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D3.5 Farming System Archetypes for each CS

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Farming System Archetypes for each CS

Deliverable D3.5

30 June 2021

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BESTMAP

Behavioural, Ecological and Socio-economic Tools for Modelling Agricultural Policy

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Summary

This deliverable provides an overview of the methods and data used for developing the Farming System Archetypes (FSAs) in the five case studies - Humber, Mulde, South Moravia, Bačka and Catalonia. Additionally, it discusses limitations as well as problems and presents solutions.

The FSAs are a generalized typology of farming systems that are assumed to have similar response to policy change. FSAs are a major component of the BESTMAP modelling architecture because they provide linkages between many aspects of the project, especially connecting the biophysical and agent-based modelling in the case studies (CS), based on local data (e.g. IACS/LPIS, for explanation see Methodology), with the modelling of policy effects at the EU level, based on FADN micro-data within the FADN regions. The FSA framework defines the main farm characteristics determined by two main dimensions: firstly farm specialization and secondly economic size, both calculated and mapped for each farm in the CSs. 'Farmer agents' who belong to the same FSA are then assumed to have similar decision patterns regarding the adoption of agri-environmental schemes, based on the relationships revealed in the CS agent-based models.

This work is linked directly to two work packages, namely WP4, where FSAs will be used in the agent-based modelling, and WP5 where they will be used to upscale to European level. During the development of the FSA definition, several aspects have been considered that will assure smooth applicability of the FSAs in WP4 and WP5. The general approach to develop the FSAs is already documented in the deliverable 'D2.2 - Conceptual Framework' (Section 1).

This deliverable includes (A) the general methodology for developing the FSAs, (B) the actual applied methods, limitations and solutions and (C) the results depicted in figures and maps including a concluding discussion.

1. Introduction

The Farming System Archetypes (FSAs) are a generalized typology of farming systems that are assumed to have similar response to policy change. They are a major component of the BESTMAP modelling architecture because they build on spatial data (as included in the Preliminary Case Study Base Layer, see D3.1 for details) and empirical information, and link many aspects of the project, e.g. farmer interviews/surveys on revealed behavior, characteristics of an agent in the ABM modelling, spatial patterns of agricultural land use in the case studies (CSs), and statistical/biophysical models for biodiversity and ecosystem services.

As a preliminary step, we developed proto-FSAs (Activity 3.4.1, M5) to provide a first stratification of farming systems in each CS, in order to select a representative sample of farmers for the project's interview campaigns. Proto-FSAs were a simplified version of FSAs based on (1) the type of farming system as defined by Farm Accountancy Data Network (FADN), (2) the Environmental stratification of Europe (EnS) and (3) the JRC typology of farmer profiles. Proto-FSAs were used to stratify groups of farmers in the CS areas from which we selected a representative sample that were interviewed to identify potential key factors for farmers' decision-making on agri-environmental schemes (described in D3.4).

To develop and map the full classification of FSAs in our five CSs, we originally envisioned that FSAs would be characterized by (1) dominant environmental conditions (e.g. climate, soil), (2) land-use intensities and management practices (e.g. crop types, crop rotations, mechanization, fertilizer application), but also by (3) socio-economic factors (e.g. land tenure and ownership, size of the fields/agricultural holding) that would provide a link to farmers' behavioral characteristics. However, in order to meet the assumptions required to upscale our FSA classification from CS to EU level (see D2.2 for details) and after discussing possible attributes included in IACS/LPIS and FADN, BESTMAP made the decision to keep the FSA classification simple, and build it on two primary dimensions, following the FADN approach of **(1) farm specialization** and **(2) economic size**. Therefore, the methodology below describes in detail the data sources and procedures needed to identify and map the FSAs for **individual farms** in each of the CS areas.

The five CSs of BESTMAP - namely Humber (UK), Mulde (DE), South Moravia (CZ), Bačka (RS) and Catalonia (ES) - are distributed across Europe, covering a range of agri-environmental conditions. The predominant environmental difference between the case study areas is climate which largely determines the overall types of agricultural uses possible. Figure 1 and Table 1 give an overview of the case study areas' characteristics.

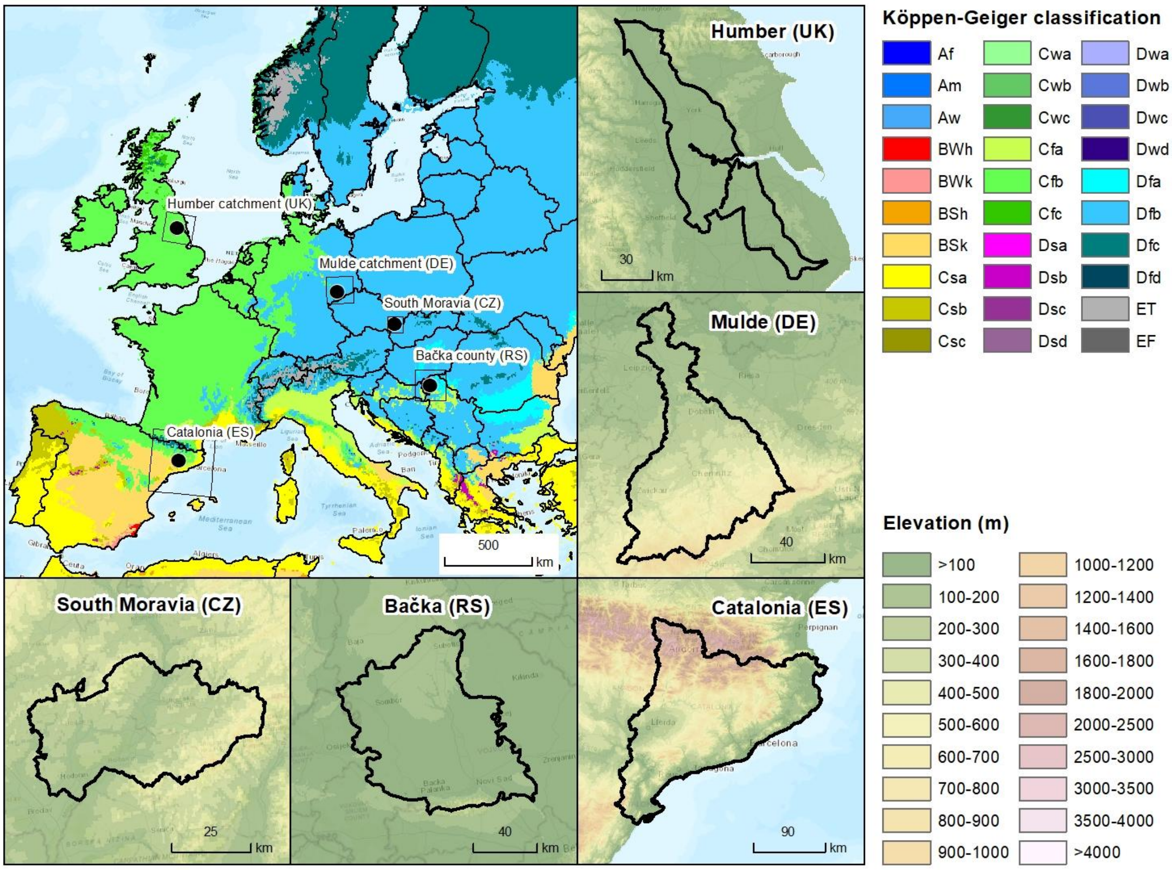

Figure 1: Location of the BESTMAP case study areas.

Table 1: Overview description of the 5 CSs. Climate zone according to Köppen (Beck et al. 2018, Nature Scientific Data 10.1038/sdata.2018.214)

CS	Elevation	Climate zone	Total area [km²]	Land in agriculture [%]
Humber	10-140 masl	- temperate, no dry season, warm summer (Cfb)	4,664	79
Mulde	100-1000 masl	- cold, no dry season, warm summer (Dfb)	5,812	51
South Moravia	170-800 masl	- cold, no dry season, warm summer (Dfb)	2,089	62
Bačka	70-300 masl	- cold, no dry season, hot summer (Dfa) - temperate, no dry season, hot summer (Cfa)	8,218	84
Catalonia	50-2500 masl	- arid, steppe, cold (Bsk) - temperate, dry summer, hot summer (Csa) - temperate, no dry season, hot summer (Cfa) - Temperate, no dry season, warm summer (Cfb)	32,108	40

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2. Methodology

In order to meet the requirements of the BESTMAP conceptual framework and modelling architecture, the FSAs that are defined at the CS level also have to be applicable at the European level. This precondition limits the use of data with specific spatio-temporal resolution or thematic detail tailored towards one or a few CS, since such information is not available at the European level and/or scalable to a larger extent. To overcome this limitation we made use of data that can be linked to the European FADN data (link).

To define the FSAs, there are several characteristics the data must meet. In order to ensure a harmonized approach across CSs and enable Europe-wide upscaling, the data must be mappable for each individual farm in all CS, based on spatial data from public or administration sources (1). The data have to be mappable from FADN microdata, so that they can be linked to the FADN data in the upscaling step (2). The data have to use weighing coefficients based on Standard Output (economic size) and Farm Specialization (type of farm) which FADN already includes (link) (3).

Additional characteristics that were originally considered are that the information should be based on attributes that farmers can easily and reliably answer in an online survey (4) and should correspond to, or be proxies of factors affecting farmers' AES adoption decisions (5). Please, refer to D2.2 'Conceptual framework' for details on the required characteristics.

The main data on farmland in each CS are IACS/LPIS (Integrated Administration and Control System / Land Parcel Identification System). These include land use (e.g. annual crops but also perennial use such as orchards) for each field for several years. Additional information for each field includes the user, the implementation of EFA and/or AES, size, spatial location and especially the specific crop grown on the field.

We intended not to exceed a reasonable number of different FSAs, allowing for surveying farmers in these FSAs with reasonable resources while still including the most relevant information. Given the above mentioned considerations, we chose two dimensions to develop the FSAs. These are the **Farm specialization** (5 categories) and the **Economic farm size** (4 categories), resulting in a total of 20 distinct FSAs. The method to extract this information and the definition of the specific FSAs is described below.

2.1. Source of data

For South Moravia, we received the LPIS data for the years 2015 to 2019 from the Ministry of Agriculture of the Czech Republic in January 2020. For the analysis we used the latest 2019 data. This case study covers parts of two counties (Jihomoravský kraj and Zlínský kraj). We combined the data from both and cropped it to the CS boundary.

For Catalonia, we used the DUN (Declaració unificada agraria; Agrarian Unified Declaration) instead of LPIS for the years 2015 to 2018. The DUN is an annual declaration that must be submitted by the person in charge of the farm, whether or not he/she is applying for subsidies. The DUN is implemented in a web environment and must be

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identified with a digital certificate. This information is open in Catalonia and was facilitated by the Department of Agriculture from the Catalan government (DARP GenCat) (https://aplicacions.agricultura.gencat.cat/dunweb/login.html), as files per year and “Comarca” (The Catalan territory is divided in 42 comarques that are smaller than provinces but bigger than municipalities). For the analysis we used the 2018 data. For additional information see section 3.5 ‘Specific problems for Catalonia’.

For the Mulde CS, InVeKoS (IACS/LPIS) data of the years 2016 to 2019 were provided by the Saxon State Ministry for Energy, Climate Protection, Environment and Agriculture (Sächsisches Staatsministerium für Energie, Klimaschutz, Umwelt und Landwirtschaft - SMUL). They contained spatially explicit data at the agricultural parcel level including crop type, AES and EFA type and a pseudonymised farm ID. Data for the year 2019 were used for the analysis.

For the Humber CS, data were supplied under license from the Rural Payments Agency (https://www.gov.uk/government/organisations/rural-payments-agency) with details of individual crop types declared with claim area, and associated parcel polygon data. For this deliverable the most recent year (2019) was used.

For Bačka CS, we used AgroSens (https://agrosens.rs/#/app-h/welcome), a digital agriculture platform of Serbia that was launched in October 2017. For the study, we used primarily data from 2018, additionally we also used information from 2019 to 2020. The platform is voluntary, free to use and enables monitoring of crops by combining processed Sentinel pictures with meteorological data (historical data and forecasts) and on the ground information received through various measurements and farmers’ inputs. For additional information see section 3.6 ‘Specific problems for Bačka’.

All CS data were stored and managed via the Preliminary Case Study Base Layer and were handled according to GDPR rules and local data sharing agreements (see MS3 for details). For clarity, the agricultural data we used are called ‘LPIS’ in this document, although the data were not only based on actual LPIS.

