GenTORE

Genomic management Tools to Optimise Resilience and Efficiency

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Expected challenges to the resilience and efficiency of cattle farming in various European regions – stakeholder views and analysis

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- ☐ **CO:** Confidential, only for members of the consortium (including the Commission Services)
- ☐ **CI:** Classified, as referred to in Commission Decision 2001/844/EC

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Summary

The need for resilient animal production systems is clear and increasingly urgent. In order to achieve an optimal trade-off between resilience and efficiency, tailored solutions to optimizing resilience and efficiency are needed, and these will differ according to the local production environment. The different local livestock systems have social, economic and ecological characteristics, functions and dependencies, within which they display resilience and efficiency in various definitions. At the same time the different system levels are the environments within which the cattle live, perform more or less efficiently and against which they have to develop their specific forms of resilience.

This analysis put the question of resilience and efficiency on the environmental level; the main question we asked was: do the systems and regions, as we defined them, differ in (economic) resilience and efficiency? And a subsequent, still open, question will be: do resilience and efficiency interact between the scales (e.g. to which extent is farm resilience a function of cow resilience? etc.). Secondly, the farming systems are largely influenced by socio-economic factors, thus, the people are very much part of the environment. Therefore, task T1.2 aims at analysing the stakeholders' views on resilience and efficiency across the different European regions.

Stakeholder survey

Resilience is a complex characteristic, which regards a combination of biological processes within an animal, together with best practice in husbandry and management. And so, in order to foster resilience, efforts must be made in both breeding for appropriate traits (and trait complexes) and management to limit the impacts of sustainability challenges. Across the sector, there is a clear requirement for cattle to efficiently convert resources into product, but it is less clear to what extent the perceived antagonisms between resilience and efficiency are likely to hamper strategies focussed on gains in both areas.

We used an online survey to understand the perceived benefits and barriers to genetic improvement, along with anticipated system challenges. We also sought to understand the most favoured traits (and potential antagonisms) in the contexts of resilient production and efficient production using a discrete choice framework. Finally, following an earlier face-to-face survey conducted with Spanish beef farmers, we asked stakeholders across Europe about the most effective management actions towards resilience and efficiency.

The survey was promoted to cattle system stakeholders across Europe, following a snowball sampling approach. The survey was live for 5-weeks from early March to mid-April 2019. We received 123 complete responses, mostly from stakeholders who identified as either researchers, veterinarians, consultants, breeders working for breeding organisations, and farmers. Additionally, most of the respondents had been involved with their profession for more than 10-years – indicating a knowledgeable sample population.

From the results, we understand that, although there is high confidence in the ability of genetic improvement technologies to promote resilient and efficient production, as it stands, the way we are selecting cattle may not be optimal towards this goal. Underlying this statement, we

see that further barriers to genetic progress stem from issues of phenotyping, perceived cost-effectiveness, uncertainty of future production circumstances, and disagreement with the priorities of breeding societies. We also see differences in management actions perceived to be important for maintaining each resilient and efficient production.

From results of the discrete choice experiment, we see that stakeholder preference for traits in cattle breeding goals are quite similar across Europe, suggesting regional drivers of preference may not be so clear as originally thought; this is especially true in the dairy context, for which we had most survey responses. Furthermore, results suggest that, in stakeholders' perceptions, there are antagonisms between traits that support resilient production and those that support efficient production. This re-enforces the importance of considering efficiency over a period that is relevant to ensure gains are sustainable (Friggens *et al.*, 2017) and appropriate to future production circumstances.

Spanish cattle farmer survey

In order to determine the factors contributing to efficiency (at the cow and the farm levels), the resilience of suckler cattle farming systems in Mediterranean mountain areas and their long-term evolution, a survey was conducted in three valleys of the Central Spanish Pyrenees (Broto, Baliera-Barrabés and Benasque). With the aim of analysing the dynamics of these farms, a constant sample of cattle farms located in the valleys was surveyed in 1990 (101 farms), 2004 (71 farms) and 2018 (54 remaining farms). Data were obtained by means of direct interviews with farmers, using a fully structured questionnaire.

The questionnaire included two specific sections addressing animal efficiency and resilience. Farmers were presented with a set of traits and asked to score their relative importance in order to define the efficiency of their cows, by using a 1-5 Likert scale. The traits considered were age at first calving, calving ease, fertility, cumulative number of weaned calves, calf weight at birth, at 90 days and at weaning, calf carcass conformation, cow size, cow udder conformation, feet and legs morphology, docility and use of low quality feedstuffs (and others if considered necessary). Farmers were also asked if they actually registered these traits, and if they provided the information to any breeder association.

Our results indicate that despite 85% of the farmers belonged to breeder associations only 21% of them delivered data for their breeding programmes. In fact, data were registered by relatively few farmers (age at first calving by 51%, fertility and calf birth weight by 32%, calving ease by 30%, calf weaning weight by 9%), mainly in large farms (> 65 cows) but irrespectively of major cow breed (autochthonous vs. imported specialized beef breed) or type of marketed product (weaned or fattened calf).

Despite the low recording rates, most of these traits were regarded as important or very important to determine cow efficiency, with the highest scores given to calving ease (4.9), fertility (4.6) and docility, udder conformation and cumulative number of weaned calves (4.3). Adult leg (4.2) and calf birth weight and beef conformation (4.0) were also considered important. Surprisingly, calf weight at 90 days (3.7, related to dam's milk yield) and at weaning (3.6) were scored lower

The results of this survey show a gap in Mediterranean beef cattle systems between the farmer's perceptions of relevant breeding traits for resilience and efficiency and their activity to record them within associations' breeding schemes. Consequently, less the definition of traits than the encouragement and organisation of farmers to actively join breeding programmes is the challenge to improvements in the aimed direction.

Farm efficiency and resilience data assessment

An analysis of farm efficiency and resilience using economic and production data was undertaken using a newly generated farm production environment dataset comprising dairy (141,961) and beef (54,417) systems. To allow a deeper analysis of the effects of production environment, the Farm Accountancy Data Network (FADN) dataset was spatially linked to the Gridded Agro-Meteorological Data in Europe (AGRI4CAST) data at a NUTS 2 regional scale. European climatic zones have previously been developed, but integrating these classifications with the FADN data that only provides an approximate geographical location for each farm (the NUTS 2 region) has not been undertaken. The Latent Class Analysis (LCA) process is a robust and standardised method used to split data into more homogenous groups and was utilised to assign a climate class at a NUTS 2 regional scale. These climatic zones were further divided into different farm types using a farm typology, based on the forage type proportions of the farm area (grass, grass-mixed, mixed) and the stocking density to identify feedlot/indoor systems (industrial). The basic typology provided 4 lowland (grass, grass-mixed, mixed and industrial) and 2 upland (mountain and industrial) types.

Efficiency scores were calculated for each farm using the Cobb-Douglas production function, in Stata software using the frontier function and exponential distribution. The output considered was the revenue expressed in € per dairy cow or beef livestock unit. Therefore, the technical efficiency measured the ability of the farm to generate a given revenue, using the least inputs. Drivers of efficiency were then subsequently analysed and presented.

The economic resilience was also calculated for individual farms, based on the margin difference (€) from one year to the next from 2005 to 2013 and then averaged by region and / or farm type. A value above 0 indicated resilience, and the margin difference was analysed over the period from 2005 to 2013 but also more specifically in some years where important changes were identified. A further step aimed to identify challenges to resilience, through the utilisation of a linear interactive model. Therefore, the model identifies the factors of variability in margin over time; which can be economic (shock in the price), meteorological, or more structural factors like the specialisation rate, though small sample sizes could not be calculated with ~<250 farms.

