Deliverable 2.3

Report and maps with main farming systems on PG in Europe

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Dissemination Level

PU	Public	**X**
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

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Summary

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University of Newcastle upon Tyne	UNEW	UK
RSK ADAS Limited	ADAS	UK
The University Court of The University of Aberdeen	UABDN	UK
Mendelova Univerzita V Brne	MENDU	CZ
Magyar Kutatási Hálózat Ökológiai Kutatóközpont	HUN-REN ÖK	HU
Javna Ustanova Univerzitet Crne Gore Podgorica	UOM	ME
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Universita Degli Studi Di Torino	UNITO	IT
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Szkola Glowna Gospodarstwa Wiejskiego	UWA	PL
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1. Introduction

Farming systems (FS) are a result of environmental conditions (e.g. climatic conditions, elevation and soils), historic factors (e.g. inheritance law, cultural aspects), policies and management (conventional, organic; dairy, beef, sheep, pigs, other, mixed; grazed, cut, mixed), and are in many cases closely connected to the specific grassland types in a region. Based on these regional differences, the ability of different FS to deliver ecosystem services (ES) can vary. In some regions, whole farms operate using almost only permanent grasslands (PG) for production, while in other regions, farms partly rely on PG, and partly (for instance in valleys, plains, and better soil conditions) on temporary grasslands in combination with fodder crops or arable crops.

The SUPER-*G* project uses the Eurostat definition of PG, originating from Directive CE 1307/2014, i.e. "any land dominated by grasses or herbaceous forage that can be grazed/mown and has not been included in the crop rotation of a holding for five years or more". However, we are aware of the complication that, for instance, grasslands that have a rotation of seven years grass with one year in arable production fulfil the Eurostat definition for the 6th and 7th years 'in grass', and that on some farms this results in the inclusion of some PGs on land that has grown an arable crop grown within the previous ten years.

Definition: According to the FAO[1] "*a farming system is defined as a population of individual farm systems that have broadly similar resource bases, enterprise patterns, household livelihoods and constraints, and for which similar development strategies and interventions would be appropriate. Depending on the scale of the analysis, a farming system can encompass a few dozen or many millions of households*", so that when "a few dozen […] of households" share a similar proportion of resources (crops, such as PG in our case) a FS can be identified.

A new typology of FS across Europe could help clarify how FS relate to environmental conditions, historic factors, policy, and grassland management. The FS typology proposed in SUPER-*G* characterises different farm types in terms of different levels of management intensity, which directly affect PG and the delivery of associated ES. Additionally, it could be considered as a starting point to assess how farms should be managed to improve productivity, create resilience, optimize farm profitability, and deliver ES for society. Thus, the FS typology could also be of considerable importance for training farmers and farm extension services. The FS typology will also be useful for other tasks and actions in SUPER-*G*, such as grading FS on their ES delivery, defining the main threats for the different FS, adapting policies to specific FS, adapting management practices to FS, and defining agri-environment payments to improve the sustainability of FS.

[1] http://www.fao.org/farmingsystems/description_en.htm

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A farming system (FS) classification can also help to adapt management and policies to set objectives as well as agri-environmental payments to improve sustainability at the farm level. A unitary approach to the farming system, at the European level, based on the knowledge of the different characteristics of farming systems can reveal the impact of possible management changes in response to different challenges.

The main objective of T2.2 was to define the main farming systems in which PG are included in five biogeographic regions (BGR) across Europe through the following activities:

- A literature review based on scientific papers and grey literature produced in the different countries belonging to the five BGR. Literature reviews take advantage of the technical papers produced in national languages included in the project.

- The analysis of technical and administrative information on farm typologies acquired from census and other data from SUPER-*G* partner countries. Administrative databases and reports on farming type (conventional/organic), livestock (dairy/beef/sheep/pigs/other/mixed), cropping and land use were utilised by the review. The information derived from European, national, and regional databases is of particular interest to Eurostat, which lacks regional specific information.

- The analysis of the information (database and maps) concerning PG management and vegetation traits produced at finer scale by T2.1

The specific objective of T2.2 was to characterise the main farming systems managing PG in Europe with a view to assessing how they deliver for a range of ES. The main outcome is the present report, i.e. a summary of main FS on PG in Europe (linked to the grassland typology), resulting in conceptual models of the 'typical' FS on the main PG types in Europe.

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2. Workflow

To classify the European FS based on reliable drivers, we implemented a workflow to explore the different situations that can be found in Europe, to propose a typology or classification system accounting for the main distinctive factors, and to apply the typology to existing datasets retrieved at continental scale.

We:

1. Circulated a questionnaire among the contributors within SUPER-*G* to provide a description of the FS in their region/country, and based on the received descriptions, we assessed the most relevant variables characterising the different FS.

2. Implemented a FS typology, based on the main factors highlighted by the questionnaire and the most important categories used in existing typologies; this was discussed, reprocessed, and approved by the SUPER-*G* consortium.

3. Applied the SUPER-*G* typology to two farm-based datasets, representative of the European situation, retrieved at different scales and with different levels of detail for the provided information.

4. Used this classified data to produce distribution maps and size statistics for the main FS across Europe.

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3. Questionnaire on main FS in Europe

As a preliminary step, we circulated a table to the SUPER-*G* partners involved in Task 2.2. Using the table, an explorative list of the most relevant FS in each country/region was requested from all recipients, based either on scientific/grey literature or on expert knowledge/interviews. The aim of this first survey was to explore the diversity of FS across Europe and to highlight the features that would be useful to differentiate the FS from each other.

We asked the involved partners to describe each FS using the following variables:

- Farming system type - A short, qualifying name for the FS
- Country of the FS
- Geographical area of interest - If the data related to a smaller scale than "country" (e.g. regional, departmental, etc)
- Short description - A short description of the FS, highlighting its general features, especially those not explicit from the following variables
- Farm Accountancy Data Network (FADN) code(s)[2] (if available)
- FADN description[2] (if available)
- Main products retrieved from the FS - e.g. hay, milk, cheese, meat, wool, live animals, agritourism, phytochemicals, etc.
- Biogeographic region of the FS
- FS frequency (in relation to the total number of farms) - the importance of the FS type in the geographical area of interest (widespread; locally frequent; rare; very rare)
- % utilised agricultural area (UAA) as PG - PG (either owned or rented) share on utilised agricultural area (UAA - <25; 25-50; 50-75; >75%)
- Haymaking on PG (Yes or no)
- Silage from PG (Yes or no)
- Grazing on PG (Yes or no)
- Other PG uses (e.g. biomass, phytochemicals, etc)
- PG exploitation period - The approximate start and end dates for PG exploitation (grazing, haymaking, silage, others)
- PG duration - The number of years since the PG has been sown (Short, 5-10; Long, >10)
- PG rotation - If PG were periodically rotated with other crops and the crop(s) with which they were rotated
- Overseeding - If PG were periodically overseeded or reseeded
- Mineral fertilisation on PG: Use of mineral fertilizer (Yes; Usually yes; Usually no; No)
- Organic fertilisation on PG: Use of manure (Yes; Usually yes; Usually no; No
- PG irrigation (Yes or no)

[2] http://ec.europa.eu/agriculture/rica/detailtf_en.cfm?TF=TF8&Version=13185

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- Livestock species and category - The main livestock species (e.g. cattle, sheep, pigs) and category (e.g. dairy, meat, mixed) (more than one allowed)
- Livestock units per hectare (LU/ha) - The approximate number of LU on a single farm (according to the official EU conversion table from livestock heads to LU[3])
- Grazing management - The main applied grazing management (none; continuous extensive = free roaming; rotational; continuous intensive; shepherded)
- Overnight grazing season - In which season animals stay at pasture overnight
- Organic or conventional - If the FS was mainly organic or conventional or both
- References – If the FS was described by any scientific or grey reference or by 'Expert knowledge'
- Other possible management options
- Notes (open ended)

Fifteen countries were involved in completing the questionnaire, with 92 FS types described. This first exploration of European FS showed a high complexity of management systems in several regions. Nonetheless, the descriptive information provided by the contributors highlighted a number of pivotal features useful to characterise and differentiate FS across Europe.

Features that discriminate between PG-based farm types were identified using Multi Correspondence Analysis (MCA). The MCA is an extension of the simple correspondence analysis for summarising and visualising a data table containing more than two categorical variables[4]. It can also be seen as a generalisation of principal component analysis when the variables to be analysed are categorical instead of quantitative (Abdi and Williams 2010[5]). The goal of the analysis was to identify i) the groups of individuals having a similar profile and ii) the associations between variable categories. The analysis was performed in R using FactomineR package (Le et al., 2008[6]). Variables used in the MCA included:

- BGR (Alpine, Atlantic, Boreal, Continental, Mediterranean)
- FS products, classified as crops, bioenergy, live animals, meat, dairy, and wool
- PG exploitation options (i.e. haymaking, silage, and grazing)
- PG agronomic management (i.e. overseeding, mineral fertilisation, manure fertilisation, and irrigation)
- Livestock species (cattle, goats, sheep, horses, pigs, or other)

[3] https://ec.europa.eu/eurostat/statistics-explained/index.php/Glossary:Livestock_unit_%28LSU%29

[4] http://www.sthda.com/english/articles/31-principal-component-methods-in-r-practical-guide/114-mca-multiple-correspondence-analysis-in-r-essentials/

[5] Abdi, Hervé, and Lynne J. Williams. 2010. “Principal Component Analysis.” John Wiley and Sons, Inc. WIREs Comp Stat 2: 433–59..