2.2. Farm specialization

The “fit to farm” practice was identified as an important aspect in our interviews with farmers. Therefore, we decided to use farm specialization as one main dimension of FSAs. To connect our classification to FADN data, we chose to use the farm typology classification ‘Type of Farming’ (TF8) of FADN (defined in Annex IV of EU regulation 2015/220), which represents the farm specialization. However, we reduced the eight TF8 to four types (Table 2): general cropping (P1), horticulture (P2), permanent crops (P3), grazing livestock (P4). Additionally, we used a mixed class for farms with no dominance of one of the above mentioned types. To map spatial LPIS data to these five classes, we used the area-based rules defined in EU regulation 2015/220, stating that farms classified as P1, P2, P3 or P4 have to dedicate at least 2/3 (66,6%) of the total farm area to the corresponding land use type. If this condition is not met, the farm is classified as mixed.

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For completeness, the definitions of P1, P2, P3 and P4 are given below (Table 2) based on FADN microdata field names.

Table 2: The crop types (including FADN microdata field names) for the four farm specialization types.

Farm specialization	consists of (code)	consists of (description)
General cropping (P1)	P15	cereals
	2.01.02.	dried pulses and protein crops
	2.01.03.	potatoes
	2.01.04.	sugar beet
	2.01.06.01.	tobacco
	2.01.06.02.	hops
	2.01.06.03.	cotton
	P16	oilseeds
	2.01.06.09.	flax
	2.01.06.10.	hemp
	2.01.06.11.	other fibre crops
	2.01.06.12.	aromatic plants, medicinal and culinary plants
	2.01.06.99.	other industrial crops not mentioned elsewhere
	2.01.07.01.01	fresh vegetables, melons, strawberries — outdoor or under low (not accessible) protective cover — open field
	C1 2.01.10.	arable land seed and seedlings
	2.01.11.	other arable land crops
	2.01.12.	fallow land
	FCP1	forage for sale
Horticulture (P2)	2.01.07.01.02.	fresh vegetables, melons, strawberries — outdoor or under low (not accessible) protective cover — market gardening
	2.01.07.02.	fresh vegetables, melons, strawberries — under glass or other (accessible) protective cover
	2.01.08.01	flowers and ornamental plants — outdoor or under low (not accessible) protective cover
	2.01.08.02.	flowers and ornamental plants — under glass or other (accessible) protective cover
	2.06.01.	mushrooms
	2.04.05.	nurseries
Permanent crops (P3)	2.04.01.	fruit and berry plantations
	2.04.02.	citrus plantations
	2.04.03.	olive plantations
	2.04.04.	vineyards
	2.04.06.	other permanent crops
	2.04.07.	permanent crops under glass
Grazing livestock and forage (P4)	GL	grazing livestock
	FCP4	forage for grazing livestock

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2.3. Economic farm size

Income is a well-known factor affecting decision making in the agricultural sector and it was also highlighted as the main factor in the interviews with farmers. The economic size of farms is given as variable SE005 in Standard Result in FADN microdata. To define classes of economic farm size, we first adopted a simplified version of FADN ES6 (6 classes, see Table 3), which is available in the microdata. Secondly, we grouped these into three categories to reduce the total number of FSAs, classifying economic size as small, medium and large, see section 2.3.2 for more detail. This allows easier mapping and comparison of FSAs between the CSs. However, for the CS-level analysis of FSA effects on AES adoption, we may opt for using the original 6 classes, in order to preserve a wider variability of economic sizes within individual CSs (see also Figures A6, A7).

Economic size is not directly available from the LPIS data, but can be calculated using FADN Standard Output Coefficients (SOC in EUR per hectare, for ~90 crop types) available for 2013 in Eurostat (link). SOC represent the average monetary value of the agricultural output at farm-gate price, in Euro per hectare or per head of livestock. For 2013 SOC values per region were calculated using the average of 2011-2015 prices in 2016 Farm structure survey data.

The Economic size of each farm was hence calculated by multiplying the area of each crop (extracted from the LPIS data) by the corresponding SOC.

2.3.1. Economic size according to FADN

The adopted simplified version of FADN ES6 (6 classes, Table 3) includes the following thresholds:

Table 3: Monetary thresholds for the ES6 classes, which will define the economic farm size.

ES6 class	from	to
1	2 000 EUR	< 8 000 EUR
2	8 000 EUR	< 25 000 EUR
3	25 000 EUR	< 50 000 EUR
4	50 000 EUR	< 100 000 EUR
5	100 000 EUR	< 500 000 EUR
6	500 000 EUR	

2.3.2. Economic size classes

The thresholds for the economic size classes (small, medium, large) for each farm specialization were determined by analysis of the 2018 ‘farms represented’ (SYS02) within YEAR.COUNTRY.SIZ6.TF8.zip standard report (see also BESTMAP D2.2). We then

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combined the ES6 classes for each of the five farm specializations (see above) to get as close as possible to 33% / 33% / 33%, respectively (Table 4).

The lowest threshold for the economic farm size is 2000€ (see Table 3). In cases that farms have a smaller economic size we refer to them as ‘<2000’.

Table 4: Assignment of the ES6 classes to economic farm size as small, medium or large.

Farm specialization (FS)	**ES6 classes included** (% of farms in 2018 FADN for FS)		
General cropping (P1)	small = 1 (23.6%)	medium = 2 (35.6%)	large = 3-6 (40.7%)
Horticulture (P2)	small = 1-2 (32.9%)	medium = 3-4 (35.8%)	large = 5-6 (31.4%)
Permanent crops (P3)	small = 1 (15.3%)	medium = 2 (48.2%)	large = 3-6 (36.5%)
Grazing livestock and forage (P4)	small = 1-2 (43.3%)	medium = 3-4 (33.8%)	large = 5-6 (22.9%)
mixed	small = 1 (35.2%)	medium = 2 (28.6%)	large = 3-6 (36.3%)

2.4. Farming system archetype

The mapping of individual farms to a specific FSA makes use of the combination of both dimensions explained above. By overlaying the farm specialization (P1 to P4, and mixed) with the economic size of the farm (small to large, and <2000), we identify and map the FSA for each individual farm in all CSs (Table 5). This procedure gives an overall number of possible combinations of 20 FSAs.

Table 5: Definition of the FSA using farm specialization and economic farm size.

	General cropping (P1)	**Horticulture (P2)**	**Permanent crops (P3)**	**Grazing livestock and forage (P4)**	**Mixed**
<2000	P1 <2000	P2 <2000	P3 <2000	P4 <2000	Mixed <2000
small	P1 small	P2 small	P3 small	P4 small	Mixed small
medium	P1 medium	P2 medium	P3 medium	P4 medium	Mixed medium
large	P1 large	P2 large	P3 large	P4 large	Mixed large

3. General issues with FSA classification and their solutions

In the following chapter, details on problems that occured during FSA classification and approaches to circumvent them are explained. Depending on the CS characteristics and data availability, some changes to the methods had to be applied.

3.1. Definition of farm

The main spatial unit we performed our analysis on is the farm. In the Humber and Mulde CSs, an anonymised farm business ID was used that groups each field in the CS into a single farm business. For the South Moravia CS, there was no farm ID available. Instead we used the information about the 'user' of the field that is eligible to apply for agricultural subsidies, assuming that the user is the individual farmer or a farm business in charge of the farm management and AES adoption. For the Bačka CS, the farm was defined by the user who entered information in the AgroSens database (see section 2.1). For the Catalonia CS, there was an anonymized code which corresponded to the NIF (*Fiscal Identification Number*) of the exploitation (i.e. farm). For specific limitations and problems for Catalonia and Bačka please see sections 3.5 and 3.6. In all CSs, the data that allowed us to assign each field to a farm do not include information on ownership. Therefore, a farm can consist of fields that are owned, leased or a mixture of both.

3.2. Farm specialization

To assign a farm to a certain type of farm specialization we had to group the crops into categories. However, due to limited information from the LPIS data (in comparison to FADN which is much more detailed in terms of farm characteristics) this was not always possible. The main limitations are listed below.

3.2.1. Distinguishing market sale vs. direct sale and in/out of glasshouses (P1 vs. P2)

- Issues: Hard to distinguish between different vegetable types, such as in glasshouses, in 'protected' space, for market sale vs. for direct sale (P1 vs. P2).
- Solution/approach: For Humber and Mulde OpenStreetMap (OSM) data was investigated, though few glasshouses were identified for the case study areas. If a glasshouse was identified, it was often found to only encapsulate a small proportion of farm fields and did not allow allocation of the entire field, surrounding fields, or complete farm as a horticulture (P2) designation in our analysis. In Mulde the area extent of glasshouses cannot be estimated but it can be considered negligible as well. There are only 300 glasshouses located in the case study area according to OSM. Therefore we did not include the presence of glasshouses in Humber and Mulde to assign a classification. For Bačka there was no glasshouse-related data in OSM and in general only 17 farms were annotated in this database. Overall in Serbia less than 0.5% of the agricultural area is covered with glasshouses (based on national statistics). The estimated numbers in Catalonia for glasshouses are about 0.07% of the fields (based on LPIS). In the whole Czech Republic about 0.7% of the agricultural area is covered with glasshouses (based on national statistics) and in South Moravia this number is even lower. Glasshouses only cover a small portion of all of our CSs and are therefore not used in our analysis.
- Remaining caveats: Fresh fruit and vegetables are currently all being categorised as P1 rather than P2, as we do not have 'market gardening' data needed to categorise P2. Hence we might underestimate the coverage of P2 farms. We only identified P2 farms based on other land uses (i.e. flowers and nurseries). Additionally we might also

underestimate the economic size of the farms, since SOC are mapped to open field prices (as all classed as P1) and not with the higher prices for market gardening

3.2.2. Distinguishing between general cropping and livestock farming (P1 vs. P4)

- Issues: To identify livestock farms we have to distinguish between permanent and temporal grasslands assuming that livestock farms need permanent grassland. We only had sparse and inconsistent information on livestock. For Bačka, only information about ‘grassland’ is given, but no distinction between permanent and temporary grassland is made. Even if we have data for 3-5 years, we can’t be sure whether the fields remain grasslands or are changed (regularly) to some other crop/use. South Moravia and Humber had information about permanent/temporal grassland. For Catalonia, we had a class of permanent grassland as part of DUN, but to distinguish between P1 and P4 we used information about the occurrence of certain ‘fodder’ crops.
- Solution/approach: In the Humber CS permanent and temporary grassland were distinguished from each other in the data, and coded as P1 and P4, respectively. To explicitly identify livestock farms we tested (for Humber) whether they could be discerned through the presence of animal shelters. Animal shelters were not present in the UK LPIS data for the years 2015-2016, and were only present in limited quantities in the 2017-2019 data (only 4 within the Humber in 2019). Therefore they were not a viable option for the discernment of livestock farms.
- Remaining caveats: We rely on the assumption that permanent grassland defines livestock farms.

3.3. Economic size

To estimate the income that farmers can gain from each crop, we had to choose a specific Standard Output Coefficient (SOC) for each crop. However, for some crops this information was not available. In the next paragraphs we present issues and solutions for the calculation of the farm economic size.

3.3.1. Standard Output Coefficients

SOC can generally be derived from a common database (link). However, assigning the correct/best values was hampered by several issues:

- Issues: For matching crops with SO it’s sometimes not clear which value to choose. For the Humber all permanent grassland was designated to the SOC “Permanent grassland and meadow - pasture and meadow”, which has a value of €237.28 per/ha rather than the “Permanent grassland and meadow - rough grazings” variant which has a value of €1.25 per/ha. For Catalonia, in some cases the price of the last current year (2013) cannot be traced, only data from the previous period (2004) are available. Additionally, there are no different economic values for organic farming, which would be expected.

- Solution/approach: If we could not find a SOC for any specific crop/land use we used a crop that was most similar or a value for the larger group, e.g. for ‘buckwheat’ and ‘sorghum’ we used ‘other cereal’. Winter and summer varieties (i.e. wheat) were given the same SOC, although it can be assumed that the values are different. In Humber some fields have the category ‘wooded land’. It was not clear if this belongs to P3 (permanent crops) or should be excluded? In the UK, woodland was excluded from the analysis.
- Remaining caveats: For Bačka we could not use the same data but instead calculated with national statistics

3.3.2. Economic size

- Farms with an economic value lower than 2000 € are not classified under the ES6 groupings. We therefore categorised all farms with economic size lower than 2000 € as “<2000”. As the FADN don’t survey these ‘very small’ farms, a different approach for their upscaling to European level will have to be discussed.
- As FADN data does not include an economic size classification for mixed farms, we therefore classified them as “others”.

3.4. Minor issues

- *Field definition:* One methodological limitation arises from the different definitions of ‘field’. See document (link). CZ has *Farmers Block*; UK, ES and RS have *Cadastral Parcels*. RS data is pixel based. In Mulde data are provided at agricultural parcel level. All case study leads agreed that ‘fields’ translates to ‘agricultural parcels’ in LPIS. Mulde is the only CS with a single crop field as the smallest unit in LPIS/IACS.