Dairy:

Our analysis shows that the European dairy sector is very efficient at >=90%, (using the Cobb Douglas production function to calculate return from input). When considered under the same frontier, it is implicitly assumed that the regions can achieve the same performance, however given that climatic and other factors are very different across Europe, climatic regions were subsequently assessed individually. Performance between regions with the average milk yield per cow as the main trait, ranged from less than 6000 kg (North Atlantic region) up to more than 8000 kg (Boreal region; Table 1). The cost structure is also very variable, reflecting different input levels, and feed sources. In the forage based regions purchased feed costs are lower and forage costs higher, whereas in the Mediterranean region feed costs are much greater, with 50% lower forage costs per cow. As a result, the highest margins were achieved in the Boreal region, the lowest in the North Atlantic region.

Table 1 European regional dairy farm efficiency and key variables

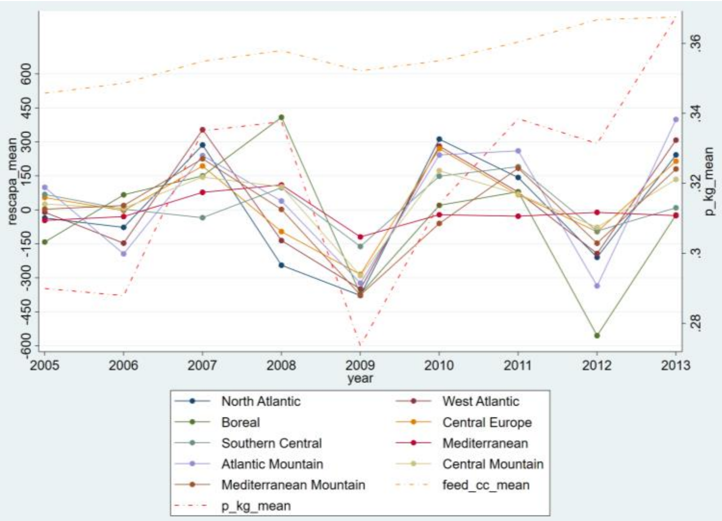
Climatic region	Value	Common frontier	Specific frontier	Milk yield /cow (kg)	Revenue /cow (€)	Feed cost /cow (€)	Forage cost/ cow (€)	Margin / cow (€)	n
North Atlantic	mean	0.98	0.89	5932	1736	520	115	826	6952
	sd	0.01	0.07	1457	533	291	50	354	
West Atlantic	mean	0.95	0.86	7227	2340	674	131	1220	38555
	sd	0.02	0.11	1642	644	407	83	507	
Atlantic Mountain	mean	0.96	0.93	7105	2227	569	126	1225	244
	sd	0.01	0.05	1350	538	391	84	470	
Boreal	mean	0.90	0.89	8353	3193	1043	151	1532	3966
	sd	0.03	0.10	1353	658	523	87	666	
Central Europe	mean	0.89	0.87	6102	1808	544	103	926	53126
	sd	0.07	0.10	1724	725	335	75	498	
Central Mountain	mean	0.96	0.89	5879	2083	655	54	1093	10983
	sd	0.03	0.08	1679	740	442	62	595	
Southern Central Europe	mean	0.94	0.87	6556	2307	990	93	1024	8866
	sd	0.04	0.10	1884	921	511	79	750	
Mediterra-nean	mean	0.96	0.92	6330	2281	1102	61	963	4897
	sd	0.02	0.05	2130	860	604	73	683	
Mediterran ean Mountain	mean	0.96	0.91	6223	2132	897	55	1003	3292
	sd	0.02	0.06	1881	788	463	56	669	

When examining the key drivers of efficiency, Table 2 shows the Atlantic climatic zone as an example. The analysis found the stocking density and dairy specialisation to be the most important factors in favour of efficiency, whilst other determinants such as farm size and even increased incidence of summer heat, are generally positively significant but the coefficients were small, so they have a minimal influence. The drought in spring and summer has a positive effect in North Atlantic and Atlantic Mountain regions, possibly reflecting the increase in solar gain compared to the typically cooler and damp climates of these regions. However, in the West Atlantic region drought in spring and summer has a negative effect. The year also has a negative effect on efficiency, indicating a decline in efficiency over time, possibly due to decreasing margins over feed costs, or difficulties in adapting to structural changes over time.

Table 2 Atlantic zone drivers and challenges to dairy farm efficiency within each farm type assuming a specific frontier

Region	Farm type	n	FSIZE	HRC	FEED	FOR	STOCK	SPEC	MAIZE	GRASS	HEAT	DRY_S PP	DRY_S UM	YR
North Atlantic	GRS	6236	+	-	-	+	+	+	+	-	+	+	+	-
	GMX	625	+	ns	-	ns	ns	+	ns	-	-	+	+	-
West Atlantic	GRS	8466	+	+	ns	+	+	+	+	+	+	-	-	-
	GMX	12306	+	-	+	+	+	+	+	-	+	-	-	-
	IND	1879	+	-	+	+	-	+	ns	ns	+	-	ns	-
	MIX	15903	+	-	+	+		+	-	-	+	-	-	-
Atlantic Mountain	MNT	243	+	ns	+	-	+	ns	ns	ns	+	+	+	ns

Beyond efficiency, when resilience is considered, Figure 1 indicates the evolution of the margin difference annually. When considered at the enterprise or systems level, clearly, the main issue in terms of resilience is of an economic nature. Overall, the margin seems strongly correlated with the price of milk. Most of the regions showed strong parallel alterations, indicating clear reactions to price shocks, but high resilience, meaning they recovered again. This way of interpretation, however leads to conclude a weaker resilience in most of the regions from 2012 on. In contrast, the Mediterranean region reacted less, thus showing clear signs of higher robustness against price shocks compared to the other regions.



(n=93,922; minimum group size=180)

Figure 1 – Dairy farm economic margin resilience of climatic regions over from 2005 to 2013

Beef

The beef sector was analysed separately as suckler (breeder) beef and finisher beef systems, though often the beef finisher sample sizes were too small for a detailed study. Analysis indicates that for both systems, the West Atlantic and Southern Central regions were the most and North Atlantic and Boreal regions the least efficient (Table 3). Beef revenue per beef livestock unit was highest in the West Atlantic and Southern European regions, whilst feed costs were greatest in the Mediterranean region. Forage costs were highest in the Boreal and

North Atlantic regions, with the highest margins achieved in the West Atlantic region, but the Boreal averaging a negative margin during the 10 year study period.