[6] Le S., Josse J. Husson F. (2008). FactoMineR: An R Package for Multivariate Analysis. Journal of Statistical Software, 25, 1-18.

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- PG share on total farm as a percentage of UAA (using the following categories: <25%, 25-50%, 50-75%, and >75%)

The data analysis could have been carried out using other methods such as cluster analysis, classification and regression tree analysis and canonical correspondence analysis. Each of these methods has relative strengths and weaknesses, but we chose MCA due to the categorical nature of the data. MCA is designed to analyse datasets that include both continuous and categorical variables.

The outcomes from the multivariate analysis are presented in Figures 1 and 2. Ellipses representing the confidence intervals of the distributions show a good cohesion of FS around centroids when plotted by BGR, but also a high degree of overlap (Figure 1). Overlaps between BGR and between countries confirmed the need for a harmonised farm typology across Europe. Farm products, PG exploitation and PG management were the main variables affecting farm characterisation, as highlighted by the percentage contribution of these variables on dimension one (Figure 2). In particular, the main drivers were the absence of cattle (A_cattle_no), and consequently the absence of dairy products (P_dairy_no), main agronomic management options (M_overseeding, M_mineral_fert, M_manure_fert) and cutting for silage (U_silage). Conversely, the proportion of the farm area occupied by PG had limited power to separate FS types.

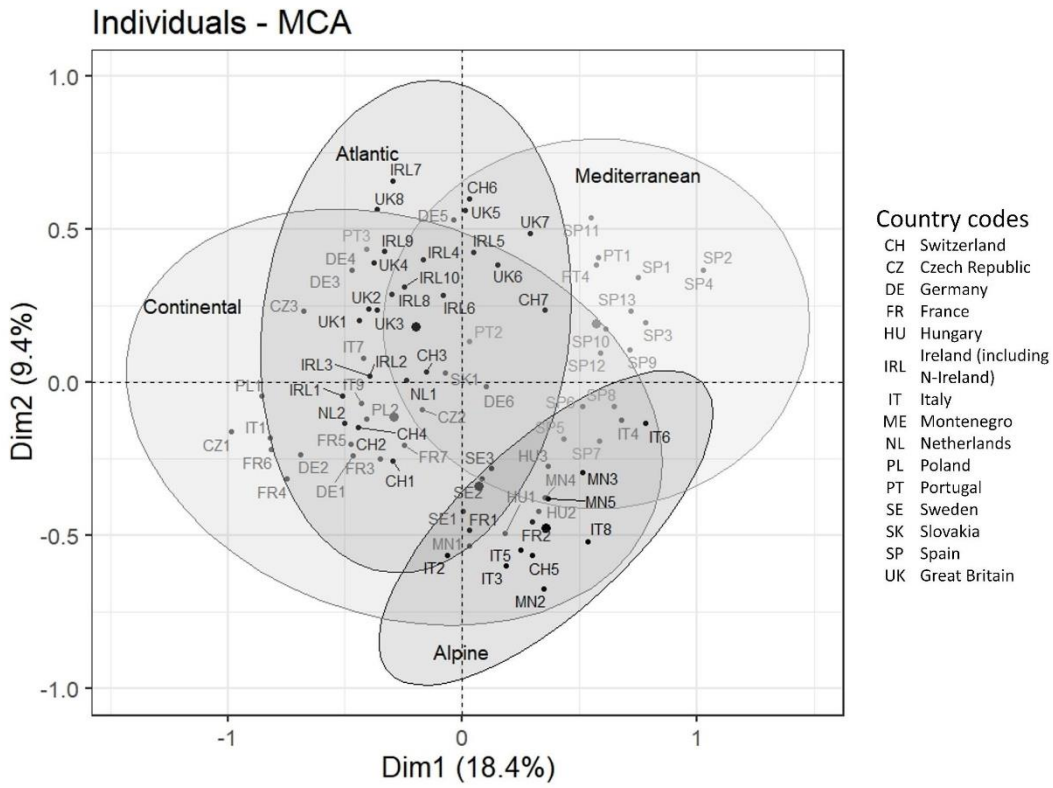

Figure 1: Biplot of all farming systems showing the first two MCA dimensions (the explained variance is reported in brackets). The Boreal BGR has been excluded due to the small number of FS. Numbers after country codes indicate different farming systems.

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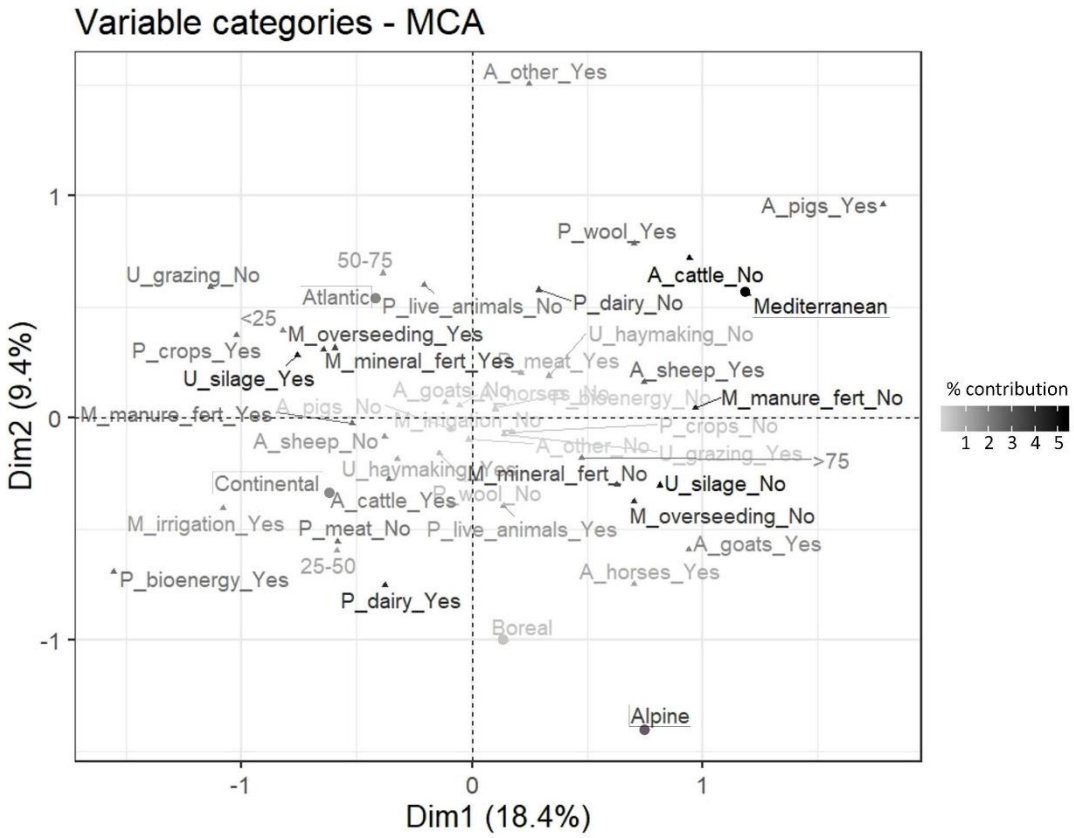

Figure 2: Biplot of the variables, including BGR identified by dots, using the first two MCA-dimensions (the explained variance is reported in brackets). Grey shades indicate different percentages of contribution of each variable to Dimension 1.

Generally, the variance explained by an MCA is relatively low, since it depends on the mean, which in the case of categorical data is simply a proportion. So the total variance explained by the above analysis can be regarded as a satisfactory outcome. Nonetheless, it is important to note that not all the possible variables accounting for the fitness of the model could be included in this analysis. The purpose of this multivariate analysis was to perform an initial screening of the collected information in order to provide a preliminary description of the farming systems.

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4. Proposed FS typology

The aim of our typology is to describe each FS by considering the relationships between each FS and the PG included within it. The resulting typology could thus be used to address management options, innovations, policies, etc. Therefore, the different FS types should be set up primarily to capture how much each FS is connected to its PG in terms of management intensity and type, and the importance of PG in the respective FS.