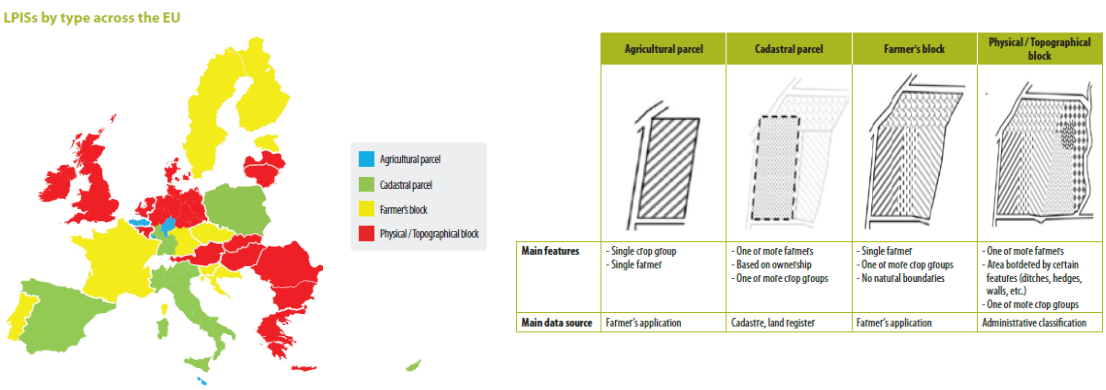

Figure 2: Definition of ‘field’ in the LPIS data across Europe. Source: https://www.eca.europa.eu/Lists/ECADocuments/SR16_25/SR_LPIS_EN.pdf (p.11/12).

- *Inconsistency in the data:* E.g. in the Czech LPIS for a few parcels (in 2018 N=32 about 0.18%, in 2019 N=64 about0.36%) the area of the parcel (‘vymera’) is smaller than the

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total crop cover. These few cases have been neglected, since they would neither influence the farm specialization nor the economic farm size.

3.5. Specific problems for Catalonia

After confirming that filling the DUN is 'mandatory for all the agricultural land even if they do not ask for subsidies' we decided to use the DUN data instead of LPIS. Some small farms, production for self-consumption or temporarily not cultivated fields are still not declared.

Although the individual fields in the LPIS are connected to the DUN database, the LPIS only applies to those fields where a subsidy has been requested or otherwise administratively processed. A significant percentage of fields thus remain unallocated (in some cases it is more than 50% of the area) and so it is not possible to determine with certainty the actual size of the farm if the farmer did not apply for subsidies for some fields, or farms that did not apply for subsidies at all.

One issue we found is that about one quarter of the agricultural land (23% in 2018) is covered by fields on which more than one user (ID_EXPLOTACIO that can be interpreted as farmer identification code; instead of owner code) occurred in the DUN. Mainly, this is related to permanent pastures where there is an agreement between the owner of the land and some livestock farmers that use the area for grazing (this can be the dominant situation in mountain areas such as the Pyrenees). Indeed, in some Pyrenees areas 70% of the forests are "common land" and have no private owner as described in the report originated by a recent study (link). Pasture is one of the usages specifically mentioned in the report. A second reason is related to land rented by more than one farmer in a single year. The usage is in most cases annual crops (e.g. barley, soft wheat, corn, rice) and trees (peach, apple, pear, nectarine, olive). In these cases the owner likely rents his land temporarily to certain farmers who will manage the land and its production, and is also responsible for the DUN entry, whereas the actual land owner is not mentioned in the database. We have decided not to include these "shared lands" into any spatial analysis because the results would be biased.

3.6. Specific problems for Bačka

Serbia does not have LPIS. However, we do have access to the volunteer database *'AgroSens'* and can extract data for several years to 2020. About 25% of the parcels in the CS are included in *AgroSens*, this represents around 30K parcels with around 1K+ users. User account is associated with a farm but could also split one big farm into 3 users. For these data we can't guarantee if the user put all fields they manage into the database. There is quite some variability in data. The average number of parcels per user is 9. The spatial representation and the representation of different crop types is reasonable.

The platform was launched in 2017, and data from 2018 cover 59649.70 ha across 6811 parcels. The data for 2019 includes 3511 parcels covering 33454.95 ha and for 2020 the database has 3828 parcels covering 22999.52 ha. We used the most representative year as the main source of information. For other years we also calculated distributions of farm

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specialization and economic farm size classes, and distributions are similar, but we will further use the year 2018 due to better spatial coverage.

Users of the platform optionally provide information on crops on parcels. If the information is not entered by the farmer, the unknown crop is denoted as ‘other’. The majority of the farmers provide this information, but in some years this class is in the top ten classes. Some of these missing values can be imputed by information from crop classification maps derived from satellite data.

4. Results and Discussion

In the following, we show how much the case study areas differ with respect to the farm specialization (main crop), the economic size of the farm (income) and, combining these two, the farming system archetype. In the paragraphs below the results of each of the above mentioned aspects are described.

4.1. Farm specialization

The farm specialization reflects the main land-use type of the farm. There are four types of specialization - general cropping (P1, for definition see above Table 1), horticulture (P2), permanent crops (P3), grazing livestock and forage (P4) - and mixed land use.

The most dominant farm specialization is P1 (field crops), which covers most of the area in 4 of the 5 CSs. However the number of farms with this specialization differs substantially amongst the CS areas. Most farms in Humber and Bačka are P1 farms, while it is only the second most dominant farm specialization in Mulde, South Moravia and Catalonia.

The distribution of the different farm types is rather uniform for Humber and Bačka, due to the homogenous elevation profile of these CSs. Whereas for the other CSs there is a strong gradient showing large areas of general cropping (P1) in the lower parts and a more pronounced use for grazing (P4) or mixed use in the elevated part. The strong heterogeneity in Catalonia is also driven by the topography that results in a variety of climatic zones ranging from Alpine, through continental Mediterranean, to coastal Mediterranean. Arid environment characterizes farms in the center of Catalonia, traditionally producing cereals (see also Figure 1), which contrasts with other areas: grazing (P4) is dominant in the highlands, general cropping (P1) and permanent crops (P3) in the lowlands. Therefore, the distribution of P1 and P3 is driven largely by topography and the availability of water.

In the Mulde CS, most farms belong to the P4 category, although these farms cover only a few percent of the area. In South Moravia, P3 is the dominant type of farm specialization, but the area is comparatively small.

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Farm specialization.

Legend for Figures 3 to 7

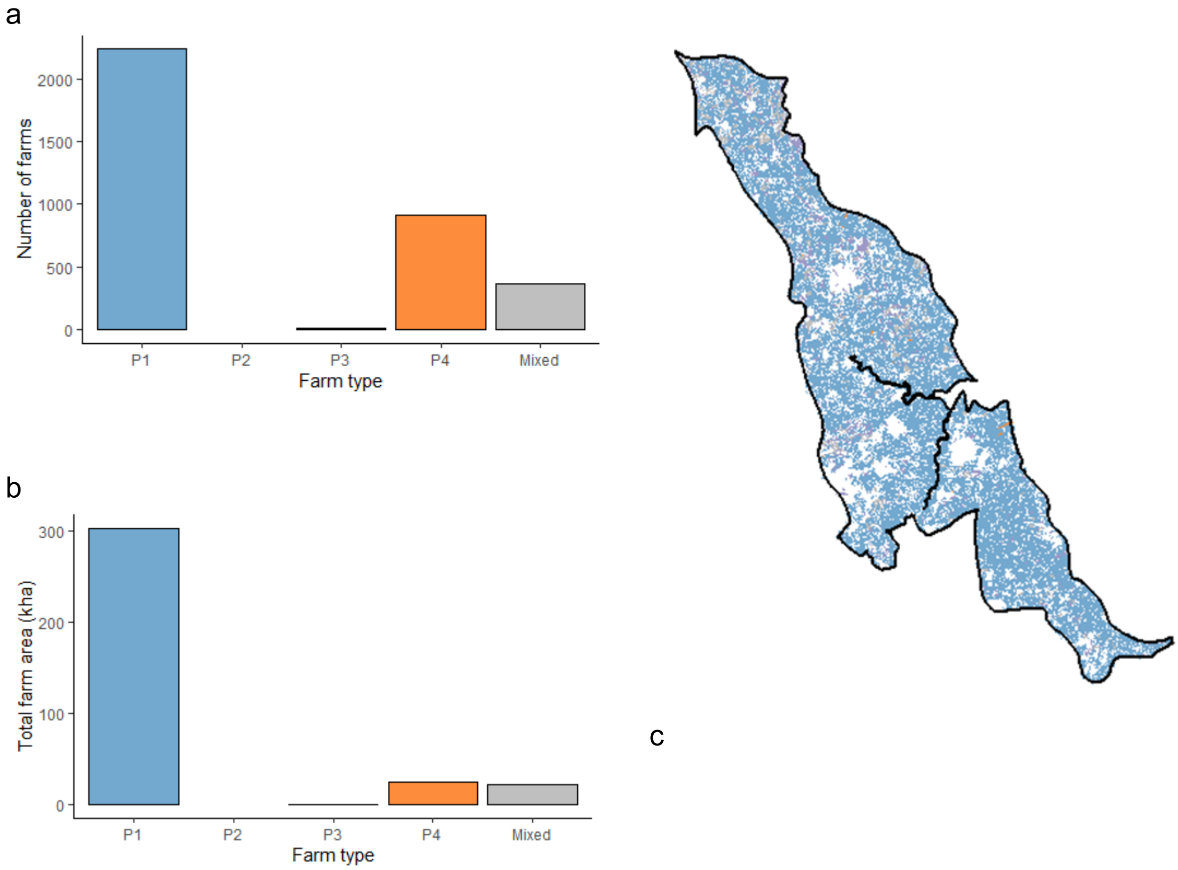

Figure 3: Farm specialization for Humber (UK). a) number of farms in each class b) area covered with each class. c) map of the classes.

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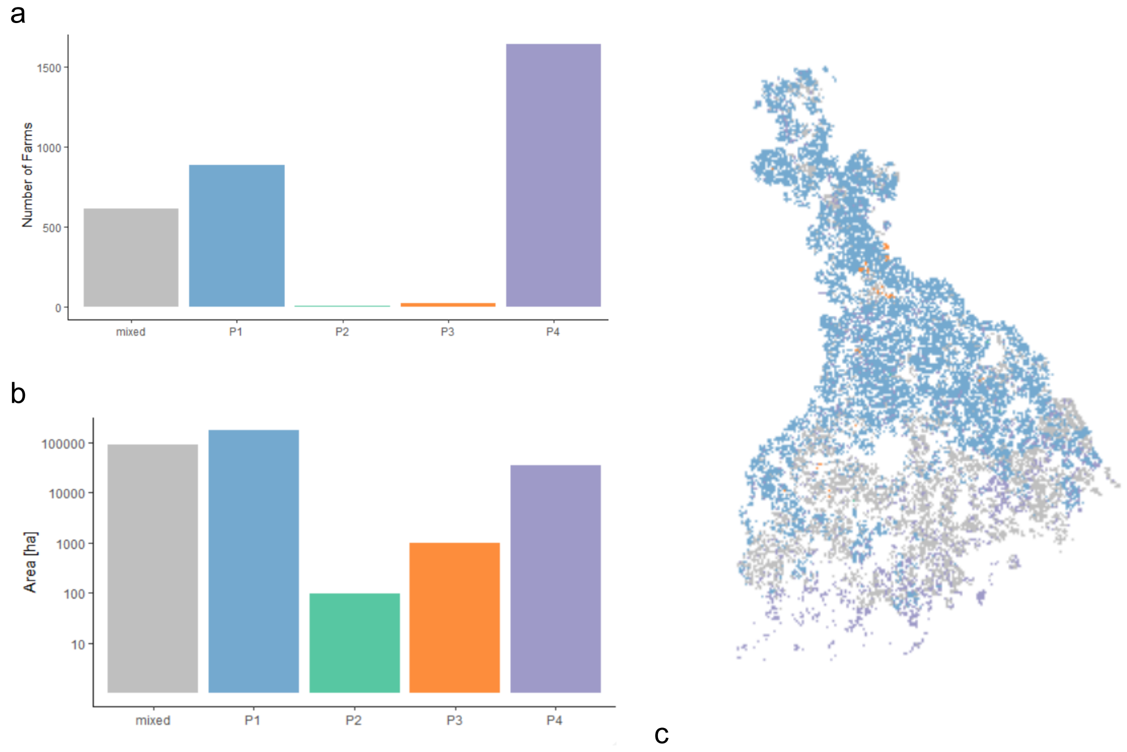

Figure 4: Farm specialization for Mulde (DE). a) number of farms in each class b) (logarithmic) area covered with each class. c) map of the classes.