Table 3 Suckler beef efficiency in European regions

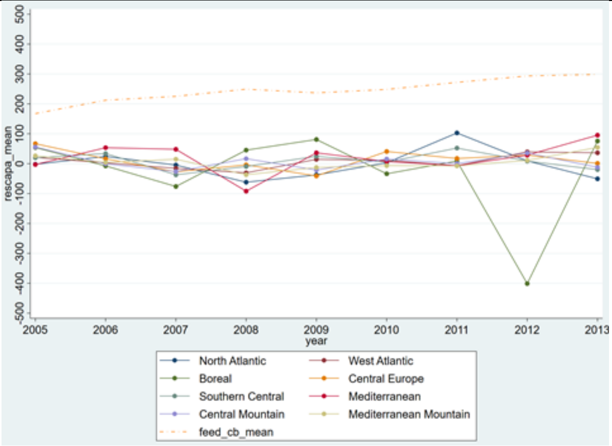
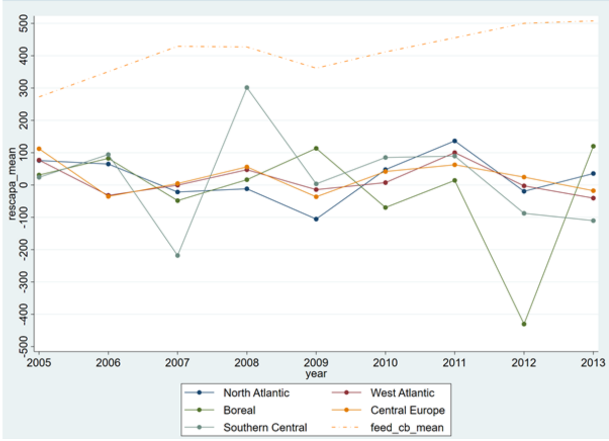
Climatic region	Value	Common frontier	Specific frontier	Revenue /BLU (€)	Feed cost/BLU (€)	Forage cost/BLU (€)	Margin/ BLU(€)	n
North Atlantic	mean	0.72	0.83	555	188	101	114	9454
	sd	0.11	0.10	216	120	60	187	
West Atlantic	mean	0.82	0.80	776	227	93	322	13129
	sd	0.10	0.13	311	179	68	267	
Atlantic Mountain	mean	0.79	0.88	700	171	97	263	135
	sd	0.12	0.14	312	90	80	246	
Boreal	mean	0.75	0.74	659	318	112	-45	492
	sd	0.15	0.16	311	330	84	375	
Central Europe	mean	0.79	0.81	630	224	62	216	7476
	sd	0.12	0.13	260	191	61	280	
Central Mountain	mean	0.80	0.87	662	216	53	258	2053
	sd	0.09	0.11	253	163	57	264	
Southern Central Europe	mean	0.82	0.81	793	324	74	289	2724
	sd	0.11	0.14	377	218	68	345	
Mediterranean	mean	0.76	0.74	634	286	33	256	3306
	sd	0.16	0.16	381	197	57	302	
Mediterranean Mountain	mean	0.77	0.79	636	337	35	173	4459
	sd	0.13	0.13	282	174	58	254	

When examining the key drivers of efficiency in the beef sector, shown in Table 3 below (beef fatteners in the Continental region), the most important factors in favour of efficiency in Central Europe were the farm size and feed expenditure, as well as warm summers, but the year was a negative factor for both farm types shown below. Many factors were not significant in the beef analysis, but it can be seen that for grass-mixed farms the grass % was a positive influence, whilst for mixed farms, increasing grass area impacted negatively on efficiency.

Table 4 Continental region drivers and challenges to beef finisher farm efficiency within each farm type assuming a specific frontier

		n	FSIZE	FEED	FOR	STOCK	SPEC	MAIZE	GRASS	HEAT	DRY_SPR	DRY_SUM	YR
Central Europe	**GMX**	473	+	+	ns	+	ns	ns	+	+	ns	ns	-
	MIX	2196	+	+	+	ns	+	ns	-	+	+	ns	-

When assessing the regional system resilience, Figure 2 indicates the evolution of the margin difference annually for the suckler cow and finisher systems respectively. For both systems the level of variability is limited, especially compared to the sharp changes in the dairy margin during 2009 and 2012. The few more erratic lines are for smaller samples

<table>
<tr><th>Suckler beef</th><th>Finisher beef</th></tr>
<tr><td>
</td><td>
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<tr><td>(n=29,534: minimum sample size=360)</td><td>(n=5,016 minimum sample size=328)</td></tr>
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Figure 2 – Suckler beef farm economic resilience of climatic regions from 2005 to 2013

Conclusions

The presented results are an overview of the manifold and deep perspectives, the combined approaches of analysing the extensive FADN/Agri4cast-based farm database, together with stakeholder engagement through online and direct interviews give us on dairy and beef system performance, as well as breeding aims and objectives.

It is clear from this first data analysis that whilst the European dairy sector has a high efficiency rate, its resilience to economic shocks in particular is low. The beef sector appears to operate at a lower level of efficiency, and in some regions, e.g. Boreal, the margins are often negative. The reasons for these empirical facts can be discovered in the underlying regional, climatic and farming systems' structures, which the database gives excellent opportunity to realise.

Climatic shocks caused a more variable reaction, and were regionally specific, with cooler wetter regions such as North West Atlantic benefiting from increased heat and even drought in the spring. The farm systems of the Mediterranean seemed most of all resilient to increased heat and drought, probably because they are historically adapted to such climates. By contrast, the Western Atlantic region showed a negative effect on efficiency from drought in particular, indicating weak resilience. These differences show, how important the interaction between regional systems' conditions and increasing climatic impacts is. These interactions will be further analysed and sharpened by exploiting the given database.

In summary, it is clear that European cattle production has strong regional and farm system related differences, which define the challenges to efficiency and resilience against them. The analysis is ongoing and will result in a series of publications, quantifying these differences and their meaning to the economic development of the cattle sector across Europe. Finally, this will also result in a clear picture of what is required biologically from a cow that should contribute best to resilience and efficiency of the farm it lives in.

1. Introduction

Modern animal agriculture has many challenges, but with increasing economic pressure as well as societal challenges including climate change, there is an urgent need to balance resilience and efficiency. Whilst at the animal level this is essential for survival, at the farm or enterprise level this is usually more an economic resilience. The balance of resilience and efficiency determines the ability to adapt to changes. The need for resilient production systems is clear and increasingly urgent, and such systems include resilient animals that future farming conditions will expose them to increasing challenges in under different production systems and grazing environments. They also need an ability to recover from challenges like diseases which can vary across environments and farm systems.

In order to achieve an optimal trade-off between resilience and efficiency, tailored solutions to optimizing resilience and efficiency are needed, and these will differ according to the local production environment. What is a production environment though and how can we measure or understand it?

GenTORE as a whole aims at improving resilience and efficiency of cattle by means of genomic advances, thus the main focus is on the levels of animals and genomes. However, these are parts of systems, which are farms, ecosystems, regions. These systems have social, economic and ecological characteristics, functions and dependencies, within which they display resilience and efficiency in various definitions. At the same time the different system levels are the environments within which the cattle live, perform more or less efficiently and against which they have to develop their specific forms of resilience.

The challenges may be manifold: for instance, different production systems require animals that either cope with very high nutrient density promoting high yields or on the opposite with extensive grassland systems, that provide more natural conditions, however with larger alterations in nutritive value of the feeds. Feeding concepts, genetic background, herd sizes, barn systems, milking techniques are further examples for farm-related characteristics on which the cattle with their performance and well-being, i.e. efficiency and resilience depend (Knaus 2009). On a larger scale, climatic conditions are of growing importance (Gauly, Bollwein et al. 2013).This is particularly the case because they are changing, and changing conditions are the more a challenge to a system, the more optimized it was. Adaptation to changes is, for sure, a key feature of robustness or resilience, required for cattle systems with increasing urgency (Friggens, Blanc et al. 2017).

Narrow, performance-targeted breeding goals, especially for dairy cattle, have for decades increased yields, but requiring for that more and more standardized environments (in particular feeds; Knaus, 2009). A broader, more holistic approach requires the inclusion of alterations in conditions , thus, the environment is indispensable part of the approach; this the more because efficiency and resilience are relative rather than absolute values, and relativity needs a function term, which, in this case, is the environment. In order to achieve an optimal trade-off between resilience and efficiency, tailored solutions to optimizing resilience and efficiency are needed, and these will differ according to the local production environment.