Considering these objectives, and the results from the questionnaire data, we propose a typology based on five levels, where each FS type is defined by a combination of characteristics; one at each level. The five levels are not proposed in order of importance. The options within the five levels are:

1st level: Livestock species and categories

1. Beef cattle
2. Milking cows (dairy)
3. Mixed bovines; i.e. farms with both beef cattle and milking cows
4. Sheep & Goats
5. Mixed ruminants; i.e. farms with bovines (either beef cattle, or milking cows, or both) and sheep & goats
6. Mixed & Others; farms with other livestock species (such as horses or pigs) together or not with bovines, sheep, or goats
7. None

This level considers the main farmed livestock species and categories, i.e. corresponding to the species or category with more than >75% of LU on the farm.

2nd level: Stocking rate on total UAA

1. <0.5 LU/ha
2. 0.5-1 LU/ha
3. 1-2 LU/ha
4. >2 LU/ha

The stocking rate is calculated for every farm as the ratio between LU of ruminants (i.e. bovines, sheep, and goats) and total UAA (ha), and provides information comparable to the main available databases at European scale[7].

[7] https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Agri-environmental_indicator_-_livestock_patterns

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3rd level: PG share on total UAA

1. <10%
2. 10-30%
3. 30-50%
4. 50-70%
5. >70%

The third level focuses on the importance of PG on the farm in terms of its area.

4th level: PG exploitation regime

1. Predominantly grazing; >75% of the total PG area (ha) on the farm is managed through grazing
2. Predominantly cutting; >75% of the total PG area (ha) on the farm is managed through cutting either for haymaking, or for silage, or for fresh fodder
3. Grazing & cutting; includes grazing & cutting regimes on the same PG area and predominantly grazing and predominantly cutting regimes on different PG areas within the same farm, but without one regime exceeding the 75% of managed PG
4. Non-feeding (e.g. biomass for anaerobic digestion) or not relevant (farms with PG rarely used or almost completely unmanaged)

The different exploitation regimes determine contrasting management settings, machineries, farm structures, supply chains, etc. associated with the farm.

5th level: PG forage value at farm scale

1. Very low
2. Low
3. Intermediate
4. High
5. Very high

Each PG within the farm can contribute to forage supply for ruminants. The quantity and quality of the forage produced from each PG type can be synthesised in a single value to characterise each PG, which can then be used to calculate an overall PG forage value at farm scale as the average value of all PG on the farm, weighted on each PG type's share of the total PG area:

$$Farm\ PG\ forage\ value = \frac{\sum_{i=1}^{i=n}(value_i \times area_i)}{Total\ PG\ area}$$

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where $value_i$ and $area_i$ are the forage value and the area of each *i* PG within the farm, respectively, and with PG forage value ranging from 1 (very low) to 5 (very high). The 'Very low' category can support very extensive farming especially by less-demanding livestock (e.g. mountain pastures exploited by sheep), while the 'Very high' one can support more intensive farms with very productive animals (e.g. milking cows at the barn).

Further specific details (such as organic vs. conventional management) could be considered as add-on information for each resulting FS type.

This fifth level of the FS typology is based on the forage value of the PG on a farm, which is related to plant species composition, at least in terms of dominant species. Unfortunately, it has not been possible to take into account the floristic composition of PG or their plant diversity, since data on botanical composition did not exist in the databases we were using, and, to the best of our knowledge, there is currently no dataset at EU scale that links botanical composition to farm types or management intensity.

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5. Applying the FS typology to existing databases

The data collected from the questionnaire offered useful information for further analyses, but they did not provide quantitative and validated records throughout Europe.

FADN databases

To fill the gaps in our questionnaire information, we considered a few different European databases and finally selected the FADN database[8]. The choice was based primarily on the possibility of accessing detailed information at single-farm level, in a 2017 updated version, for all the countries in the European Union (EU28).

The resulting database contains a number of suitable records to describe the FS, such as the share of each agricultural land use and the proportions of livestock species and categories within the farm. Of particular note was that these data were available at NUTS3 level and at European scale, making them particularly relevant to our objectives. Therefore, the original database was structured on the basis of about 1.100 NUTS3 regions belonging to 28 member states. The maps and size statistics presented in this report were derived from this data collected at single farm level.

First, we calculated the total PG area for each farm as the sum of the following FADN classes: i) 'meadows and pastures', ii) 'rough grazing', and iii) 'PG not used' (i.e., abandoned PG). This PG value was used to exclude farms with null values of PG share, i.e. farms without any PG among the land they manage. We applied our SUPER-G typology to this subset, which included 41.926 out of 83.958 farms, located in 1.063 NUTS3 regions. Each farm was assigned to one class at every level of the typology, as described in the previous section. However, for the livestock categories (1st typology level), an explicit value for 'Beef cattle' was not available in the FADN database, while the data referring to 'Dairy cows' accounted only for adult females which had already calved (thus excluding all other bovines, even if ascribable to the dairy herd). All non-dairy cows, thus adult beef cattle and youngstock of both dairy and beef herds, were reported in a pooled class 'Other cattle.' Therefore, a farm was assigned to the milking cows or to the beef cattle class on the basis of a mean proportion of the livestock classes in a typical dairy herd, as reported in Table 1.

8 https://ec.europa.eu/info/food-farming-fisheries/farming/facts-and-figures/farms-farming-and-innovation/structures-and-economics/economics/fadn_en

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Table 1. Proportion of livestock classes within a typical dairy herd.
LU, livestock units; m, month.

	Dairy cows >24m	*Youngstock 12-24m*	*Calves <12m*	Total
% heads	60%	20%	20%	100%
LU/head	1.00	0.75	0.40	-
heads in a sample herd of 100 heads	60	20	20	100
LU in a sample herd of 100 heads	60	15	8	83
% LU	72%	18%	10%	100%

In this typical dairy farm the 75% (i.e. the lower boundary for that class) of the dairy heads (i.e. 72% of the total LU) correspond to a minimum of 54% of the total LU (75% out of 72%). Consequently, whenever more than 54% of the LU in the farm were dairy cows, the farm was assigned to the 'Milking cows' class. The dairy herd was considered to be composed of dairy cows with 18% youngstock and 10% calves, which correspond to 39% of total dairy cows >24m, i.e. (18% + 10%) / 72% = 39%. Therefore, a farm was categorized as 'Beef cattle' when the 'Other cattle' category, from which we excluded the dairy youngstock ascribable to the dairy herd, were more than 75% of the total LU in the farm.

The stocking rate (2nd level) was calculated as the ratio between the total LU of ruminants (i.e., dairy cows, other cattle, sheep, and goats) within each farm and the UAA (ha), while the PG share (3rd level) depicts the percentage of the UAA (ha) occupied by PG (ha).

An alternative approach could have been to map the number of animals (headage) per hectare of each livestock type, as animal type affects grazing behaviour. We considered both methods (heads and LU) and concluded that the advantages of using LU outweighed the disadvantages. LU are widely recognised as the reference unit for livestock management, since they can be compared regardless of the livestock species, category, age, etc. For this reason, LU are commonly used in scientific research and in policy development, and the EC (e.g. Eurostat) encourage their use in research and innovation projects. Also, from a management point of view, using livestock heads may lead to misunderstandings: for instance, a herd of 500 milking cows is quite a big herd, while a flock of 500 sheep is quite small. In the FS typology, predominant livestock type is therefore included as the first level of the typology ("Livestock species and categories").

The information in the 2017 FADN database does not provide any detail on related management measures. Indeed, it was not possible to disentangle mown PG from those subjected to grazing (both management regimes are pooled together within the 'meadows + permanent pastures' variable), while grazed PG are split into two variables (i.e. 'meadows + permanent pastures' and 'rough grazing' variables).

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Therefore, the only class available for the 4th level of SUPER-G typology was the exploitation regime 'Non-feeding or not relevant'.

The characterisation of the forage value of the PG types within the farms (5th level), still needs further exploration and should be assessed based on reliable data. This kind of detailed information is not available in the FADN database, but it could potentially be retrieved from the PG typology developed in SUPER-*G* Task 2.1 once it is connected to the geographical distribution of the FS.

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Table 2. List of FADN variables (FADN code and description) used for the FS typology.

FADN code	Description
NUTS3	Geographic information at NUTS3
SE025	Total Utilized Agricultural Area
CGRSXRG_A	Meadows + permanent pastures (Agricultural Area)
CGRSNOUSESUB_A	Permanent grasslands not used (Agricultural Area)
CRG_A	Rough grazing (Agricultural Area), i.e. permanent grazing with low yield, and normally on poor soils, in mountainous areas, normally not improved by use of fertilizers, cultivation, sowing or drainage, and which are only suitable for extensive grazing
SE080	Total livestock units
SE085	Dairy cows
SE090	Other cattle
SE095	Sheep and goats

SUPER-*G* database

Additionally, a similar approach was used to apply the SUPER-*G* FS typology to another database of individual farm data. This was the dataset of information obtained within the project from Task 3.1, 'Farm Networks'. For this task, a total of 184 farmers belonging to ten different countries were interviewed to assess farm as well as PG management practices and business profitability across Europe. As part of the questionnaire, specific questions were asked to collect all the information needed to classify the farms up to the 4th level of the FS typology. The 5th level (PG forage value at farm scale) could not be assessed since it was only possible to derive a subjective evaluation of PG productivity in the farm interviews.