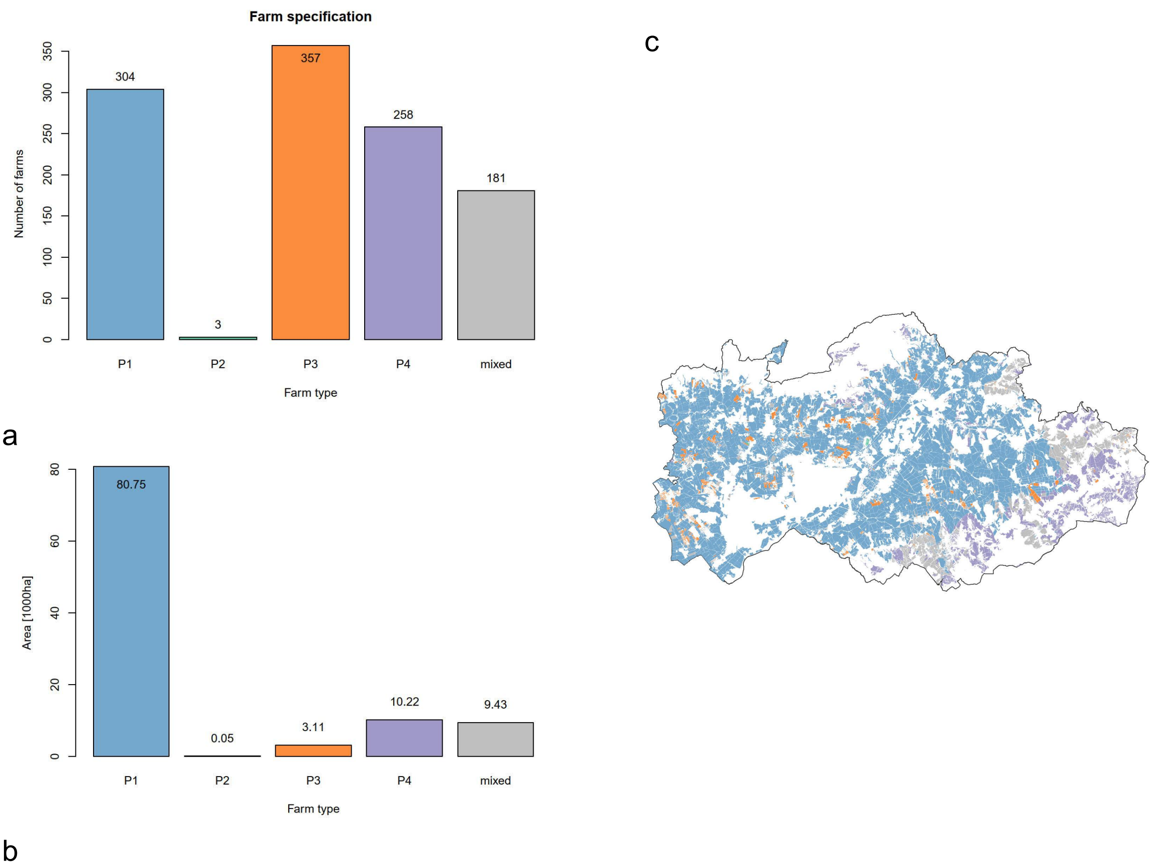

Figure 5: Farm specialization for South Moravia (CZ). a) number of farms in each class b) area covered with each class. c) map of the classes.

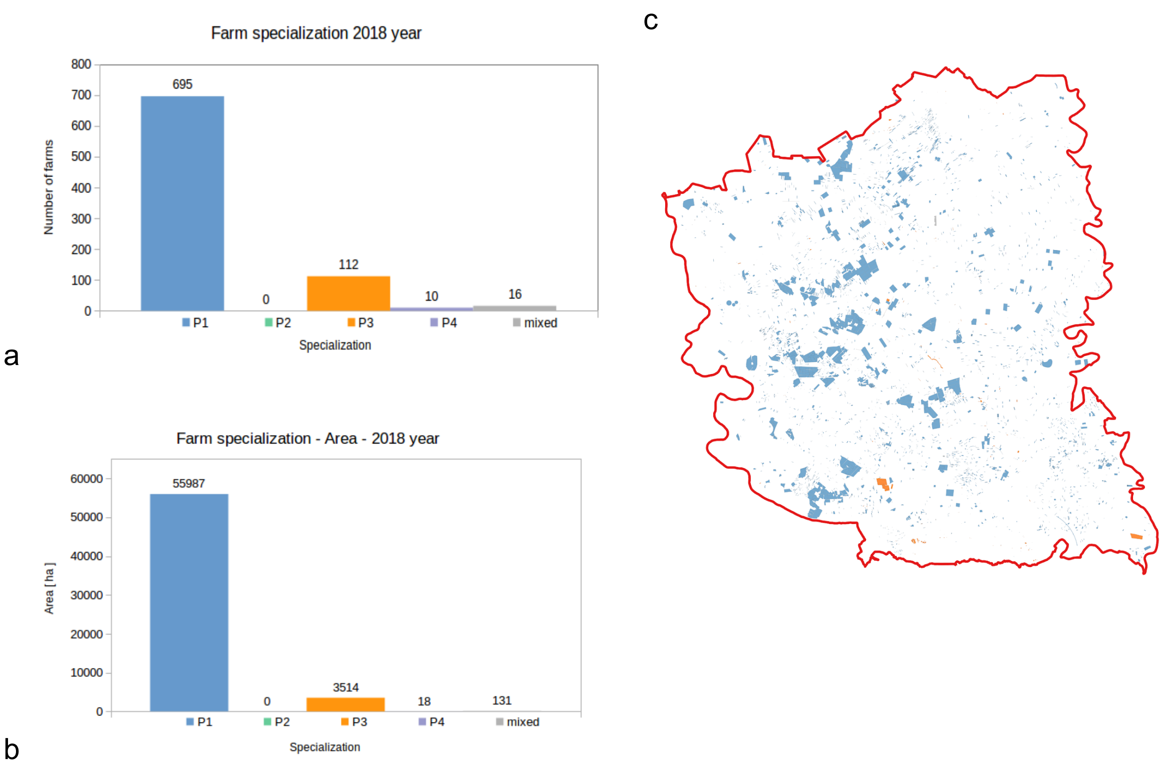

Figure 6: Farm specialization for Bačka (RS). a) number of farms in each class b) area covered with each class. c) map of the classes.

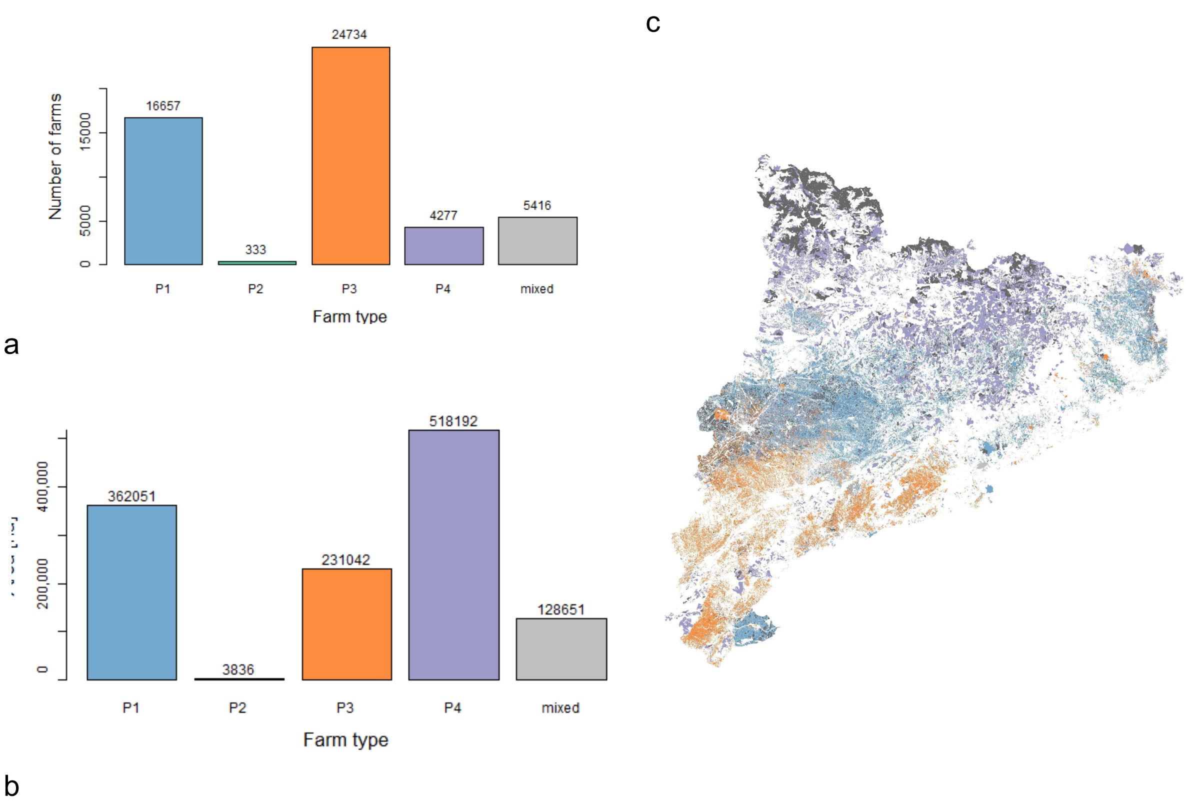

Figure 7: Farm specialization for Catalonia (ES). a) number of farms in each class b) area covered with each class. c) map of the classes - dark grey represents field parcels shared by multiple users with possibly different classification.

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4.2. Economic farm size class

The economic farm size is used to estimate the income each farmer or farming business can derive from their farm. It integrates, as described above, the grown crops and the corresponding average income per ha. The following figures and maps show the composition of economic farm sizes in each CS area.

The Humber, Mulde and South Moravia CSs are comparable with respect to the dominance of large farms. The category “large” covers most of the area in all CS which is expected because large farms tend to manage more fields than farms of smaller economic size. However, unlike in the case of farm specialization, the category “large” is the most frequent even in terms of the number of farms. The only exceptions are the South Moravia CS where farms with economic size <2000 EUR are by far most frequent and small farms are almost as equally frequent as large farms, and also the Mulde CS that has a slightly higher number of small farms than large farms.

In the CS areas with a strong elevation gradient, such as Mulde, South Moravia and Catalonia, there is a trend (particularly strong in Catalonia) to have farms with smaller economic size in areas with higher altitude. For Bačka, there is no such elevation-dependent trend apparent.

Economic group.

Legend for Figures 8 to 12

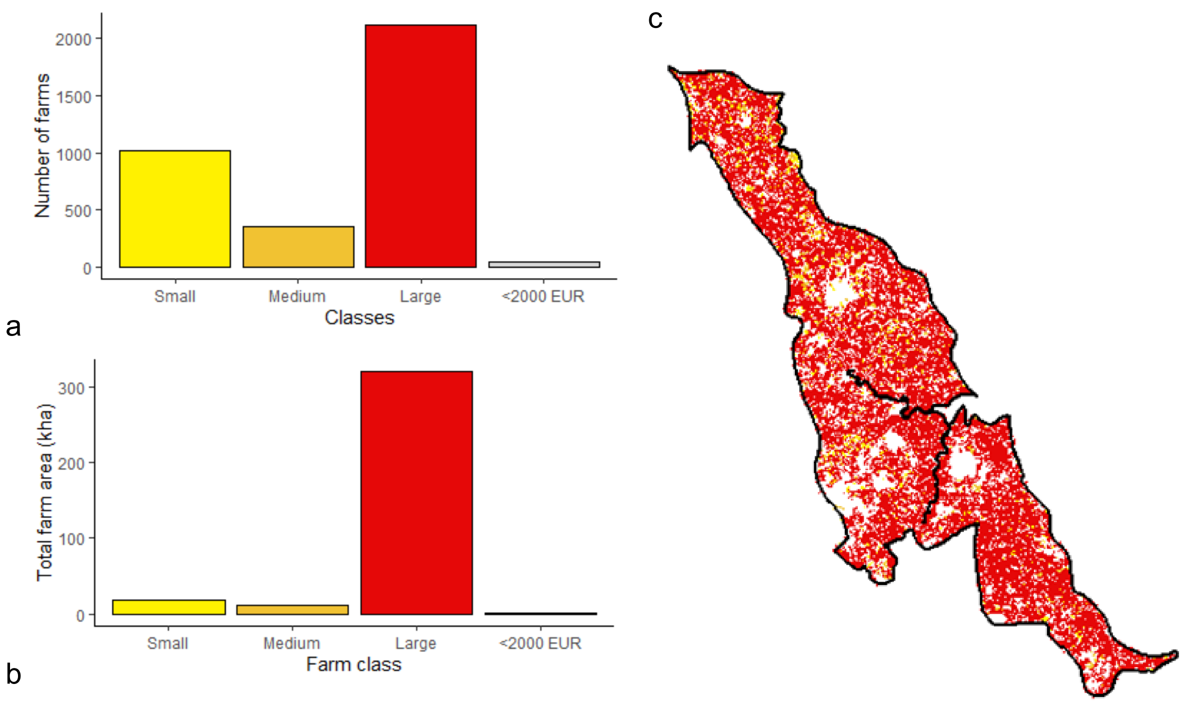

Figure 8: Economic size class for Humber (UK). a) number of farms in each class b) area covered with each class. c) map of the classes.