What is a production environment though and how can we measure or understand it? The definition and analysis of the environmental factors in order to create terms which can be used in genomic evaluations, is the general target of WP 1. The main approach is therefore looking at European farming systems within geographical regions, taking into account climatic scales like temperatures and humidity. After analysis and processing of respective databases (FADN, (EC, 2019a), Agri4cast, (EC, 2019b), this shall result in geo-climatically based farm typologies, functional as environment-axis in genomic modelling. This is the content of task T1.1; and this deliverable presents the first form of results of this analysis.

The analysis performed put the question of resilience and efficiency on the environmental level; the main question we asked was: do the systems and regions, as we defined them, differ in (economic) resilience and efficiency? And a subsequent, still open, question will be: do resilience and efficiency interact between the scales (e.g. to which extent is farm resilience a function of cow resilience? etc.).

Secondly, the farming systems are largely influenced by socio-economic factors, thus, the people are very much part of the environment. Therefore, task T1.2 aims at analyzing the stakeholders' views on resilience and efficiency across the different European regions. Besides a very regional approach, we decided here to conduct a generalizable standardized web-based stakeholder survey that ensured comparability of the regions and future compatibility with the Europe-wide regional data.

2. Stakeholder opinions

2.1. Stakeholder survey

The stakeholder survey was conducted as part of Task 1.2, with the aim of engaging GenTORE partners and stakeholders towards understanding the breeding and management choices that best support resilient and efficient cattle production across Europe.

Firstly, we were interested in the attitudes- and perception of barriers- to genetic improvement in European cattle systems. From these questions, we aimed to understand whether current within breed breeding goals are perceived to be appropriate, given the multitude of challenges that are anticipated. Additionally, we aimed to understand whether cattle system stakeholders believed current breeding goals to be missing animal characteristics (traits) that are important to efficient and resilient production. Beyond specific traits, we were further interested to understand barriers to genetic improvement, which have the potential to slow the rate of genetic gain, with resultant missed opportunity in terms of economic gains and GHG mitigation.

Secondly, we were interested in the challenges that stakeholders perceived to be most important in their region. We know that cattle production will face many challenges from economic, environmental and social sources, and as such, we aimed to understand the relative importance of these challenges, together with details of specific challenges facing European cattle production. Outlined challenges will inform scenario selection for modelling in WP6.

A substantial part of the survey was allocated to eliciting partner and stakeholder preferences for specific cattle traits in the context of efficient and resilient production, using a discrete choice experiment. We were interested to understand how preferences could be influenced by different challenges. Stakeholders made a series of choices, which reflected the relative importance they assigned to a series of traits, in the contexts of future efficiency and resilience. This method also allows for trade-offs and win-wins in terms of efficient and resilient production to be identified.

Finally, stakeholders identified their preferred management options for efficient and resilient production. This question was intentionally linked to CITAs survey of Spanish mountain cattle farmers in order that comparisons could be made.

The online survey was disseminated by GenTORE partners and affiliated institutions. GenTORE partners encouraged respondents to pass the survey on to additional relevant individuals and organisations, following a snowball sampling procedure. In total, 200 completed responses were returned over a 5-week period (March-April 2019); 114 responded in the context of dairy production, and 86 responded in the context of beef production. Most respondents were either researchers, farmers, consultants, veterinarians or breeders (within a breeding organisation), and most respondents had over 10-years' professional experience.

In the coming pages we will present the results of the survey. Starting with attitudes and barriers at an aggregate level. System challenges will be described at both an aggregate and regionally disaggregated level. Trait preferences will be described at a regionally disaggregated level for each beef and dairy production (sample size permitting).

2.1.1. Aggregated figures

2.1.1.1. Attitudes to genetic improvement tools

The general goal of animal breeding is to produce a new generation of animals that will yield the desired products more efficiently under future farm economic, social and environmental circumstances, and be more resilient to perturbations than the present generation of animals (Groen, 1989). In the development of an effective (within-breed) breeding program, the definition of a breeding goal is one of the most important steps. Breeding goals enable selective breeding on many animal traits simultaneously (using selection indices), and in nations with well-structured cattle industries, across industry breeding goals are common.

We took this opportunity to question stakeholders on the usefulness of breeding goals to support efficient and resilient production in their region, and the potential for breeding goals to contribute to system efficiency and resilience, at all levels. As is clear in Figure 3, European cattle system stakeholders do believe that the use of appropriate breeding goals offer substantial gains in terms of efficient and resilient production, however, currently, all of the traits important to efficiency and resilience are not included in the breeding goals. For beef and dairy production, we see almost identical results. These results underpin the importance of the work being undertaken within the GenTORE project, particularly in WP4&5, towards defining new efficiency and resilience traits, and in WP3, towards identifying novel, on-farm phenotyping strategies for difficult to record traits. The results also support recommendations made in a review of genetic improvement in UK beef cattle, which advises the importance of broadening the scope of traits under improvement, and to improve the understanding and recognition of the value of genetic progress across the industry (Amer *et al.*, 2015). All of which are essential in delivering improved, future-proofed breeding goals.

In addition to questions on the usefulness of current breeding goals, we were also interested to know the system level at which genetic progress is perceived to be most important. As can be seen in Figure 4, there are differences in this perceived importance between beef and dairy production systems. In beef systems, sector, international and national levels are most important, whereas for dairy, most important are international, national and farm levels.

For beef systems, given that a well-structured approach to genetic improvement in beef production is in relative infancy compared with dairy, it is suggested that any advances in the use of genetic improvement tools would be perceived as of benefit to the whole sector. However, there are more 'low hanging fruit' in beef systems, which represent significant untapped potential, e.g. simple structural changes in farm payments and phenotype recording (as in the Scottish Beef Efficiency Scheme (BES), and Irish Beef Environmental Efficiency Scheme (BEES)) (Lamb *et al.*, 2016). Whereas, in dairy systems, which are more developed in genetic improvement, the use of region (even farm) specific genetic improvement options, that could capitalise on genetic-by-environment interactions, are seen to be more important.

