of sustainable production systems. It shows parallelisms with the necessity of preserving traditional animal husbandry systems like transhumance. With a similar basis as RRM in terms of adaptability and efficient use of local resources, traditional mobile managements imply well studied positive social and environmental outcomes (Bengtsson et al., 2019; MAGRAMA, 2013; Manzano-Baena & Salguero-Herrera, 2018; Manzano et al., 2021; Pardo et al. 2023; Sayre et al., 2013). Both adaptability and use of local resources are almost lost in the context of industrialization, and traditional management now faces the options to either recover or collapse (Manzano et al., 2021). This is normal, given the difficulties to compete in economic terms with more intensified management, even if optimization of resources is higher (Manzano-Baena & Casas, 2010; Pardo et al., 2023). As RRM brings lots of positive impacts in socioecological terms, if its economic performance is at least similar to conventional management, this is enough to proclaim that its expansion is desirable.

### 4.2 The risk of dependency

Feed was positively correlated to profitability and animal density, showing different levels of dependence on inputs and intensification. Dependence on inputs is highly related to the productive orientation of farms, with gradients between productivity-oriented farms and sustainability-oriented ones. This is common in the context of Spanish grazing systems (Escribano et al., 2016). Some relation between feed and profitability was expectable, as feed is the most relevant input in economic terms in Spanish farms (Supplementary Figure 2.2; Daza, 2011; Escribano, 2014; Mena et al., 2017; Toro-Mujica et al., 2011). Even though intensity in feed expenses can be overall beneficial for the economy of farms, input intensification may not be an optimal strategy for economic sustainability. In fact, among our farms, animal density was neither related to farm profits nor to profitability. Expenditures on inputs like water or feed are not only determined by consumption, but also by their price, which is often conditioned by supply opportunities (OCU, 2020). Intensification can thus pay off when forage is abundant, but it can be risky in periods of scarcity (Irisarri et al., 2019). Dependency on inputs can therefore be risky for financial stability, especially in crises or shock events – increasingly as a consequence of climate change (Dumont et al., 2013; Irisarri et al., 2019). For example, feed prices soared from the year of study (April 2021) to April 2022 in Spain. In one year, the price of complementary feed for cattle and sheep rose by 33.3%, and by 36.8% for goats. Similar numbers are observable for other types of feed (MAPA, 2022). In this context, the studied correlation between feed use and profitability was likely less significant in 2022. Reducing dependency does not imply removing all external feeding but using it as a complement instead of feed basis (Dumont et al., 2013). In conventional grazing systems, inputs are usually overused – especially labour and feed (Gaspar et al., 2009). Here, the mentioned advantage in terms of less dependence on inputs, inherent to RRM (Ferguson et al., 2013; Machmuller et al., 2015; Spratt et al., 2021), shows potential benefits in a scenario of economic and environmental instability (Irisarri et al., 2019; WEF, 2022).

We suggest two complementary ways to reduce input dependence without compromising economic sustainability. The first is to reduce inputs in a way that productivity is not highly affected, i.e. through optimization (Gaspar et al., 2009; McLellan et al., 2018; Mena et al., 2017). Feed can be essential for the economic sustainability of farms, especially in of low-productive areas (Ripoll-Bosch et al., 2014), but it is too commonly overused in Spanish grazing systems (Gaspar et al., 2009). The second way to reduce dependency is by economically compensating productivity loss by other means, e.g., by using a larger rangeland area (Gaspar et al., 2009). In this study, correlations between feed use and profitability were weaker when scale dimensions (especially the managed area) were included. This suggests that better economic sustainability can be achieved by increasing the intake proportion of natural or self-produced forages. Increased rangeland area needs enabling land access (Sayre et al., 2013), which is not easy for new or young and new farmers (Regulation (EU) 2021/2115), explicitly mentioned by 2 of our surveyed farmers. In fact, we observed a large proportion of 'neo-rural' farmers (urban people that have settled in the countryside), and comparing RRM and conventional rangeland management in Spain (Figure 3), it seems that RRM farmers manage proportionally smaller farms. Therefore, improving access to land may be useful to promote RRM (Spratt et al., 2021). Political will and economic incentives seem then necessary – not just for RRM, but for low-input production systems in general (Manzano et al., 2021; Sayre et al., 2013; Steinfeld et al., 2009).

### 4.3 'Excuse me, we need to talk'

The analysis of personal thoughts provided by our study supports the opportunity to expand RRM. Satisfaction among the farmers is evident, and their answers give arguments for its promotion and improvement. The expansion of RRM seems therefore promising in a country like Spain, where environmental compromise and rural well-being are a political priority (MAPA, 2018). Preservation of the adequate livestock systems implies spending fewer resources directly on environmental issues or climate change mitigation (Casas-Nogales & Manzano, 2007; Fan et al., 2019), leaving more economic resources available for the wellbeing of farmers and the promotion of RRM.