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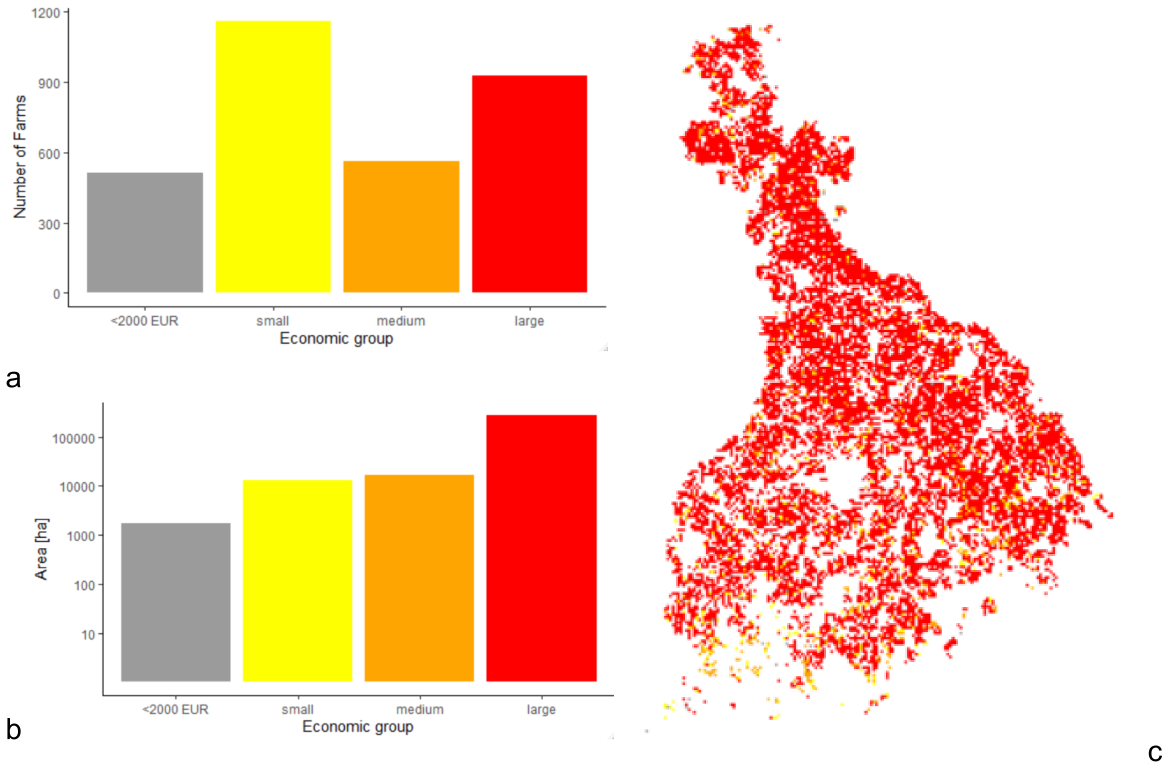

Figure 9: Economic size class for Mulde(DE). a) number of farms in each class b) area covered with each class. c) map of the classes.

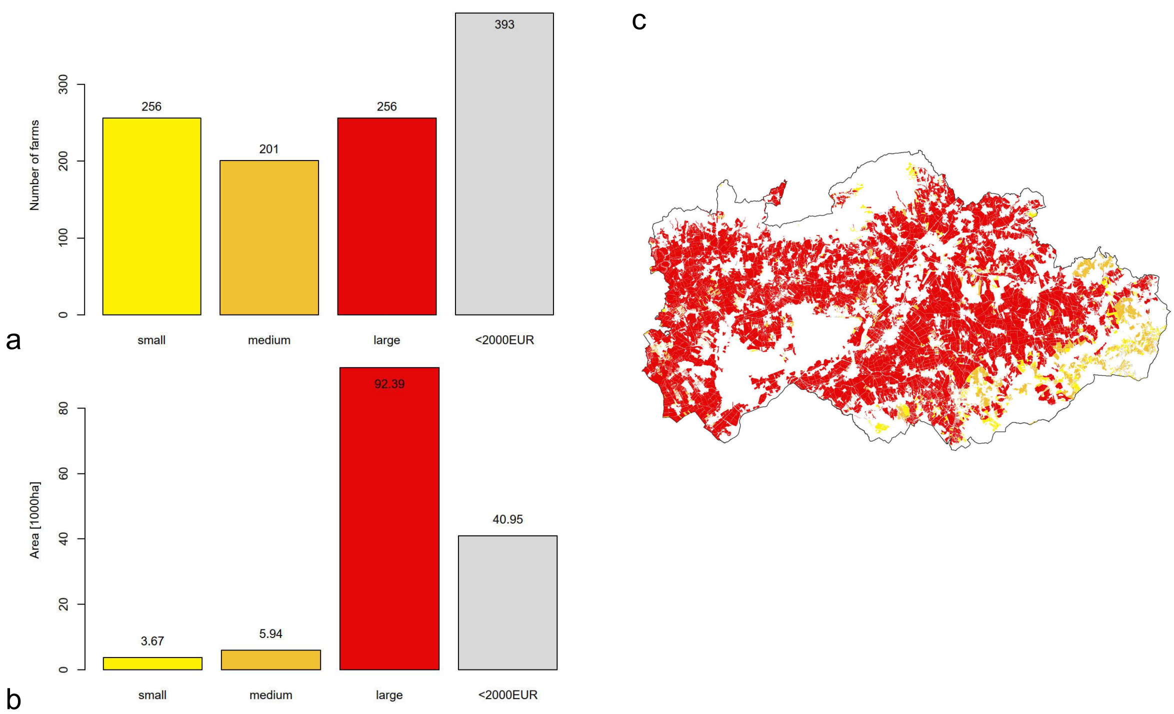

Figure 10: Economic size class for South Moravia (CZ). a) number of farms in each class b) area covered with each class. c) map of the classes.

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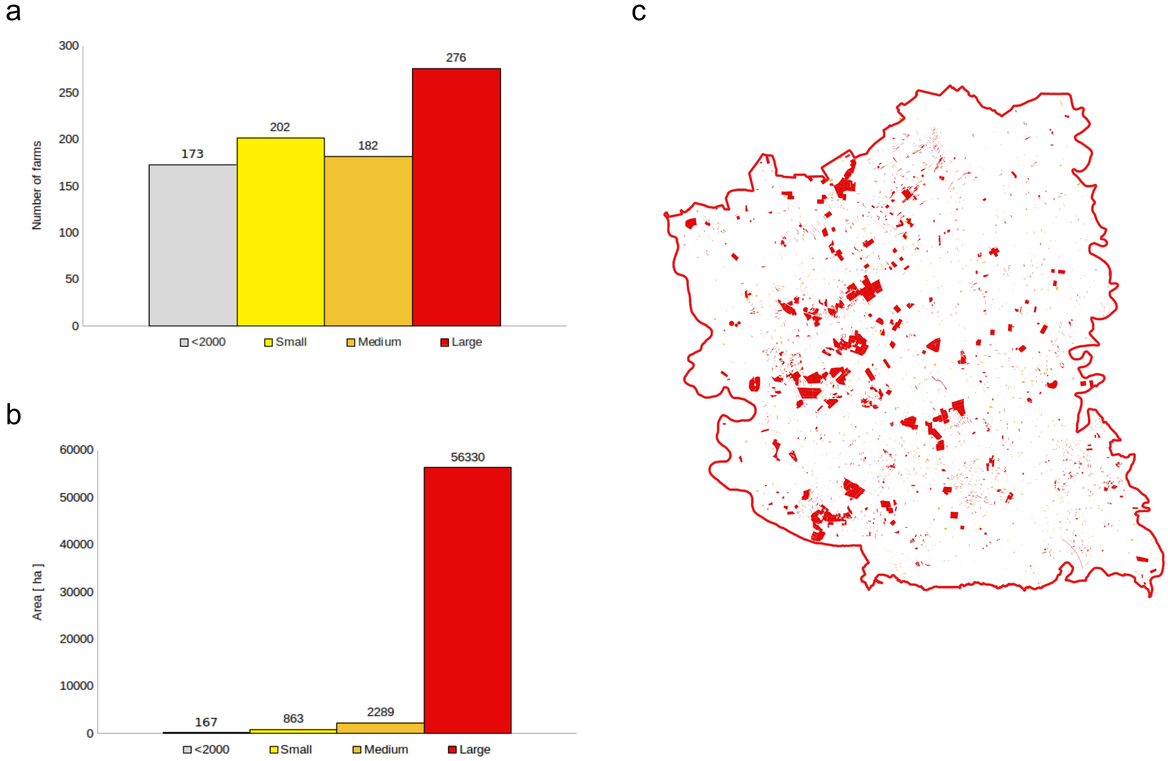

Figure 11: Economic size class for Bačka (RS). a) number of farms in each class b) area covered with each class. c) map of the classes.

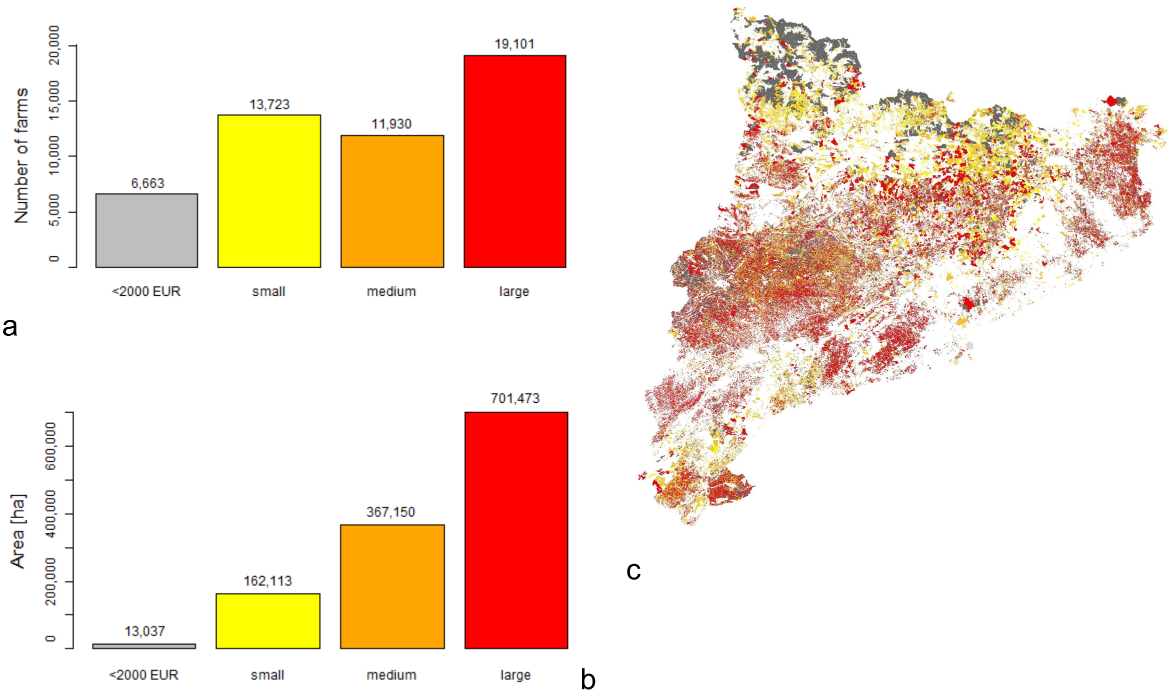

Figure 12: Economic size class for Catalonia (ES). a) number of farms in each class b) area covered with each class. c) map of the classes - dark grey represents field parcels shared by multiple users with possibly different classification.

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4.3. Farming system archetypes

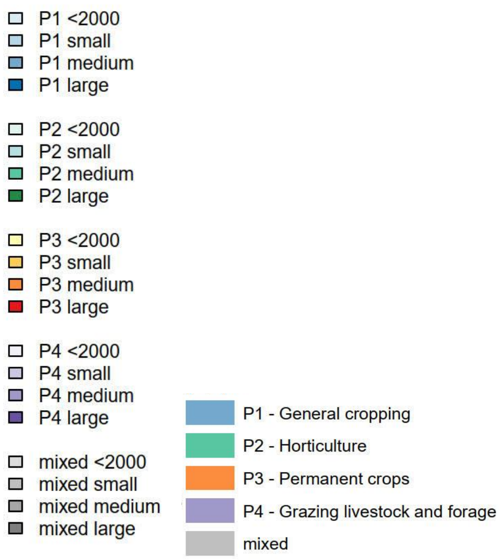
The archetypes of farming systems in BESTMAP, i.e. the combination of the above described dimensions of farms, namely farm specialization (N=4 + 'mixed') and economic farm size (N=4), are shown in the figures and maps below. The distribution of FSAs includes all potential combinations (N=20) of the two dimensions. However, not all combinations are realized in each CS area.