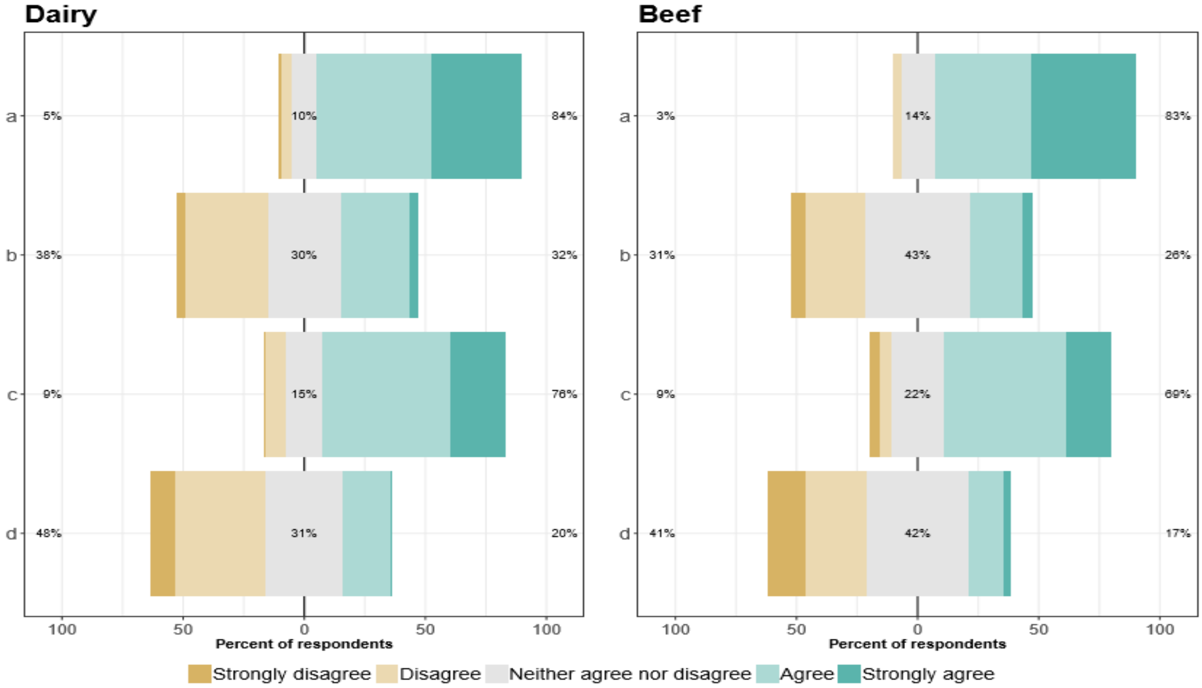


Figure 3 Plot of Likert responses to the following statements regarding attitudes to genetic improvement in dairy and beef systems: (a) the use of appropriate breeding goals offers substantial gains in terms of efficiency in European cattle production. (b) All of the traits that are important to efficiency are included in the breeding goal(s) of my region. (c) The use of appropriate breeding goals offers substantial gains in terms of resilience in European cattle production. (d) All of the traits that are important to resilience are included in the breeding goal(s) of my region.

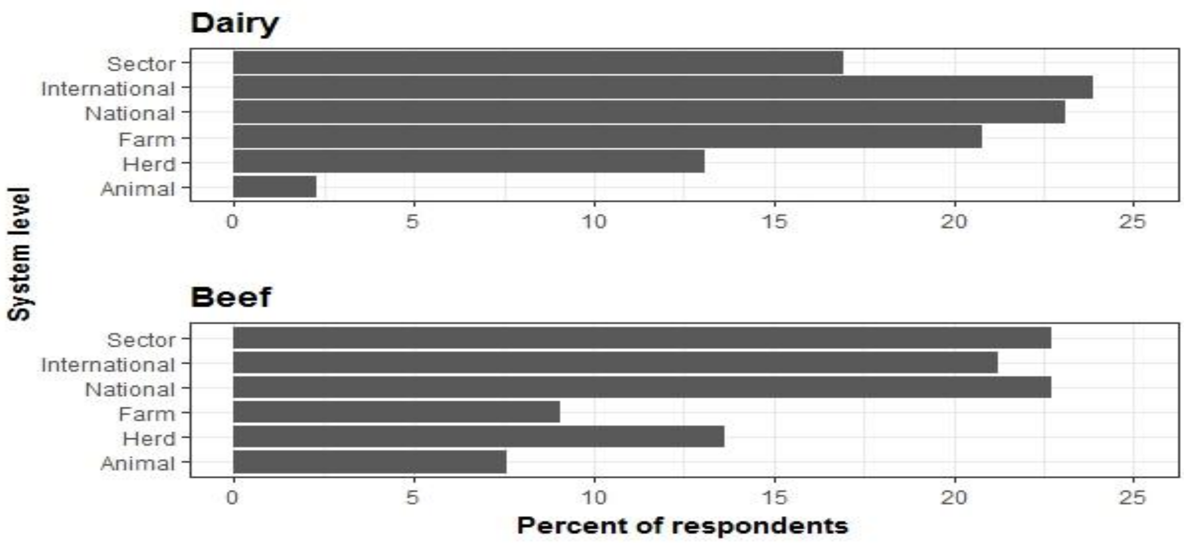


Figure 4 These figures indicate the proportion of respondents that consider genetic improvement tools to be most useful at a particular system level. Each respondent selected one system level. System levels are ordered hierarchically.

2.1.2. Barriers to genetic improvement

Now that we have identified the important role that breeding goals and genetic improvement can play in supporting efficient and resilient production, we were interested to understand the barriers that may be inhibiting our ability to mitigate against system challenges with effective genetic improvement tools.

We know that improving the rate of genetic gain relies on identifying and mating cattle with reliable estimates of high genetic merit. The rate of gain will be greater where there is large variation in a population. And the sooner we have this reliable information, the sooner cattle can be bred for the next generation. This seems simple enough, and with genetic progress providing cumulative and permanent improvements, there is significant scope for mitigating system challenges, increasing economic return, and reducing the emissions intensity of production. However, barriers exist to genetic progress, and we took this opportunity to ask stakeholders what they perceive to be the greatest barriers to genetic improvement of dairy and beef animals.

As is evident in Figure 5, the main barriers to genetic improvement, as perceived by stakeholders, were similar. Four of the top five barriers for beef and dairy systems were the same: (i) performance recording (phenotyping), (ii) uncertainty of future production circumstances, (iii) disagreement with breed society priorities, and (iv) cost for farmer. There may be some linkages in the barriers, for example, between phenotyping and cost for farmer, the value returned from time and cost spent recording trait performance may not be seen until that data is used to select the next generation of animals, and even then, it may be more time before the improvement materialises, depending on the trait. This furthers the importance of integrating the process, for example, with the aforementioned payment schemes (BES, BEES). Additionally, to circumvent the reliance on on-farm phenotyping, links with industry should be exploited, for example disease traits using abattoir data, and meat quality traits utilising supermarket engagement.

There are two barriers which differ substantially between beef and dairy systems; (i) lack of reward for improved animals, and (ii) inclusion of non-market traits. One reason for the perceived lack of reward for improved animals in beef production is likely to be a product of market failures in some areas of Europe. For example, in Spanish mountain beef production, beef cattle are often sold in groups, meaning the sale value relates to the average performance across a number of animals, which may dilute the individual value of improved animals. Hence, market failures such as this should be addressed in order to encourage uptake of genetic improvement tools, and so improve the rate of genetic gain.

For dairy production, the lack of inclusion of non-market traits is perceived to be a substantial barrier to genetic improvement. One reason for this may be the difficulty of including traits that are beneficial to the system, but have no direct economic value (particularly at farm-level); for example, traits such as methane emissions. Genetic parameters are well understand for methane emissions, particularly in dairy cattle, but including this is the breeding goal is problematic due to the difficulty in deriving economic value, which are necessary for the standard economic framework of selection indices. For traits that have no clear or direct monetary value, restricted or desired gains approaches to deriving weighting factors that reflect the desired improvement in the trait can be used. However, the difficulty here is in developing a robust way of deciding the desired improvement in the long term.