This dataset was used to explore the variability of the 4th typology level from a small sample of farms distributed across Europe, enabling comparison between farm networks in different BGR and socio-economic conditions.

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6. Maps and size statistics

The use of the FADN database to classify farms according to the FS typology resulted in the production of distribution maps and size statistics for all EU countries (as of 2017). Multivariate analyses were also carried out on both FADN and SUPER-*G* collected data, to produce a multi-level characterization.

Distribution maps

We used the geographical information contained in the FADN database to produce a series of distribution maps for three FS typology levels. Even though the FADN database provided farm data at NUTS3 level, we pooled farm data from different NUTS3 regions within a NUTS2 region whenever they belonged to the same BGR, as many NUTS3 regions had a limited number of farms represented. Therefore, when a NUTS2 region included two or more BGR it was split according to NUTS3 borders, and farm data were pooled at the resulting level. On the other hand, whenever a NUTS2 region included just one BGR or one NUTS3 region, all farm data were considered together at NUTS2 level. Each NUTS3 region was ascribed to the BGR occupying the largest proportion of its area.

The highest resolution database available for our purposes was the FADN database. This repository is derived from single farm interviews and contains a multitude of metrics. Among them, the location of the farm is provided, based on the different scales of NUTS coding: NUTS0 (Country), NUTS1 (e.g. German States, etc), NUTS2 (e.g. Italian Regions, etc), NUTS3 (e.g. French Departments, etc). An additional, finer geographical level (i.e. LAU, local administrative units, meaning municipalities) was not available to project partners due to data protection concerns. Therefore, the finest geographical scale available to the project was the NUTS3 level. Clearly, BGRs do not follow administrative boundaries and frequently fall across NUTS3 regions. As a result, BGRs are not always accurately represented in the FS typology distribution maps. However, BGR information is given as 'Main BGR' in the pop-up descriptor of the regions in the interactive map.

Figure 3 shows a blank map of the NUTS3×BGR aggregation used in further elaborations.

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a)

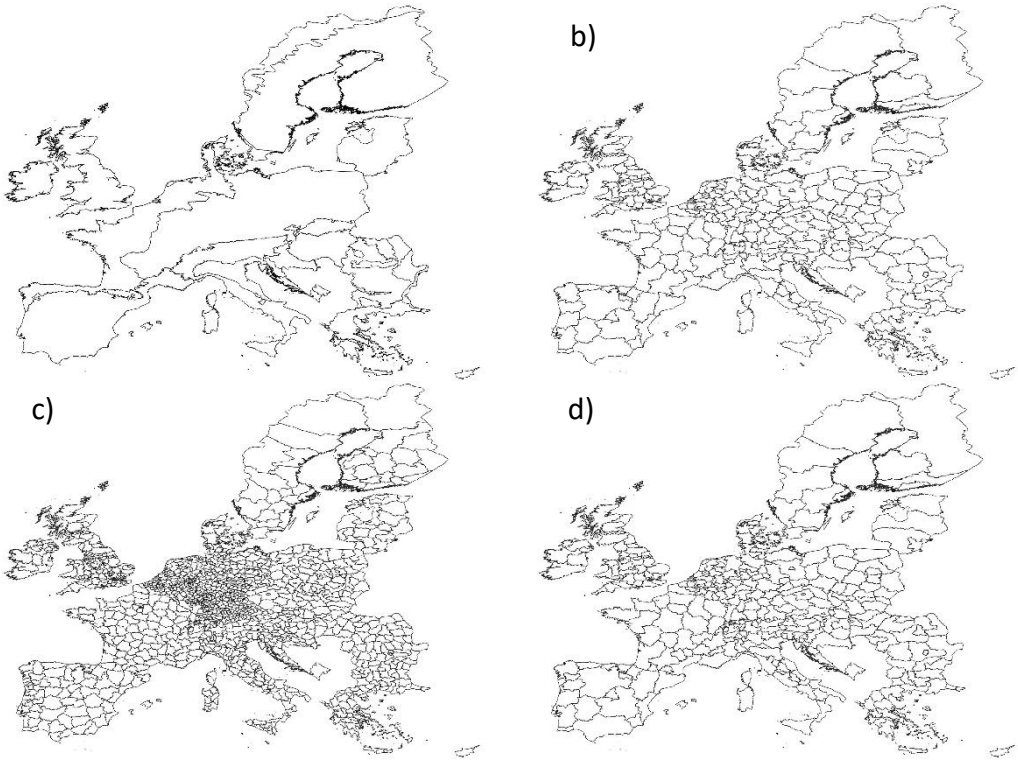

Figure 3. European blank maps of (a) BGR, (b) NUTS2, (c) NUTS3, and (d) NUTS3 aggregation based on differences in BGR within the NUTS2 regions.

1st level: Livestock species and categories

The most frequent livestock categories (corresponding to the 1st level of the SUPER-*G* typology) farmed in each NUTS3×BGR region is presented in Figure 4. According to this map, beef cattle farms dominate in several regions across Europe, with a significant number of Atlantic (especially, in France and Ireland) and some Mediterranean (in Spain) regions, having a predominance of this type of farming. Contrastingly, milking cows are more dominant in the North-Eastern parts of the EU, while 'Sheep and Goats' predominate mainly in the Mediterranean BGR, such as in Southern France, Italy and Spain, and in Greece. 'Mixed and others' and, even more, 'Mixed bovines' predominate in fewer regions across the continent, while farms based on 'Mixed ruminants' (i.e. bovines with sheep and/or goats) are only dominant in Great Britain. Finally, farms without any livestock prevail in several regions within each European BGR.

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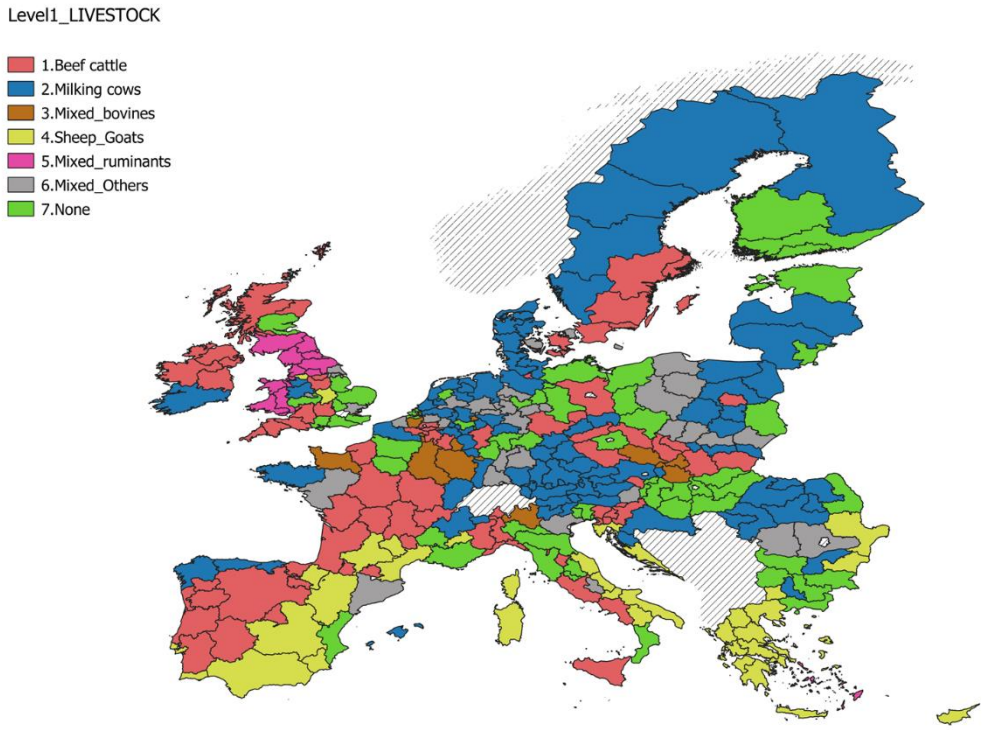

Figure 4. Map of the 1st level of the typology (Livestock categories). The most abundant livestock category (in terms of livestock units) in each NUTS3×BGR region is highlighted by different colours, as reported in the legend.

For a deeper insight into the abundance of farms based on the different livestock categories selected for the 1st level of the FS typology, we produced a second map, in which the greater dominance of farms (within the respective level class) is highlighted by darker colours (Figure 5). This visualisation highlights the regions where a particular farming type predominates. For example, beef cattle farms are particularly dominant in the Limousin and "Eastern and Midland" regions of France and the Republic of Ireland. Similarly, some regions of Austria, northern Spain, and the Netherlands appear particularly active in dairy farming. Where 'Mixed bovines' is the most common farming type, it does not dominate, representing less than 50% of farms with PG. Sheep and goats are highly represented in Greece and Cyprus, while in the UK 'Mixed ruminants' are most dominant in northeast England, and in east Wales. A great spatial variability can be observed for the 'Mixed and others' and 'None' categories, with contrasting regions with low (e.g. Cataluña in Spain and Lubuskie in Poland, respectively) and high (e.g. Münster in Germany and Calabria in Italy, respectively) proportions of represented farms.