In terms of area coverage, Humber, South Moravia and Bačka are dominated by large P1 farms (general cropping). The distribution is much more diverse in the Mulde and Catalonia CSs, potentially due to the relatively larger size of the CS area (in case of Catalonia), pronounced elevational gradient and diverse socio-economic conditions. In Mulde, the FSAs of large mixed farms and P4 farms of different sizes cover comparable areas (especially in the southern portion of the CS) as the P1 large FSA in the northern part of the CS. In Catalonia, P1 large FSA covers a similar area as P4 middle FSA, followed by P3 large category, all present in distinct regions of the CS.

In terms of the number of farms, P1 large farms are the most frequent FSA in the Humber and Bačka CSs. However, the FSA pattern is largely different in the remaining CSs. In the Mulde CS, the most frequent category is the P4 small FSA, occurring mostly in the southern, hilly part of the CS area. In South Moravia, P1 large is the most common FSA but it is closely followed by P1 <2000 farms and also by P3 farms of small, medium and large sizes. The latter FSA is not concentrated in any specific region but is scattered throughout the entire CS area. Finally, in Catalonia CS, the most common farming system is P3 large in the southern part of the CS, followed by P3 small and medium and by P1 small, medium and large, all occurring on a comparable number of farms.

Farming system archetype.

Legend for Figures 13 to 17



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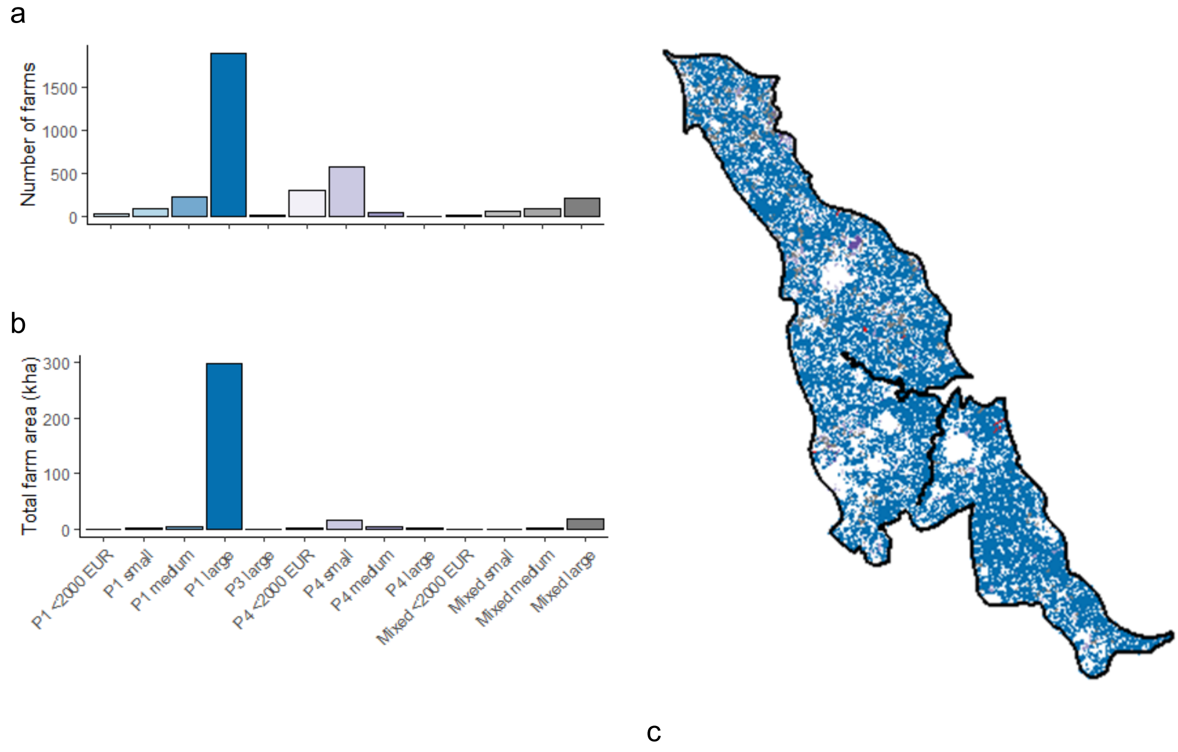

Figure 13: Farming system archetypes for Humber (UK). a) number of farms in each class b) area covered with each class. c) map of the classes.

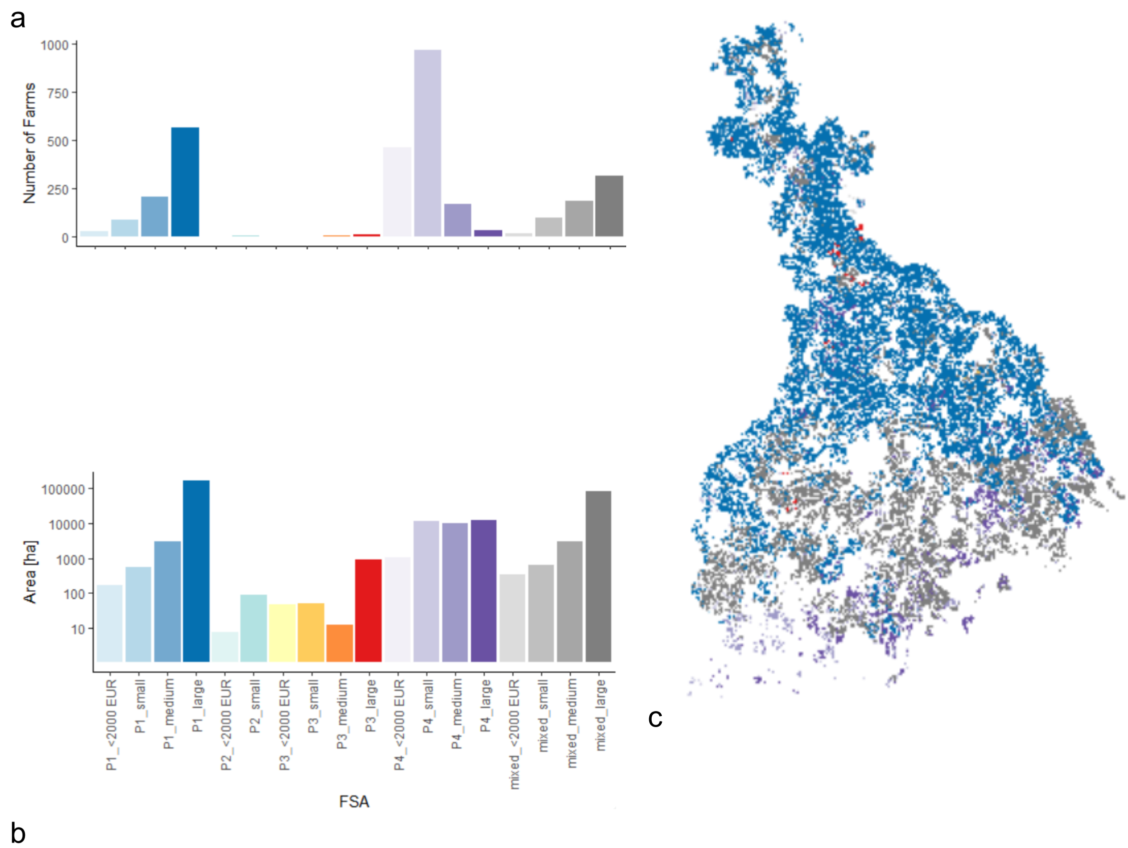

Figure 14: Farming system archetypes for Mulde (DE). a) number of farms in each class b) area covered with each class. c) map of the classes.

Figure 15: Farming system archetypes for South Moravia (CZ). a) number of farms in each class b) area covered with each class. c) map of the classes.

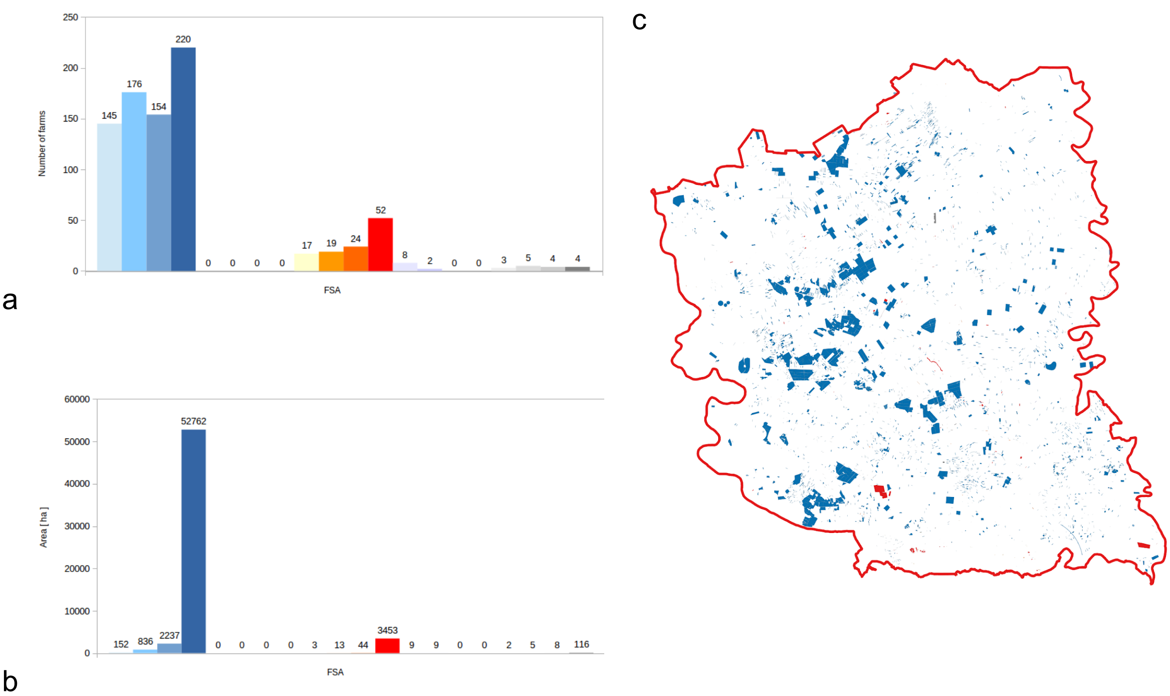

Figure 16: Farming system archetypes for Bačka (RS). a) number of farms in each classe b) area covered with each classe. c) map of the classes.

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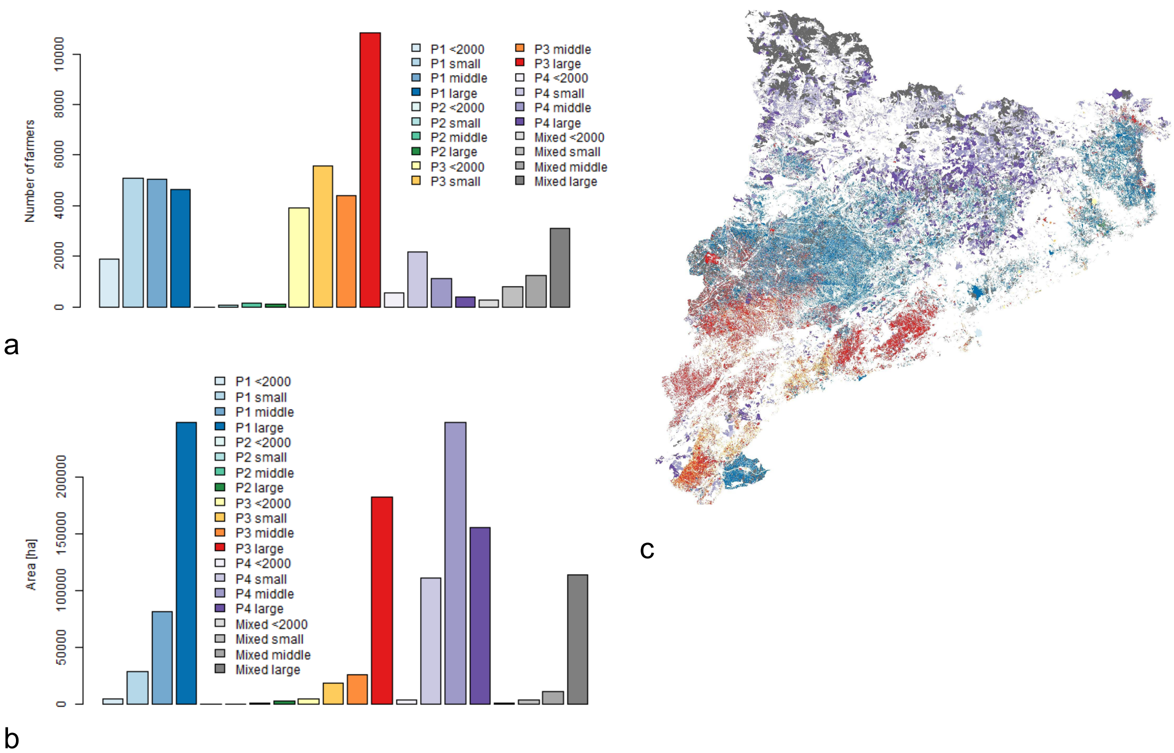

Figure 17: Farming system archetypes for Catalonia (ES). a) number of farms in each class b) area covered with each class. c) map of the classes - dark grey represents field parcels shared by multiple users with possibly different classification.