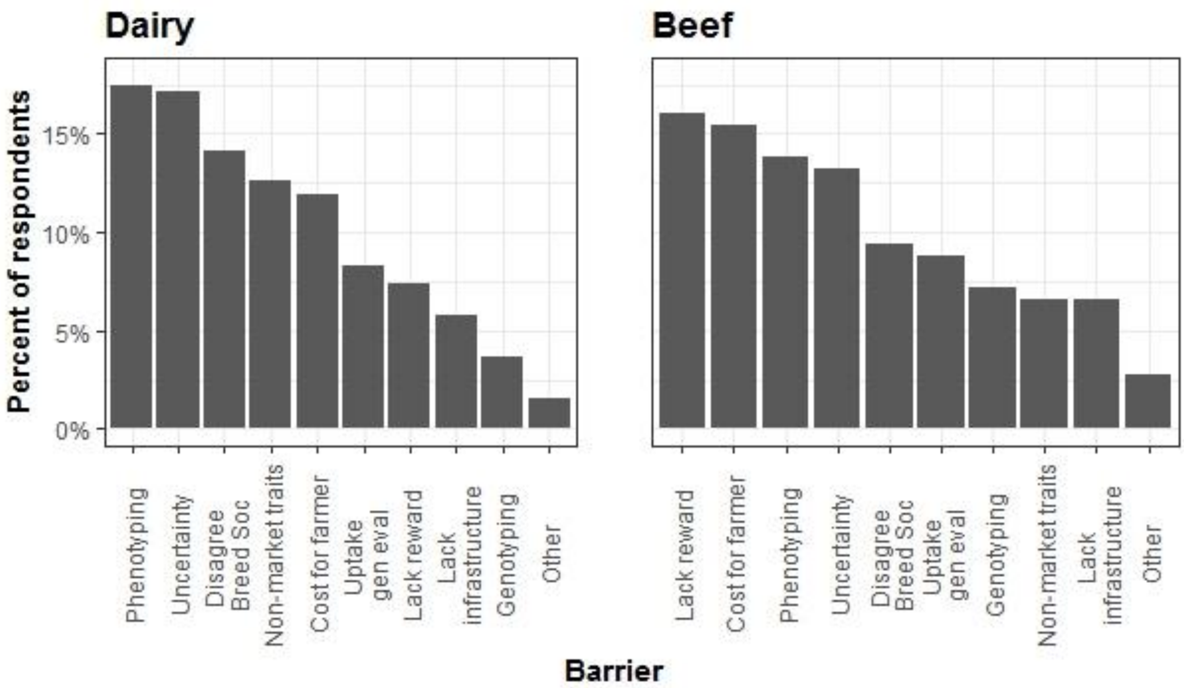


Figure 5 The main barriers to genetic improvement technologies in dairy and beef systems. X-axis labels are shortened for aesthetic reasons, but refer to the following (as they appeared on the survey): Performance records (phenotyping), uncertainty of future production circumstances, disagreement with breed society priorities, inclusion of non-market traits, cost for farmer, uptake of genetic evaluation tools, lack of reward for better animals, lack of central infrastructure, genetic records (genotyping). Respondents could select more than one barrier.

2.1.3. Regionally disaggregated analysis

2.1.3.1. Challenges

There are many challenges facing cattle production across Europe and, in order to remain competitive, cattle and cattle enterprises must be resilient to these challenges and maintain efficient production. Understanding these challenges will enable us to define scenarios of future production circumstances in order to understand the mitigation potential of different breeding and management strategies.

As part of the Stakeholder Survey we asked respondents to identify the source of challenges likely to be most pressing in future production. Respondents could select between economic pressures, environmental pressures and social pressures; descriptive statistics can be seen in Figure 6. Following this, we asked respondents to expand on some of the key challenges in these categories, with further details in an open format. We used a directed content analysis of these open responses (following Hsieh & Shannon, 2005), in which we sort statements according to the pre-defined categories: economic, environmental and social pressures. These categories are then sub-divided according to common themes that arise in the statements. A summary of the key themes arising from these open responses are given in Table 5 and Table 6, for dairy and beef systems, respectively.

Figure 6 shows that for dairy production in Alpine, Atlantic and Southern regions, environmental pressures were deemed to be the source of substantial challenges. For dairy production in Continental and Northern regions, and beef production in Atlantic region, economic pressures were deemed to be the source of the most substantial challenges. Only for beef production in Southern region were social challenges deemed to be the source of the most substantial challenges.

In terms of open responses, the most commonly mentioned challenge for dairy production was animal welfare (16% of overall comments), followed by emissions and environmental degradation (15% of overall comments); for beef production, most common was economic efficiency (15%) followed by emissions and environmental degradation (13%). This regard for issues that may drive negative association of both production systems may reflect the increasing and negative media that both sectors are currently facing, a comment that was also commonly mentioned (dairy: 10%, beef: 11%). Further to this, it is clear that the combined influence of vegans and veganism (dairy: 4%, beef: 4%) and demand/consumption (dairy: 4%, beef: 7%) present an additional challenge reflecting an on-going consumer trend.

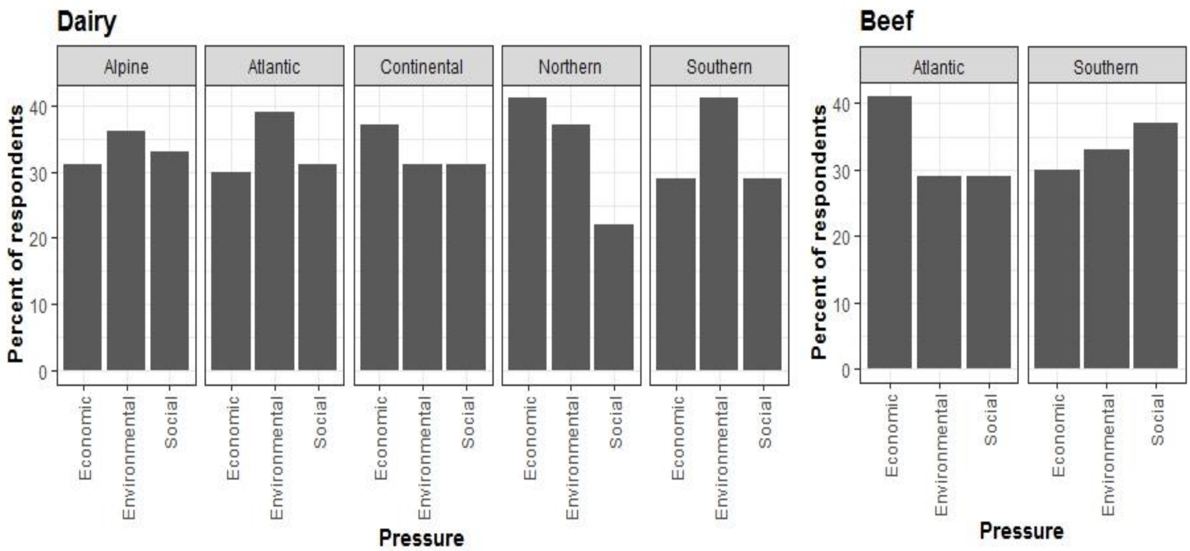


Figure 6 Regional disaggregation of challenges facing dairy and beef production in Europe. Only regions with >10 respondents were included. Respondents could select more than one source of pressure. More specific details of challenges given in Table 5 and Table 6 (overleaf).

Climate change (dairy: 11%, beef: 7%) and associated impacts, such as forage/fodder availability (dairy: 7%, beef: 5%) were also considerable themes for both systems. Reflecting this anticipated low forage/fodder availability, resource efficiency was a similarly important theme for both systems (dairy: 5%, beef: 5%).

Profit was more commonly mentioned in relation to dairy production, compared with beef (dairy: 6%, beef: 2%), where respondents answering for beef production were more concerned with economic efficiency (dairy: 5%, beef: 15%), possibly related to over-reliance on subsidy. However, for both systems, market uncertainty presents a similar challenge (dairy: 5%, beef: 5%), with issues such as uncertainty in longer term commodity prices furthering the problem.

Table 5 Challenges to the EU dairy sector. The main themes of economic, environmental and social pressures were used as the basis for a directed content analysis of comments (following Hsieh & Shannon, 2005). Percentage of overall mentions is given for each theme along with an example comment. There were 123 comment in total.