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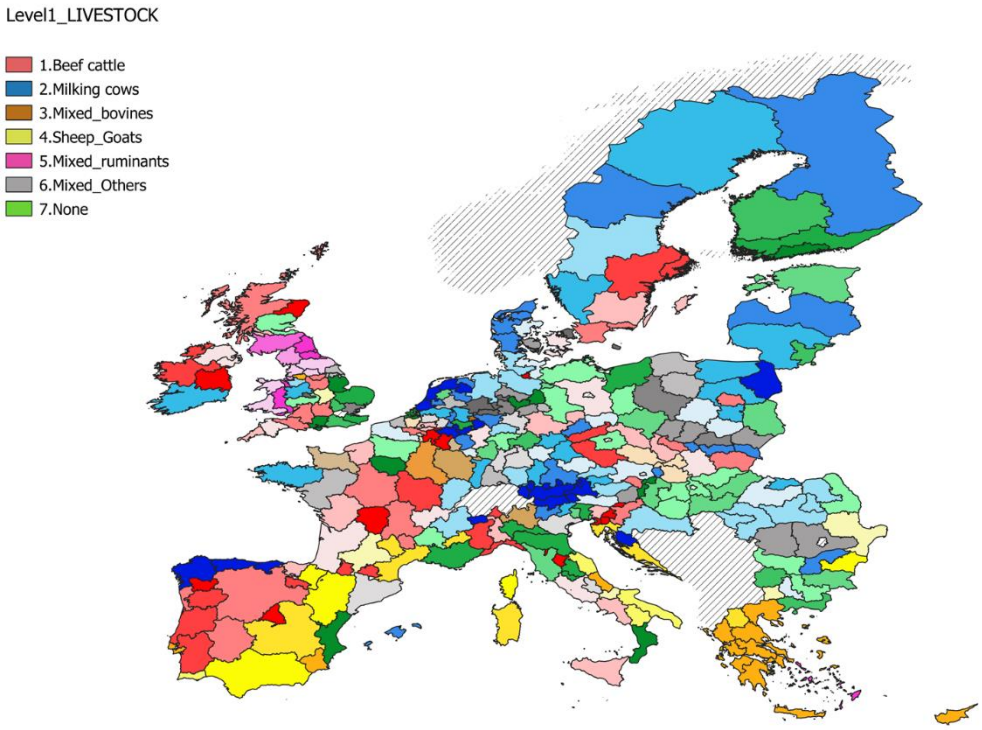

Figure 5. Map of the 1st level of the typology (Livestock categories). The most abundant livestock category (in terms of livestock units) represented in each NUTS3×BGR region is highlighted by different colours, as reported in the legend. Darker colours indicate a greater predominance of a particular livestock category (e.g. dark blue indicates greater dominance of dairy cow farms compared with light blue).

2nd level: Stocking rate on total UAA

The following map shows the dominant on farm stocking rate in each NUTS3×BGR region across Europe (Figure 6). The highest values can be found in Belgium, Bulgaria, Greece, northern Italy, the Netherlands and Spain, while in northeast Europe stocking rates were generally lower. The farm stocking rates do not appear to be clearly related to BGR, but some geographical patterns can be observed, most likely related to livestock species/category, farm size, management intensity, land availability, land tenure, use of other land for grazing (e.g. forest/dehesa) and socio-cultural context. However, it is worth mentioning that the presented stocking rates are based on mean values per region, thus including farms without livestock but with some land and farms with livestock but with very limited land surfaces or some feedlots (e.g. in central Spain and Valencia regions). Further details concerning this issue are explored in the following section of the document.

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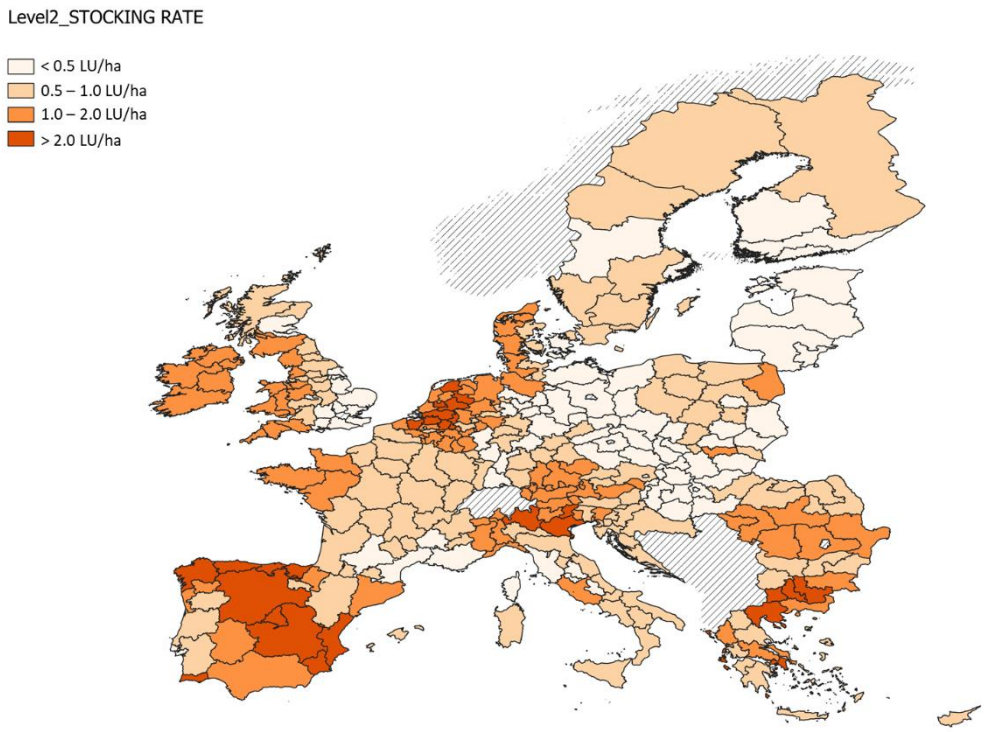

Figure 6. Map of farm-level stocking rates, the 2nd level of the typology (Stocking rate on UAA). The average stocking rate (livestock units/ha) per NUTS3×BGR region is represented.

3rd level: PG share on total UAA

The average proportion of PG within farms varies substantially across Europe (Figure 7). This map highlights those European regions, where farms are more closely related to PG or, in other words, where (permanent) grass-based systems can be found. The western part of the British Isles shows a remarkable concentration of regions with a high farm-level PG share, as well as the Iberian Peninsula and the Eastern Alps. On the other hand, Sweden and Finland are characterized by farms with very low proportions of PG in the UAA.

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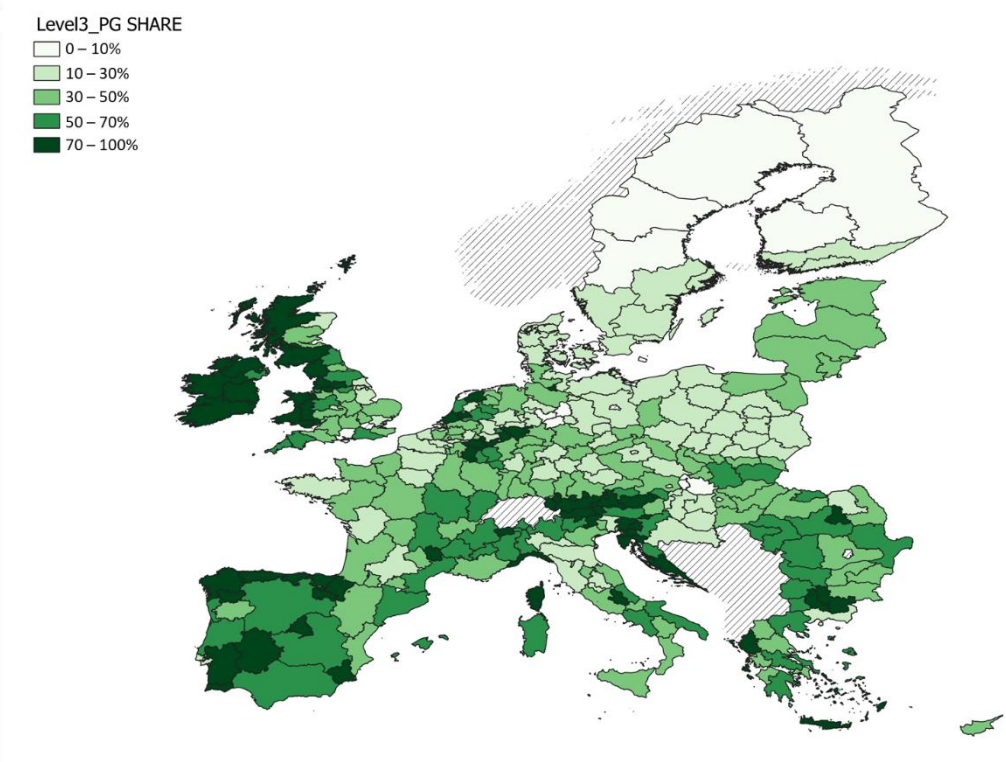

Figure 7. Map of the PG share on UAA, the 3rd level of the FS typology. The average PG share per NUTS3×BGR region is represented.