5. Acknowledgements

We thank the following organizations for providing data on agriculture:

- Ministry of Agriculture of the Czech Republic
- Saxon State Ministry for Energy, Climate Protection, Environment and Agriculture (Sächsisches Staatsministerium für Energie, Klimaschutz, Umwelt und Landwirtschaft - SMUL)
- Rural Payments Agency
- AgroSens
- Department of agriculture, livestock and fishing of the Catalan Government. (DARP-GenCat)

6. References

Beck, H., Zimmermann, N., McVicar, T. *et al.* Present and future Köppen-Geiger climate classification maps at 1-km resolution. *Sci Data* **5,** 180214 (2018). https://doi.org/10.1038/sdata.2018.214

FADN classification - https://ec.europa.eu/agriculture/rica/diffusion_en.cfm

FADN data - https://ec.europa.eu/agriculture/rica/database/database_en.cfm

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7. Appendix

7.1. Major crops and Standard Output Coefficients

This appendix gives an overview about the ten major common crops, their assignment to P1 to P4 and the corresponding SOC.

7.1.1. Humber (UK)

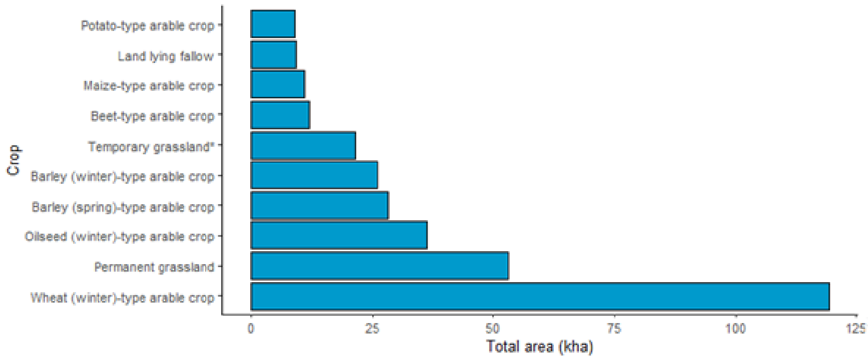

Figure A1: Crop distribution in the Humber case study in 2019.

Table A1: Classification of the 10 most predominant crops in the Humber case study in 2019.

Code	Original name	P1-P4	Mapped SOC name	2013 SOC value [€/ha]
AC44	Potato-type arable crop	P1	Potatoes	5987.86
AC03	Beet-type arable crop	P1	Sugar beet	2668.008
AC66	Wheat (winter)-type arable crop	P1	Common wheat and spelt	1618.674
AC17	Maize-type arable crop	P1	Grain maize	1522.128
AC01	Barley (spring)-type arable crop	P1	Barley	1270.85
AC63	Barley (winter)-type arable crop	P1	Barley	1270.85
AC67	Oilseed (winter)-type arable crop	P1	Other oilseed crops	755.2417
TG01	Temporary grassland	P1	Forage plants - temporary grass	254.4755

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PG01	Permanent grassland	P4	Permanent grassland and meadow - pasture and meadow	237.2776
FA01	Land lying fallow	P1	Fallow land	0

7.1.2. Mulde (DE)

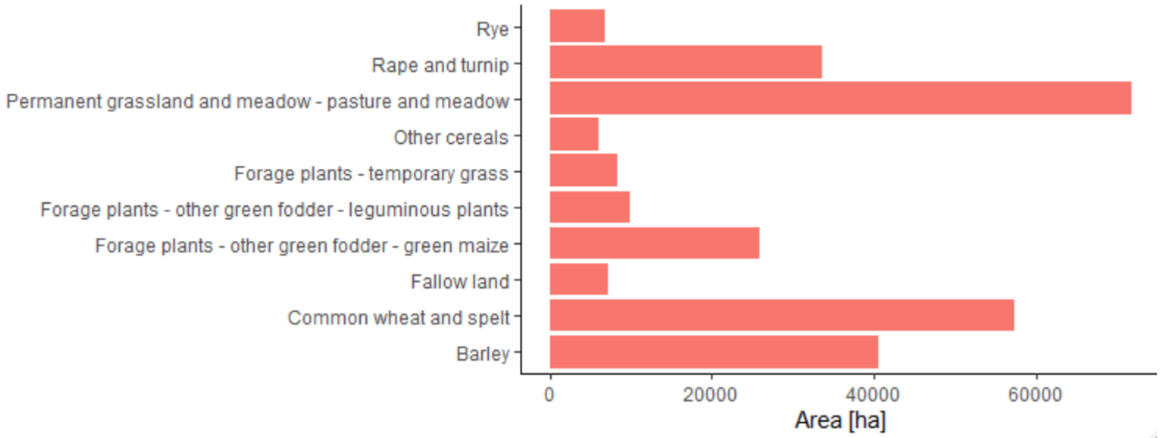

Figure A2: Distribution of the 10 most common crops in the Mulde case study in 2019.

Table A2: Classification of the 10 most predominant crops in the Mulde case study in 2019. Exact SOC value depends on the NUTs region a field parcel belongs to (source: INVEKOS). Several values for SOC per crop in Mulde CS.

Code	Original name	English translation	P1-P4	Mapped SOC name	2013 SOC value [€/ha]
115	*Winterweichweizen*	winter soft wheat	P1	Common wheat and spelt	1260-1301
452	*Mähweiden*	mowed pasture	P4	Permanent grassland and meadow - pasture and meadow	494-500
311	*Winterraps*	winter rapeseed	P1	Rape and turnip	1391-1437
131	*Wintergerste*	winter barley	P1	Barley	1028-1066
411	*Silomais (als Hauptfutter)*	silage maize (as fodder)	P1	Forage plants - other green fodder - green maize	948-958
451	*Wiesen*	meadows	P4	Permanent grassland and meadow - pasture and meadow	494-500
132	*Sommergerste*	spring barley	P1	Barley	1028-1066
424	*Ackergras*	grass ley	P4	Forage plants -	610-647

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				temporary grass	
422	*Kleegras*	clover ley	P4	Forage plants - other green fodder - leguminous plants	637-653
121	*Winterroggen, Winter-Waldstaude nroggen*	winter rye	P1	Rye	771-877

7.1.3. South Moravia (CZ)

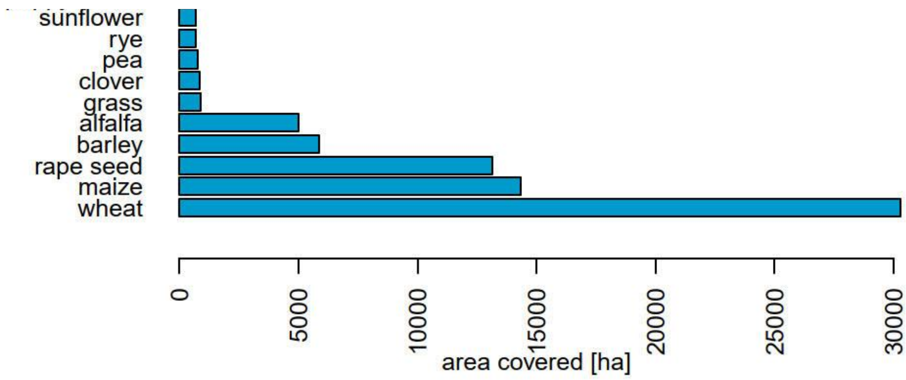

Figure A3: Distribution of the 10 most common crops in the Southern Moravia case study in 2019.

Table A3: Classification of the 10 most predominant crops in the Southern Moravia case study in 2019. One SOC per crop for the whole Czech Republic. Source: Ministerstvo zemědělství (Ministry of Agriculture).

Code	Original name	English translation	P1-P4	Mapped SOC name	2013 SOC value [€/ha]
-	*Pšenice*	wheat	P1	Common wheat and spelt	1032
-	*Kukuřice*	maize	P1	Grain maize	1284
-	*Řepice/Řepka*	rape seed	P1	Rape and turnip	1352
-	*Ječmen*	barley	P1	Barley	934
-	*Vojtěška*	alfalfa	P1	Pulses other than peas, field beans and sweet lupines	610
-	*Tráva*	grass	P4	Permanent grassland and meadow - pasture and meadow	150
-	*Jetel*	clover	P2	Pulses other than peas, field beans and sweet lupines	610

-	*Hrách*	pea	P1	Peas, field beans and sweet lupines	610
-	*Žito*	rye	P1	Rye	858
-	*Slunečnice*	sunflower	P1	Sunflower	844

7.1.4. Bačka (RS)

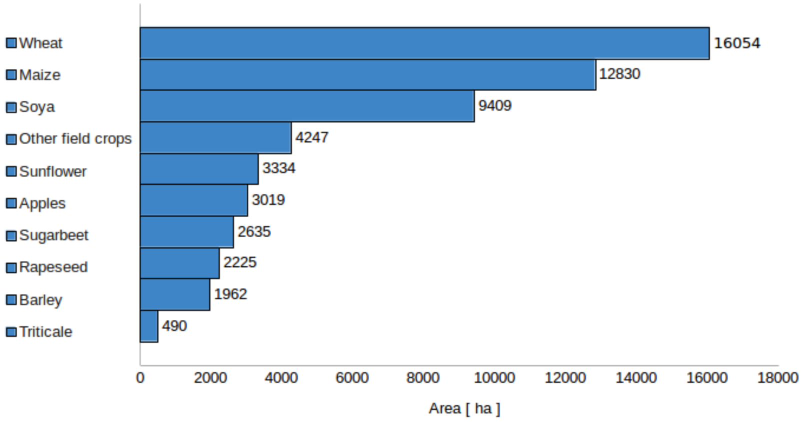

Figure A4: Distribution of the 10 most common crops in the Bačka case study in 2018 (the most representative year in the database).

Table A4: Classification of the 10 most predominant crops in the Bačka case study in 2018 extracted from AgroSens database. One SOC per crop for the whole RS. Source: AgroSens.

Code	Original name	English translation	P1-P4	Mapped SOC name	2013 SOC value [€/ha]
1	Psenica	Wheat	P1	Common wheat and spelt	763
6	Kukuruz	Maize	P1	Grain maize	1115
9	Soja	Soya	P1	Soya	993
303	Ostalo	Other	P1	/	/
10	Suncokret	Sunflower	P1	Sunflower	711
46	Jabuke	Apples	P3	Fruits spices	9100
7	Secerna repa	Sugarbeet	P1	Sugar beet	1469
8	Uljana repica	Rapeseed	P1	Rapeseed and turnip	919
2	Jecam	Barley	P1	Barley	538
	Tritikala	Triticale	P1		829

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7.1.5. Catalonia (ES)

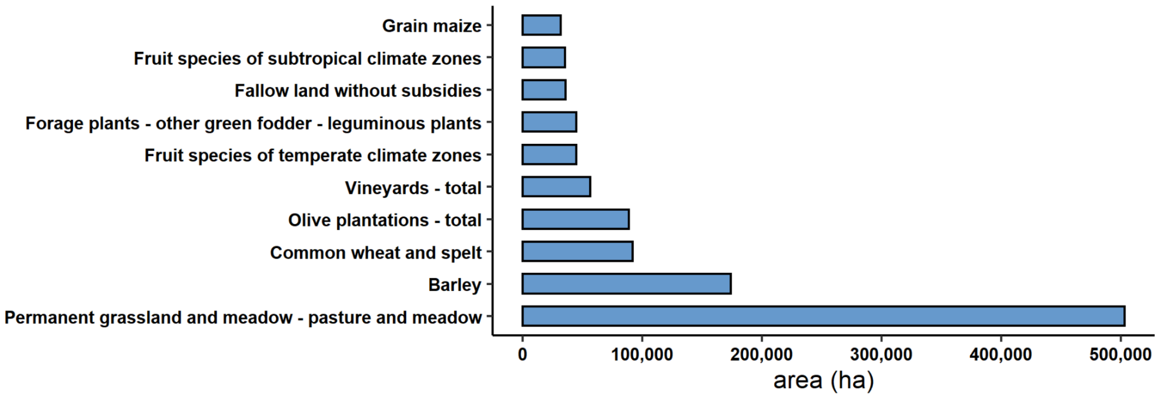

Figure A5: Distribution of the 10 most common crops in the Catalonia case study in 2018.

Table A5: Classification of the 10 most predominant crops in the Catalonia case study in 2019. Exact SOC value depends on the NUTs region a field parcel belongs to (source: DARP and Eurostat).