The spread of RRM is not an easy task. The perspective of farmers is a crucial part of this planning, despite not being frequently considered (Manzano et al., 2021; Meuwissen et al., 2019; Roncoli et al., 2007). Motivations for farmers to change their management seem to be more personal than externally-driven, and do not have to coincide with scientific and technical concerns (Garrido et al., 2017; Haigh et al., 2019; Kennedy and Brunson, 2007). In this study, the most relevant difficulties for RRM practitioners were not technical ones (excluding plot design or water transportation), but those related to the administrative and financial context. It is thus expectable that improving extrinsic conditions will enhance the recruitment of new practitioners. In order to achieve this, it seems urgent to ease relationships between farmers and institutions. Enhancing communities, collaboration and networks can be very useful as part of this motivation process (Gosnell et al., 2020a; Hodbod et al., 2016; Kennedy & Brunson, 2007; Sayre et al., 2013).

There are strategies to enhance dialogue. A participatory approach can improve relationships between farmers and surrounding agents (Gadzirayi et al., 2007). An interesting strategy is the integration of the figure of the farmer in the understanding of grazed systems. There is actually great potential to obtain information through contact between farmers and authorities, since farmers are themselves a widely underestimated surveillance tool, but perfectly compatible with scientific monitoring (Woods & Ruyle, 2015). For this reason, it will be useful to improve dialogue with farmers, giving a greater voice to their needs and demands. Is it important that farmers take their own decisions to answer to their situation, so to ensure sustainability (Dumont et al 2013), but with a conscious educational basis that allows self-monitoring and analysis (Hodbod et al., 2016). The proposed approach gives the opportunity to enhance cooperation between the scientific community, institutions and farmers as the best way to address a holistic view of the situation, and to identify possibilities for action. In the same way, it is necessary that, through alliances between these three parties, knowledge is formed, captured and disseminated to keep improving the efficiency of livestock production, so that both producers and consumers can make decisions that contribute to sustainability (Gill et al., 2010; Roche et al., 2015).

There are also opportunities for RRM expansion due to climate change, which forces farmers to look for adaptation strategies. It increases climate variability and likelihood of extreme events like droughts or floods (IPCC, 2014), which can push farmers to the wall (Briske et al., 2021). Farmers should therefore move closer to adaptive management of the type of RRM, as it promotes resilience (Gomez-Casanovas et al., 2021; Gosnell et al., 2020a; Hodbod et al., 2016; Machmuller et al., 2015; Roe et al. 1998; Weber & Gokhale, 2011). Climatically harsh events and periods actually do favour switching to adaptive management in order to better cope with future similar events (Coppock, 2011; Haigh et al., 2021; Haigh et al., 2019; McClaran et al., 2015; Saliman & Petersen-Rockney, 2022). Climate change may not be a conscious driver to take such decisions but its consequences make farmers look for new strategies to enhance adaptation (Davidson et al., 2019; Petersen-Rockney, 2022). Considering this, the dialogue with other actors becomes relevant for finding paths to promote the best management practices (Petersen-Rockney et al., 2021). In summary, in a context in which it is essential to promote more sustainable livestock practices, improving cooperation between involved stakeholders is as fundamental as the creation of scientific knowledge itself (Manzano et al., 2021).

## 5. Conclusion

Here we conclude that expansion of RRM is a logical path to achieve sustainability of the animal production system. RRM does not establish specific rules but provides guidelines for understanding the operation of rangeland dynamics, and delegates management decisions to the farmers, based on their experience and perception of the situation. Adaptation allows high levels of diversity, e.g. in terms of species, breeds, or farm size, without undermining economic sustainability. Our analysis reinforces the idea that, among RRM strategies, there are no universally positive or negative practices, and that the economic performance of farms is largely dependent on the ability of farmers to adapt to their own circumstances and their experience. In any case, it shows that inputs, especially feed, are linked to higher productivity rates due to intensification. But other strategies, such as expanding grazed areas, are tools for increasing production without increasing dependence on inputs, which can be risky in the context of climate instability. Despite uniform satisfaction among the farmers, proliferation of RRM is not possible without recovering the value of the farmer figure as part of the ecology of rangelands, as an agent with its owns needs and demands. For this, institutions and the scientific community must intensify dialogue with farmers to promote their well-being, as well as to promote networks to ease relationships and disseminating the required knowledge to recruit new practitioners.

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## 7. Disclosure statement:

The authors report there are no competing interests to declare.

## 8. Data availability statement

The datasets generated during the current study are not publicly available due to privacy of the economic parameters of the farms. A reduced dataset of the farms that accepted to share their data is available from the corresponding author on reasonable request.

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