Multilevel interactive web map

An additional map reporting the most frequent FS type in each NUTS2×BGR region has been produced and published on the web (https://drive.google.com/file/d/1-NMO_EPu0mdNKsayxlD4nUosA2sCHdj2/view?usp=sharing). The online map allows the filtering of FS type, BGR, and country and provides information on the relative abundance of each FS class within each of the three typology levels in every NUTS2×BGR region selected by the user. Different FS types are identified by different colours. A snapshot of this web-based interactive map is shown in Figure 8.

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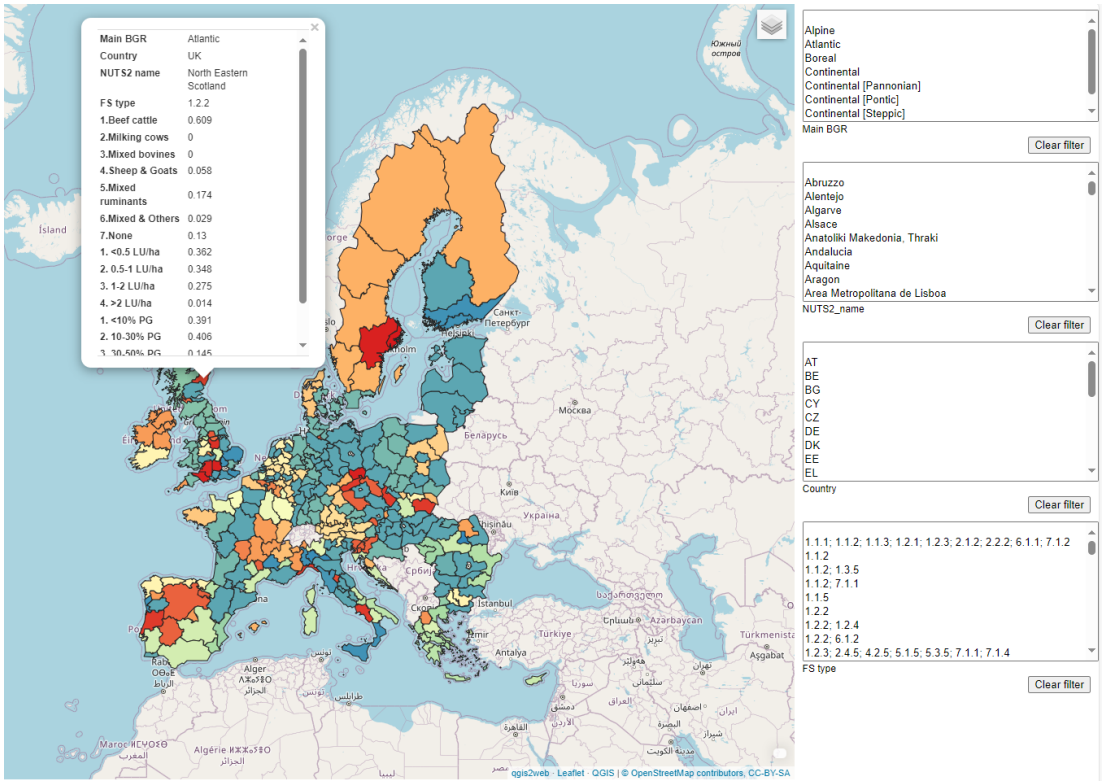

Figure 8. Preview of the interactive map published online, providing the most frequent FS typology class in each NUTS2×BGR region.

Size statistics

We calculated the frequency of occurrence of each class for the three levels of the FS typology (i.e. the percentage of farms in each NUTS3 belonging to each class within each level) within each BGR and in Europe as a whole (Table 2). The results highlight a remarkable variability in FS between the BGR for the three levels and the corresponding classes.

Milking cow farms are predominant in all BGR (except for the Mediterranean), while beef cattle farms represent around 20-25% of the farms in all BGR and in Europe as a whole, being the second most represented FS type. Sheep and goats are not common across Europe, but are frequent in the Mediterranean BGR, where they represent the most common FS class. The abundance of farms with no livestock but with PG are remarkable in all BGR and in Europe, between 15 and 25% of the cases, while the 'Mixed ruminants' and 'Mixed and others' categories are generally less well represented.

Considering stocking rates per UAA, about one third of the farms in the Alpine and Atlantic BGR have very low stocking rates (<0.5 LU/ha), while this class increases in Continental and Mediterranean regions (more than 40%) and becomes the predominant class in the Boreal BGR. However, the relevant abundance of farms with very low stocking rate is partially influenced by the proportion of farms without livestock (level 1 'None' class), which obviously have null stocking rate. Conversely,

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the highest stocking rate class (>2.0 LU/ha) is the least represented in the Alpine, Boreal and Continental BGR and across Europe as a whole, while it is the dominant one only in the Atlantic BGR.

The 'PG share of UAA' was the variable that showed the greatest variation between BGR. As reported above, all farms included in these analyses contain some area of PG. Farms with null values of PG share were excluded. The Alpine, Atlantic, and Mediterranean BGR have the largest proportions of farms in the highest PG share class (>70%), while the other classes are fairly evenly represented. The Atlantic and Continental BGR showed a similar pattern, with decreasing frequencies from the 1st to the 4th class (i.e. approximately 30 to 10 %, respectively) and an increase in the 5th one (up to 35% for the Atlantic and 20% for the Continental), as reported in Table 2. On the other hand, almost half of farms in the Boreal BGR have a very limited proportion of PG, with very few farms having high shares. At European scale, the occurrence of farms in the five PG share classes are fairly evenly distributed, but with a moderate predominance of the '>70%' class accounting for one third of the analysed farms.

Table 2. Abundance of farms (average percentage of farms per NUTS3 Region ± standard error) in each FS typology class across the five BGR and overall in Europe.

	Alpine	Atlantic	Boreal	Continental	Mediterranean	EUROPE
1st Level - Livestock category						
1.Beef cattle	17.2±2.95	23.4±1.79	24.5±3.56	21.7±1.40	23.7±2.90	22.2±0.95
2.Milking cows	42.2±4.16	24.5±2.17	33.3±2.92	24.0±1.34	12.5±1.98	25.8±1.12
3.Mixed bovines	12.0±1.60	9.1±1.02	11.3±1.98	11.5±1.18	2.8±0.50	10.2±0.67
4.Sheep & Goats	9.6±2.27	10.5±1.74	3.3±0.65	8.4±1.33	44.7±4.31	16.2±1.46
5.Mixed ruminants	5.1±0.79	15.3±1.90	1.3±0.21	3.4±0.44	9.0±1.58	7.8±0.74
6.Mixed & others	10.9±1.26	17.9±1.70	7.6±0.97	18.6±1.16	9.7±1.22	15.9±0.77
7.None	15.5±2.44	19.5±2.09	24.8±5.48	20.5±1.29	17.9±2.69	19.5±0.98
2nd Level - Stocking rate						
1. <0.5 LU/ha	32.6±4.24	30.8±2.50	54.4±5.54	43.2±2.01	46.1±3.27	39.4±1.36
2. 0.5-1 LU/ha	25.0±2.66	17.0±1.78	33.8±4.60	22.8±1.26	30.7±2.03	23.2±0.91
3. 1-2 LU/ha	32.0±3.57	27.2±1.47	10.8±2.16	23.9±1.47	16.5±1.53	24.1±0.91
4. >2 LU/ha	17.2±2.52	31.9±2.42	3.3±0.94	12.6±1.05	19.0±3.68	19.6±1.17
3rd Level - PG share						
1. <10%	16.0±2.62	26.2±2.29	47.4±5.79	30.8±1.80	13.6±2.05	26.4±1.22
2. 10-30%	13.1±1.62	21.7±1.44	30.4±3.66	24.4±0.93	18.4±2.55	21.9±0.77
3. 30-50%	13.4±1.50	14.5±0.94	11.3±2.22	16.6±0.78	15.3±2.27	15.2±0.58
4. 50-70%	13.0±1.53	11.1±0.76	6.4±1.60	12.3±1.08	13.9±1.07	12.0±0.55
5. >70%	55.3±4.86	35.5±3.31	13.9±4.49	20.9±1.84	48.8±3.72	33.9±1.67