Source	Sub-group	%	Example comment
Economic	Profit	6	"The economic viability of the farms is the major challenge, if the activity is no longer profitable it is the end of breeding!"
	Resource efficiency	5	"Use of water resources"
	Economic efficiency	5	"…the ability to adapt to other demands (social and environmental)…in my opinion, will be surmountable in the future, if we maintain [economic] efficiency"
	Market uncertainty	5	"The variability in the global market relative to animal products can lead to extreme economic variability and associated pressures seen on farm"
	Output price	4	"Consumers have become accustomed to food being cheap…Changing this mind-set will be a major challenge!"
	Lack integrated supply chains	3	"Pressure of food chain on prices at farm level"
Environmental	Emissions & environmental degradation	15	"pollution Methane emissions [*sic*]"
	Climate change	11	"Climate changes that will lead to greater thermal stresses and water shortage"
	Forage/fodder availability	7	"With regard to fodder…the quantities available and the qualities harvested"
	Parasites & disease	1	"parasites, disease pressure"
Social	Animal welfare	16	"High demands on animal welfare [are] good but cost…must be replaced"
	Counteracting negative media	10	"Social pressure on farmers from the point of view of animal welfare, there is need for a real and better communication on breeding methods to the general public."
	Vegans & veganism	4	"Rejection of the consumption of animal products by the younger generations."
	Demand & consumption	4	"Competition from plant-based protein"

Table 6 Challenges to the EU beef sector. The main themes of economic, environmental and social pressures were used as the basis for a directed content analysis of comments (following Hsieh & Shannon, 2005). Percentage of overall mentions is given for each theme, along with an example comment. There were 60 comments in total.

Source	Sub-group	%	Example comment
Economic	Economic efficiency	15	"Reduce production costs while maintaining high quality standards"
	Lack integrated supply chains	6	"Supply chain sustainability"
	Market uncertainty	5	"Brexit, depending on whether and what form it takes, will be a major disruption to cattle trade"
	Resource efficiency	5	"Producing more from less (improving output without increasing resources)"
	Profit	2	"the most important challenge is the net profit, which has declined more and more over the years. without [profit], other challenges cannot be overcome"
Environmental	Emissions & environmental degradation	13	"Political (and public) pressure to reduce the impact of beef cattle production on the environment will influence production systems"
	Climate change	6	"Climate variability and uncertainty will affect the availability of resources of all kinds."
	Forage/fodder availability	5	"…variability of forage availability"
	Parasites & disease	4	"…different disease challenges"
Social	Counteracting negative media	11	"…general misinformation, in particular through new media, on the real activities of beef production and animal husbandry management"
	Animal welfare	7	NA
	Demand & consumption	7	"Reduction of the consumption of products of animal origin in the EU."
	Health & disease	5	"Antibiotic free"
	Vegans & veganism	4	"Vociferous Vegan lobby [*sic*]"

2.1.4. Relative preference for traits

A substantial section of the survey sought to elicit stakeholder preference for traits in dairy and beef breeding goals in the context of efficient and resilient production. This work built on two earlier engagements with GenTORE partners and stakeholders. Additionally, we capitalised on discussion on the stakeholder e-platform, and literature review to define eight traits for each beef and dairy cattle. From this, we used an experimental approach following a discrete choice framework to elicit the relative utility of stakeholders in each of the five pedo-climatic regions of Europe for each of the traits (Metzger *et al*., 2005). We tasked respondents with making choices that supported either efficient production or resilient production. In this way, we aimed to identify win-wins and trade-offs.

Full details of the method are available in the appendix. However, the method followed a Best-Worst Scaling (BWS) approach, which is a form of discrete choice experiment (DCE), in which respondents make repeated choices, selecting the best and worst trait relative from a subset of four traits (a choice set), in the context of resilient production and efficient production (Louviere *et al.*, 2015). The BWS approach differs from alternative choice-based conjoint methods, in which respondents may only be required to select the best item in each choice set or may be required to rank all items in each choice set. While the former completely ignores information on the less attractive items, which affects the discriminatory power of the approach, especially for those traits that may not regularly be chosen as best, the latter can be highly cognitively demanding for respondents, especially when repeated over several choice sets. BWS addresses these limitations by capturing some information on the non-chosen traits, thus improving the accuracy of more conventional DCEs without overburdening respondents with unnecessarily complex tasks (Louviere *et al.*, 2015).

In each choice set, respondents were given three pieces of information, for each of the four options: (i) the general trait group (e.g. fertility, health, etc.), (ii) the specific trait (see Table 7), and (iii) a possible improvement in the trait, assuming 10-years of selection on that trait alone (see section 8.3.1 for details on estimating response to selection). Over 14-choice sets, respondents selected the best and worst trait for efficient production or resilient production. The number of times each trait is selected as best or worst gives a strong indication of the value a respondent places on that trait; full details on the approach can be found in section 8.3.

Table 7 The eight traits that were used for the BWS choice experiment. The initialism/abbreviation in brackets relates to Figure 7 Relative preference for traits by region of respondent for Dairy (left) and Beef (right), in terms of efficient and resilient production. A reference is also given for the genetic parameters used to calculate the possible improvement for each trait.

System	Trait	Reference for genetic parameters
Dairy	Protein yield (PY)	Pritchard *et al.*, 2013
	Calving ease (CD)	Eaglen *et al.*, 2012
	Calving interval (CI)	Pritchard *et al.*, 2013
	Residual Feed Intake (RFI)	Pryce *et al.*, 2015
	Days of productive life (Longevity)	Pritchard *et al.*, 2013
	Methane emissions (Emissions)	Lassen & Lovendahl 2016
	Mastitis resistance (Mast)	Pritchard *et al.*, 2013
	Heat tolerance	Nguyen *et al.*, 2016
Beef	Average daily gain (ADG)	Crowley *et al.*, 2010
	Calving ease (CD)	Roughsedge *et al.*, 2005
	Calving interval (CI)	Roughsedge *et al.*, 2005
	Residual Feed Intake (RFI)	Bouquet *et al.*, 2010
	Carcass weight (CW)	Berry & Evans, 2014
	Bovine respiratory disease resistance (BRD)	Snowder *et al.*, 2012
	Methane emissions (Emissions)	Donoghue *et al.*, 2013
	Heat tolerance (THI)	See method

The results of the choice experiment can be seen in Figure 7. On the vertical axis, mean-BW is a standardised score, a positive value means a trait was selected as best more times than selected as worst (a negative value means the opposite is true), the metric is explained fully in Section 8.3. Across all four facets, each trait was selected as either best or worst between 17 – 157 times; thus, although some traits have received a mean-BW score approximate to zero, this is because they were selected equally as best and worst rather than not being selected at all.