Code	Original name	English translation	P1-P4	Mapped SOC name	2013 SOC value [€/ha]
5	*Ordi*	Barley	P1	Barley	719
101	*Oliveres*	Olive tree	P3	Olive plantations - oil production	355
1	*Blat tou*	Soft Wheat	P1	Common wheat and spelt	861
102	*Vinyes*	Vineyard	P3	Vineyards-quality wine	2803
4	*Blat de moro*	Corn	P1	Grain maize	2040
104	*Ametllers*	Almond trees	P3	Fruit and berry plantations - nuts	1027
8	*Civada*	Oat	P1	Oats	393
80	*Arròs*	Rice fields	P1	Rice	1811
918	*Alfals*	Alfalfa	P4	Forage plants - other green fodder - leguminous plants	2730
69	*Ray-Grass*	Rye Grass	P4	Forage plants - temporary grass	775

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7.2. Alternative classification of the economic size class

Alternatively to our approach to merge the 6 FADN economic classes to three (and adding a '<2000€' class) we explored the possibility of keeping these 6 classes. In the following we show the maps resulting from that approach exemplarily for Bačka and South Moravia.

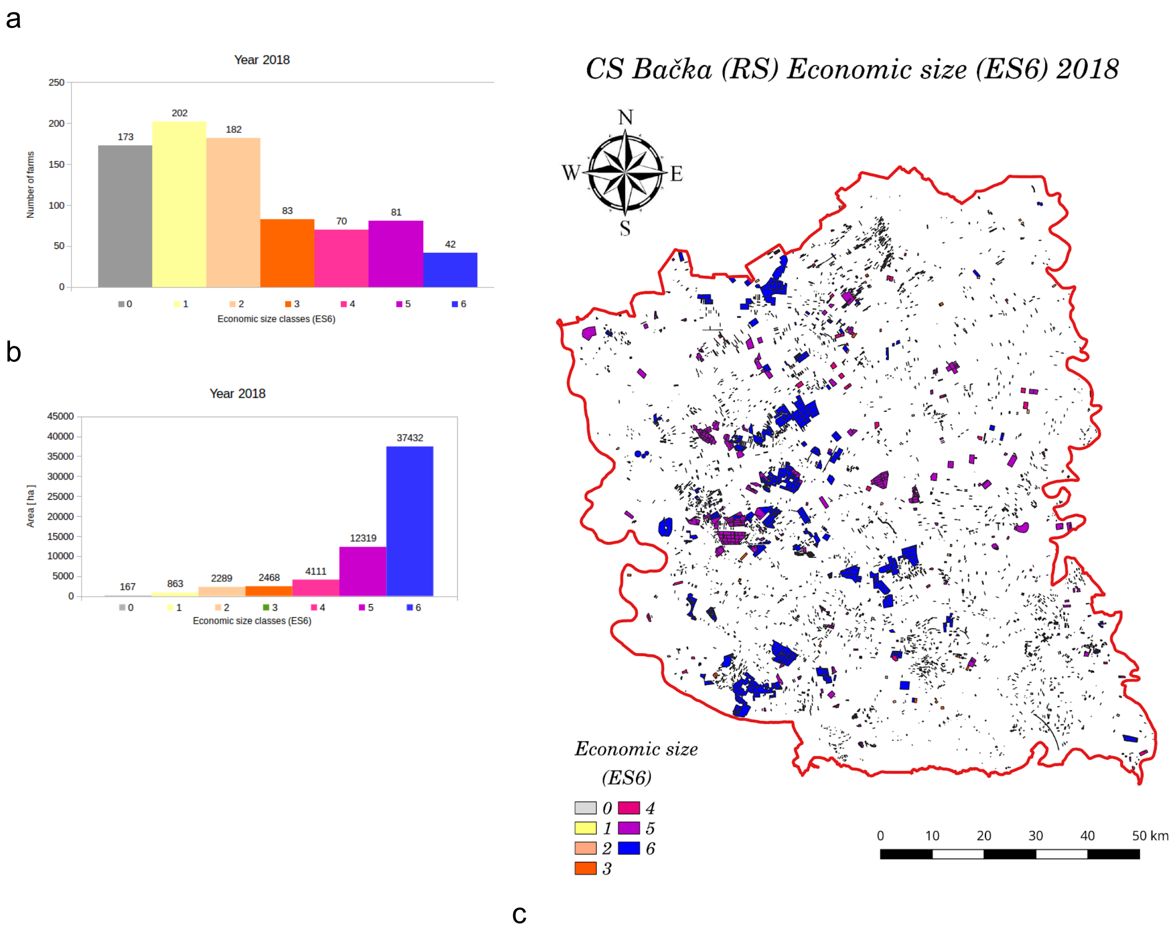

Figure A6: Economic size class (ES6) for Bačka (RS). a) number of farms in each class b) area covered with each class. c) map of the classes.

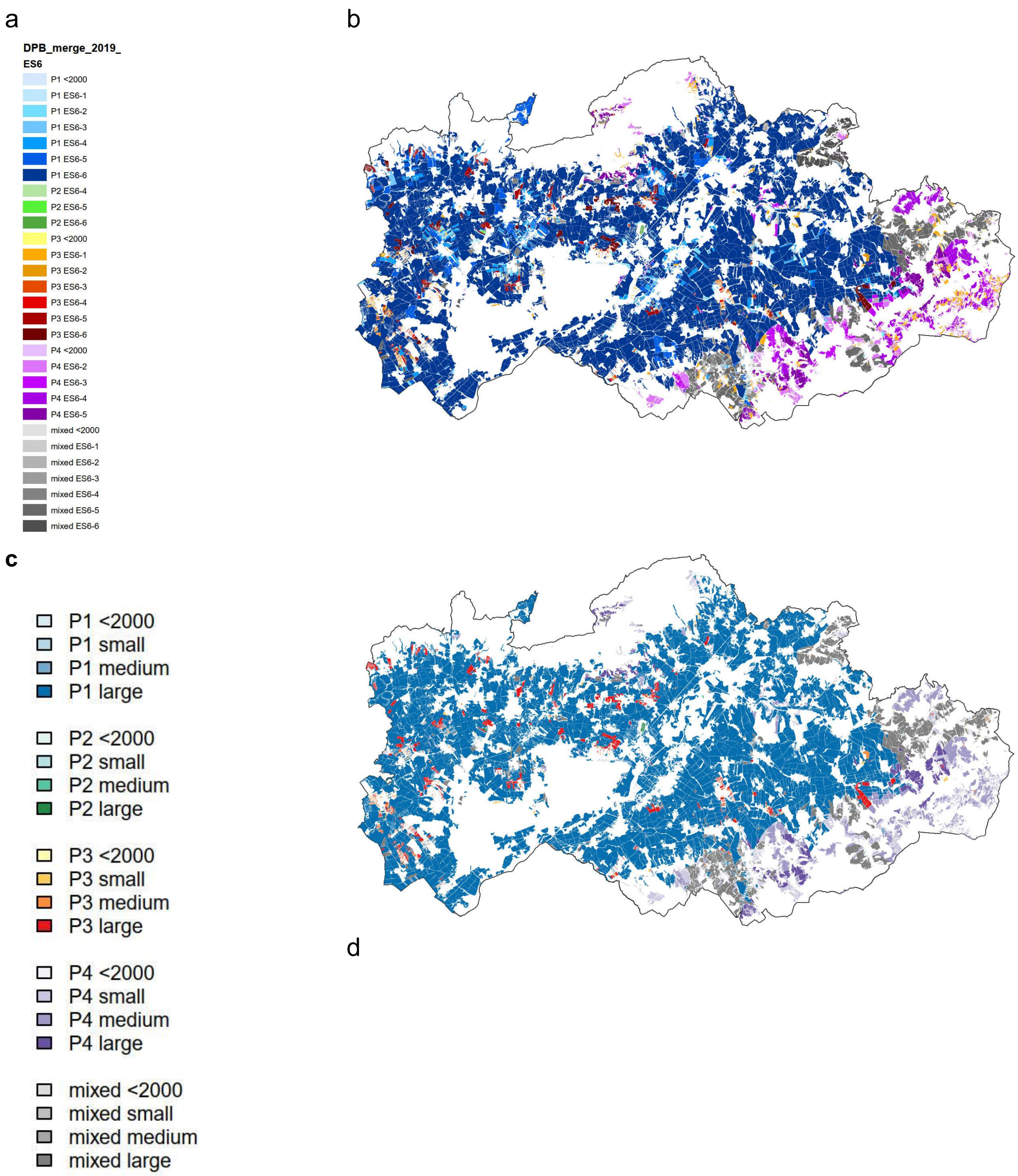

Figure A7: Farming system archetypes. (a,b) with a reduced number of economic classes (as above) and (c,d) including all 6 ES6 classes for South Moravia (CZ).

7.3. Stability of FSA in the Humber

Stability of the number or farms within each FSA was investigated in the UK CS, see Figure A8. Whereas this does not demonstrate whether each farm itself was consistently within the same FSA, it does show the stability of the frequency of the farms within each FSA.

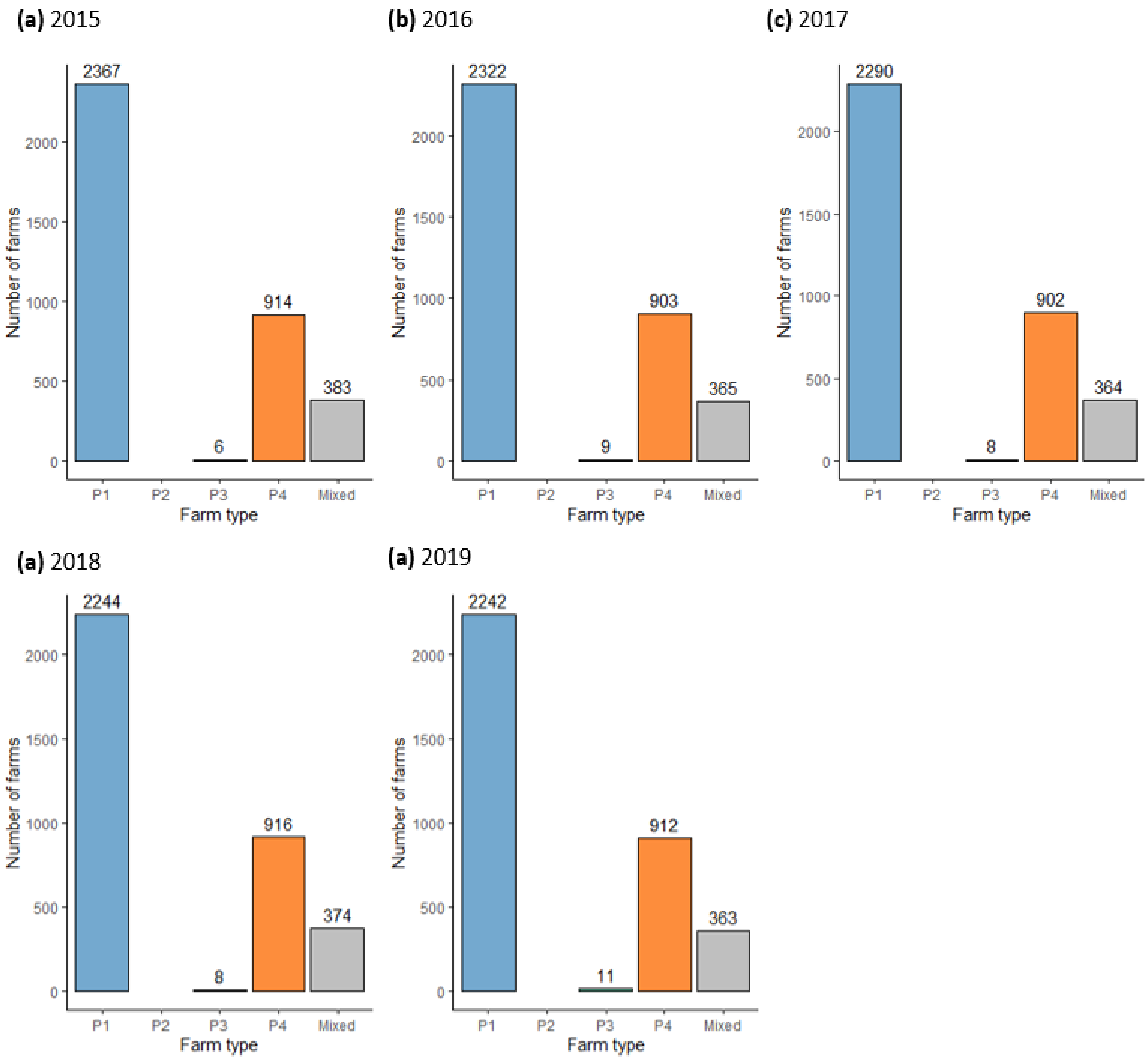

Figure A8: FSA stability in the Humber CS between 2015 and 2019. Panels (a) - (b) demonstrate the FSA stability in the Humber CS.