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Similarly, we calculated the frequency of each FS type resulting from the three-level typology (Figure 8). This exploration allows the visualisation of the variability of the FS types between and within the five BGR and in Europe. In each BGR, some FS types appear more represented than others. In the Alpine one, 2.3.5 (Milking cows, 1-2 LU/ha, >70% PG) is often the most frequent type followed by other types with Milking cows and >70% PG. In the Atlantic BGR 7.1.1 (None, <0.5 LU/ha, <10% PG) is the most common farm, followed by 2.4.5 (Milking cows, >2 LU/ha, >70% PG). In the Boreal BGR, farms are ascribable to a limited number of FS types, predominantly 2.2.1 (Milking cows, 0.5-1 LU/ha, <10% PG) and 7.1.1 and 7.1.2 (None, <0.5 LU/ha with <10% and 10-30% PG, respectively). Continental farms are almost evenly distributed among FS types, but with a peak of frequency in the 7.1.1 type again. In the Mediterranean BGR, farms are dominated by 'Sheep and goats' classes (especially, 4.4.3 and 4.4.5, i.e. Sheep & Goats, >2 LU/ha with 30-50% and 70% PG, respectively), but with relevant abundances also in other livestock-based types. Finally, at European scale the most common FS type is 7.1.1 (None, <0.5 LU/ha, <10% PG), even if other types (e.g. 2.3.5, Milking cows, 1-2 LU/ha, >70% PG; 2.4.5, Milking cows, >2 LU/ha, >70% PG; 4.4.5, Sheep & Goats, >2 LU/ha, >70% PG; and 6.1.1, Mixed & Others, <0.5 LU/ha, <10% PG) are also widespread.

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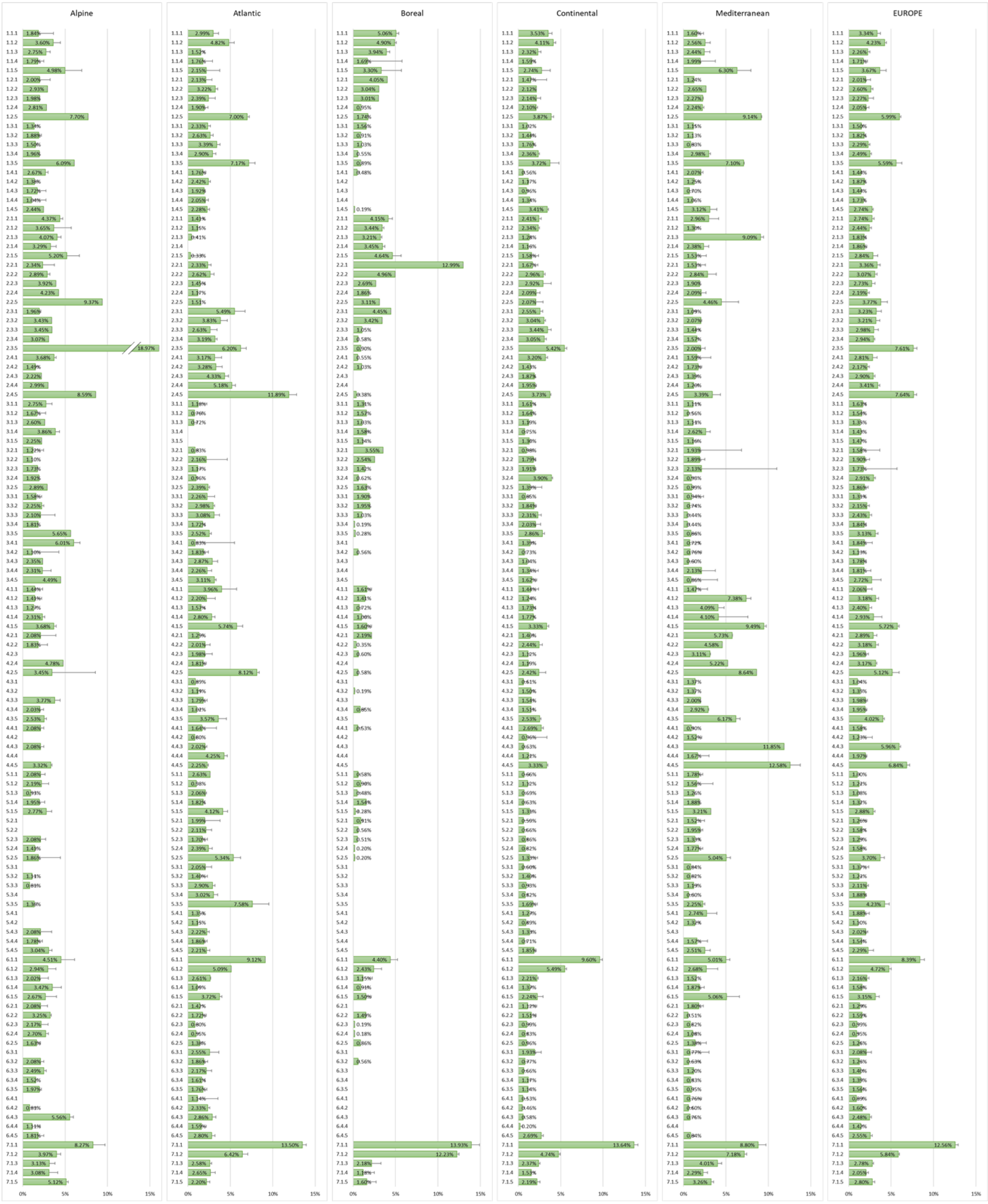

Figure 8. Frequency of occurrence of each FS typology class identified by the three-level typology in the five BGR and in Europe. Histograms and bars represent the average value of all NUTS3 regions belonging to each BGR and the standard errors of the means, respectively. The three-digit codes identify the categories of the three typology levels: 1st level, 1. Beef cattle, 2. Milking cows, 3. Mixed bovines, 4. Sheep & Goats, 5. Mixed ruminants, 6. Mixed & Others, 7. None; 2nd level, 1. <0.5 LU/ha, 2. 0.5-1 LU/ha, 3. 1-2 LU/ha, 4. >2 LU/ha; 3rd level, 1. <10% PG, 2. 10-30% PG, 3. 30-50% PG, 4. 50-70% PG, 5. >70% PG.

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Multivariate analysis

Maps and statistics can give a limited overview of the distribution of the analysed data since they are based on univariate data representation. Therefore, we present multivariate scatter plots to allow a more complete and more synthetic visualisation of FS variability and of the interaction between FS variables. We carried out a Multi Correspondence Analysis (MCA) on the classified individual farm data from the two described databases, i.e. FADN and SUPER-*G*.

The five BGR separate quite well in the first two MCA dimensions, generated by the FADN data and classified on the first three typology levels (Figure 9). More specifically, the Alpine BGR appears more related to beef cattle, relatively low stocking rates, and intermediate to high PG shares per farm. The Atlantic BGR also shows a connection to high PG shares, but with higher stocking rates and more 'Mixed bovine' and 'Dairy cow' farms. The dominance of farms without livestock in the Boreal BGR is associated with very low stocking rates, and with a very low PG share per farm. Continental farms are not clearly related to a livestock category or a stocking rate, but to the 10-30% class of PG share. Finally, the Mediterranean BGR, which can be identified in the upper part of the biplot, is separated from the other BGR, being strongly related to the presence of sheep and goats on farm.

The distribution of the variables (i.e. FS classes) is partially confirmed in the biplot of the MCA performed on the SUPER-*G* farm network database (Figure 10). Specifically, the Alpine farms are again associated with the 'Beef cattle' class, high PG share, and low stocking rates, although with a weaker connection than in the FADN data. Also, 'Mixed ruminants' were closely associated with this BGR. The Atlantic BGR also showed relationships that were similar to the previous biplot, with high stocking rates and high PG shares predominant. According to this visualisation, and in contrast to FADN data, the 'PG 10-30%' and 'Mixed bovines' livestock categories were the most relevant variables on Boreal farms. Low PG shares were again associated with the Continental BGR, but here, however, dairy farms were more important than in the previous visualisation. The segregation of the Mediterranean BGR from the other BGR was confirmed, even if with a weaker relationship to the 'Sheep and goats' class than previously observed.

The SUPER-*G* farm network database had the added value of allowing us to analyse the relevance of PG management (i.e. the 4th FS typology level), as presented in the second biplot (Figure 10). Farms with predominantly grazed PG were most common in the Alpine BGR, while mixed (grazing and cutting) regimes were associated with both the Atlantic and Continental BGR. On the other hand, predominantly cutting management was not clearly related to any specific BGR, but rather to farms with 'Mixed bovines'. Finally, the 'Non-feeding or not relevant' class for PG management did not appear to be related to any specific BGR nor to other variables, being rather isolated in the right side of the biplot. This is likely due to the limited number of cases where this option was recorded.

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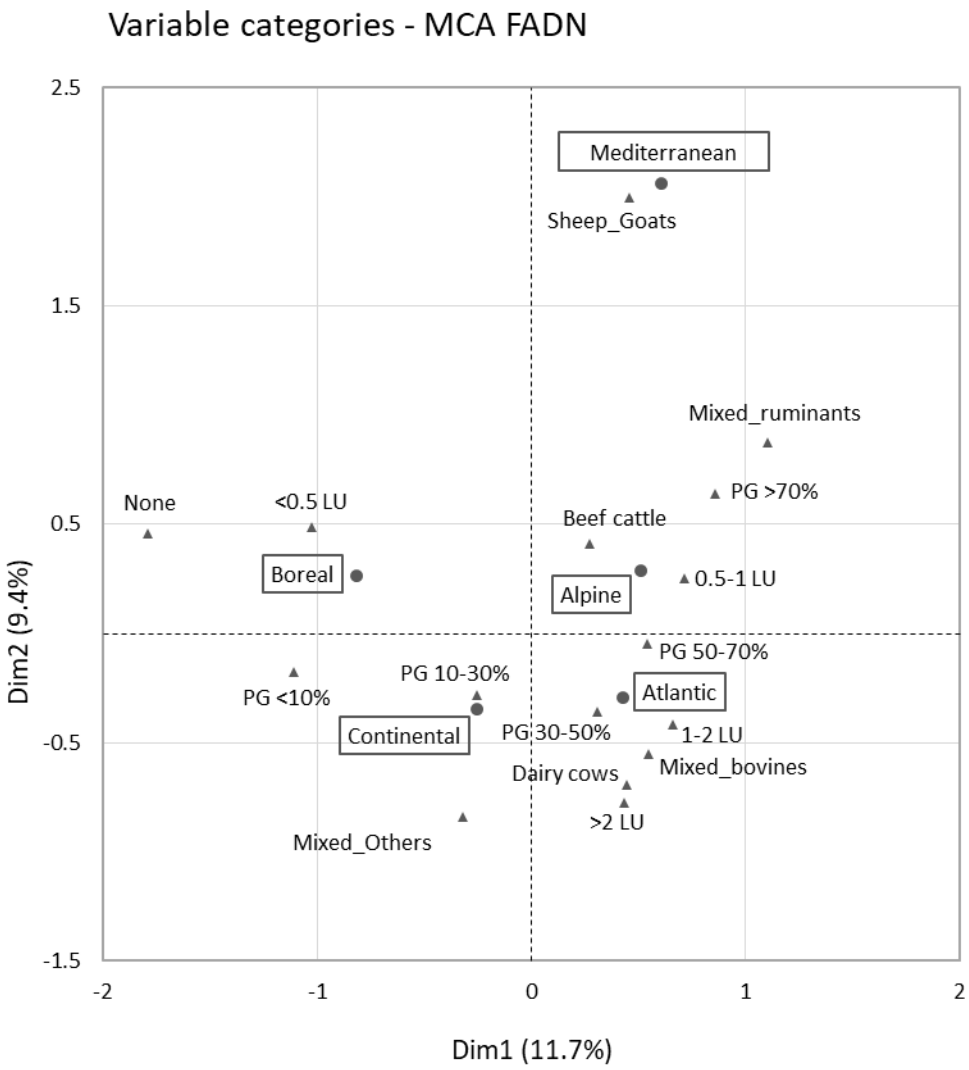

Figure 9. Biplot of the variables, including BGR identified by dots, in the first two MCA-dimensions performed on the FADN database. The variance explained by each dimension is reported in brackets.

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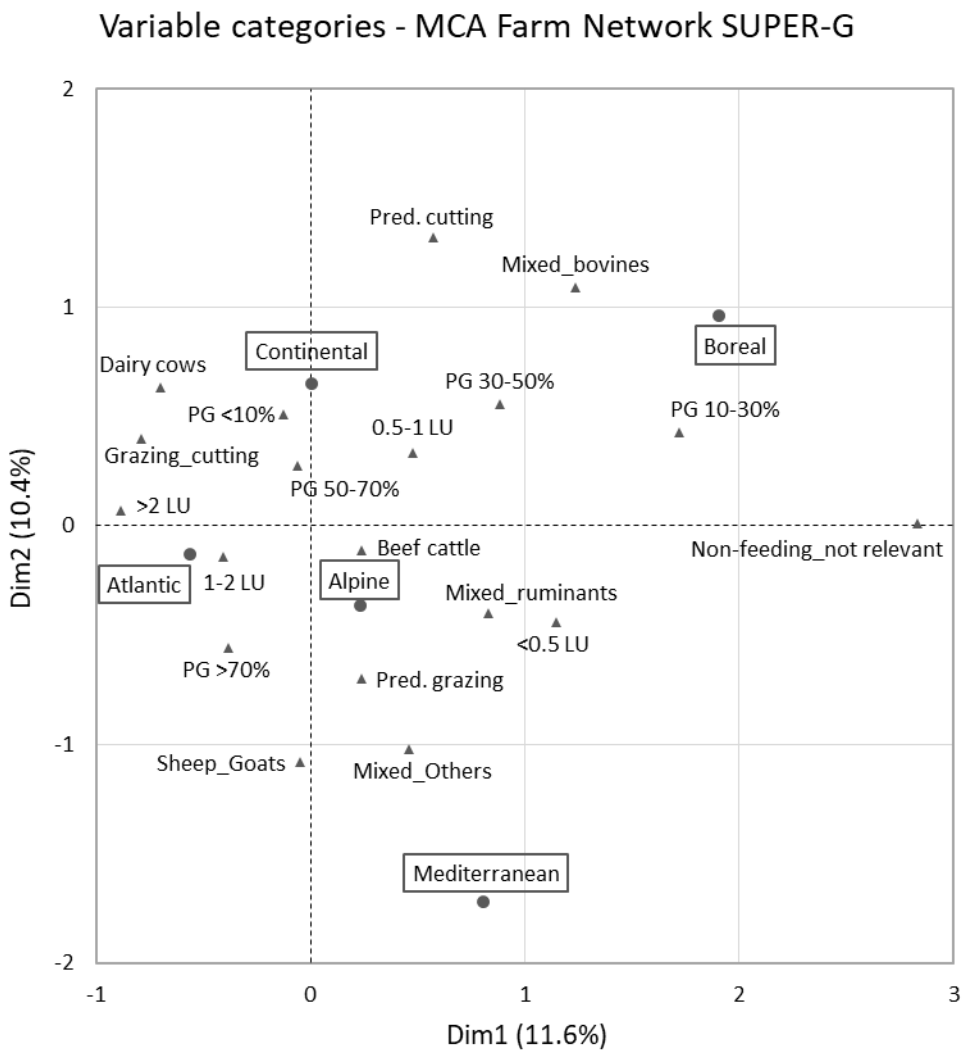

Figure 10. Biplot of the variables, including BGR identified by dots, in the first two MCA-dimensions performed on the SUPER-*G* farm network database. The variance explained by each dimension is reported in brackets.

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7. Future actions and limitations

This deliverable report presents the main outputs from SUPER-*G* Task 2.2. Nevertheless, some additional activities will be carried out within the project, based on the collated data and analysis to date.

We will retrieve data for countries and regions not included in the FADN database, but included in SUPER-*G*, such as Switzerland and Montenegro.

We will aim to find a proxy to define the main exploitation regime (4th typology level) and the farm PG forage value (5th level). This information can be likely retrieved from the collaboration with SUPER-G Task 2.1 (Development of a European grassland typology for PG) or from other land use and land cover databases. In any case, farmers, advisers, and policy makers interested in classifying farms according to our FS typology could easily adopt it.

We aim to carry out a driver analysis using the FADN database to assess the main factors that determine the differentiation of FS typology classes across Europe. We will also consider the use of other multivariate statistics, such as cluster analysis, classification and regression tree analysis, and canonical correspondence analysis on the FADN database to validate the FS classification.

The SUPER-*G* FS typology represents a new and comprehensive approach to classifying European farms in which PG has a central role. However, it has some limitations. As it is based on information that can be retrieved at a wide scale, evenly distributed on EU territory, and georeferenced, some fine information could be underestimated. For instance, we included in our classification the LU abundance classes and the PG share within the farms, but we could not take into account the actual stocking rate on PGs or its relationship with PG carrying capacity (which may change between PGs), as such data is not currently available. Future research projects may consider these points.

The use of livestock units to map livestock densities across Europe also has some limitations as the impact of livestock on permanent grasslands varies by species. Different livestock types have contrasting feeding behaviour and different forage preferences. Moreover, the indirect impact on the structure and functioning of grasslands is due, among other things, to the different way in which the livestock types impact the soil. As a result, by using LU instead of the specific number of animals of each livestock species, these aspects of grazing behaviour are not given sufficient consideration. Nevertheless, the predominant livestock species is described at the first level of the typology and the reason for using LU rather than animal numbers by species type is described above in section 5.

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