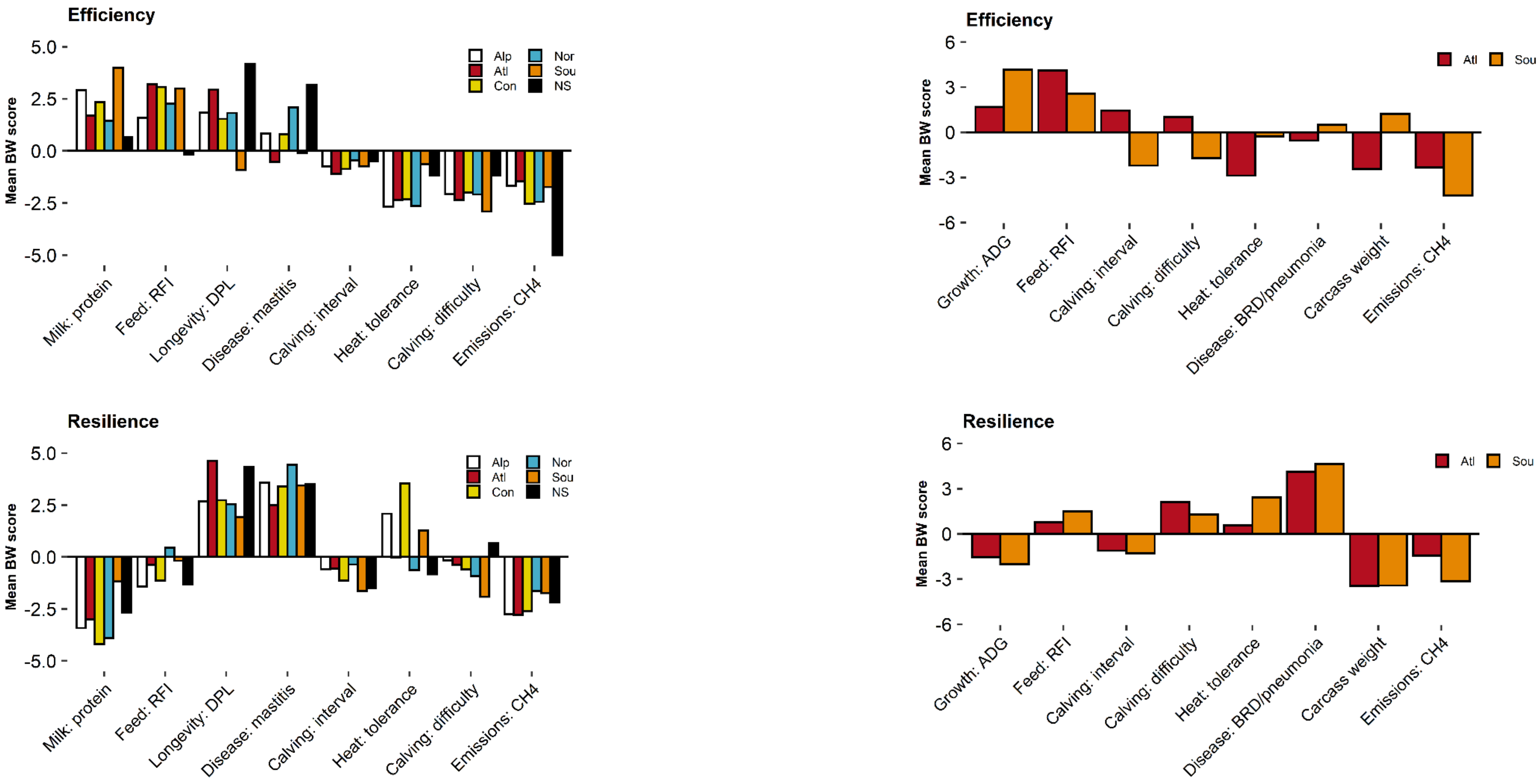
There are clear differences in the relative importance of the traits in the context of efficient production and resilient production. Consistently, for both dairy and beef systems, production traits rated highly in terms of efficient production, but much lower in terms of resilient production. Health traits were much more highly valued in terms of resilient production than efficient production. Furthermore, the low ranking of some novel traits (e.g. RFI in the context of resilient production, and emissions in both efficiency and resilience contexts) could be considered a failure by industry to confer an appropriately value to these traits, especially in the framework of commonly expected system challenges. For example, when considering the challenges explicitly outlined by the same stakeholders earlier in the survey, such as reduced forage/fodder availability, one might expect a trait such as RFI to rank higher, especially in the context of resilience.

Additionally, there are clear similarities in the relative importance of traits between respondents from different regions of Europe, although these similarities are more evident in the dairy context, for which we had many more responses. For dairy traits, only heat tolerance in the context of resilient production appears to carry substantially different value across regions. However, the overall similarities here suggest that if geographical location is not the main driver of stakeholder preference, there may be more important drivers. For beef, there appears to be more variation in the relative preference of traits, especially in the efficiency context, this may be indicative of greater diversity in beef production systems..

In this choice task, respondents made choices based on a 10-year timeline, the antagonisms identified here suggest that, for many traits, there may be trade-offs in developing breeding goals that appropriately consider both resilience and efficiency over that period. This re-enforces the importance of measuring efficiency over a period that is relevant to ensure gains are sustainable (Friggens *et al.*, 2017), and that gains remain beneficial under future production circumstances.

Following the choice experiment, respondents were asked to identify traits that they consider important but were not included. Responses were in open format, and are displayed in Table 8 and Table 9. For dairy traits, more general measures of disease resistance were recommended (16% of overall mentions), such as seeking to optimises immune function, over addressing resistance to any single disease in particular. Additionally, reducing lameness through breeding (13%) and breeding animals that can produce high yield and quality of milk on pasture (13%) were seen as equally important. For beef traits, most important was conformation traits (18%); lameness and general disease resistance also featured (9% each).

Figure 7 Relative preference for traits by region of respondent for Dairy (left) and Beef (right), in terms of efficient and resilient production. Regions are: Alpine (Alp), Atlantic (Atl), Continental (Con), Northern (Nor), Southern (Sou), and not stated (NS).



2.1.5. Other important traits

Table 8 Additional important traits for dairy cattle that were not considered in the choice exercise. Percentage of overall mentions is given for each trait along with a selected example comment for each trait group. There were 33 comments in total.

Trait group	Trait	%	Example comment
Feet & legs	Lameness	13	"To me everything related to claw health and lameness is equally important as the presented trait groups."
	Claw health	19	
Disease	General disease resistance	16	"genetic improvement on disease resistance; a highly efficient immune system"
	TB resistance	9	
Feeding	Feeding behaviour	3	"Ability to produce milk on grass and grassland products, preferably without grain feeding"
	High output on pasture	13	
Other	Phosphate excretions	3	"…for the dairy production companies, the meat production ability is of great economic importance both from the efficiency and resilience point of view."
	Rumination behaviour	3	
	Efficiency related to output	3	
	Survival	3	
	Conformation	6	
	Meat production	6	
	Milk volume	3	

Table 9 Additional important traits for beef cattle that were not considered in the choice exercise. Percentage of overall mentions is given for each trait along with a selected example comment for each trait group. There were 15 comments in total.

Trait group	Trait	%	Example comment
Feet & legs	Lameness	9	NA
Disease	Parasite resistance	9	"Resistance to other diseases, BVD, Johnes and overall health status of herd"
	General disease resistance	9	
Behaviour	General behaviour	9	NA
	Mothering ability	9	
Other	Conformation	18	"Land-wise, more medium sized cows can be carried compared to larger sized suckler cows and…I would expect more total kgs to be possible…per hectare with medium sized cows than larger cows."
	Carcass quality	9	
	Unspecified welfare traits	9	
	Smaller body size	9	
	Colostrum production	9	

2.1.6. Management factors

For the final section of the survey, we were interested to make links between previous work carried out by CITA. The survey of Spanish cattle farmers give more details of the approach (see Spanish cattle farmer survey). However, in the online survey, respondents were asked to select the top five actions, which involved different areas of farm management, to cope with challenges to resilience and efficiency. We left the challenges unspecified as we wanted respondents to consider the challenges that were specific to their regions and production systems. We also included additional actions, including options for grassland management, which mean the results of the online survey and CITA survey are not directly comparable.

2.1.7. Dairy systems

For maintaining efficient dairy production, as can be seen in Figure 8, the most important actions across the regions were the use of genetic improvement tools and culling the least adapted animals. Seeking the help of technical advisory services and modifying diets were also seen as highly important to efficient production. The use of reproductive technologies and improving equipment were also seen as useful actions in meeting efficiency challenges. In terms of resilient dairy production, again, the most important actions were the use of genetic improvement tools and culling the least adapted animals. Seeking the help of technical advisory services was also seen as important, although less so for resilience than efficiency. Appropriate manure and nutrient management was seen as important, together with the use of stable grass swards. It may be that in the shorter term (efficiency perspective), modifying diets is enough, but in the longer term (resilience perspective), the managing grass and soil more effectively is more highly regarded. Interestingly, the implementation of agro-forestry is seen as somewhat useful for resilient production, and of very little use to efficient production.

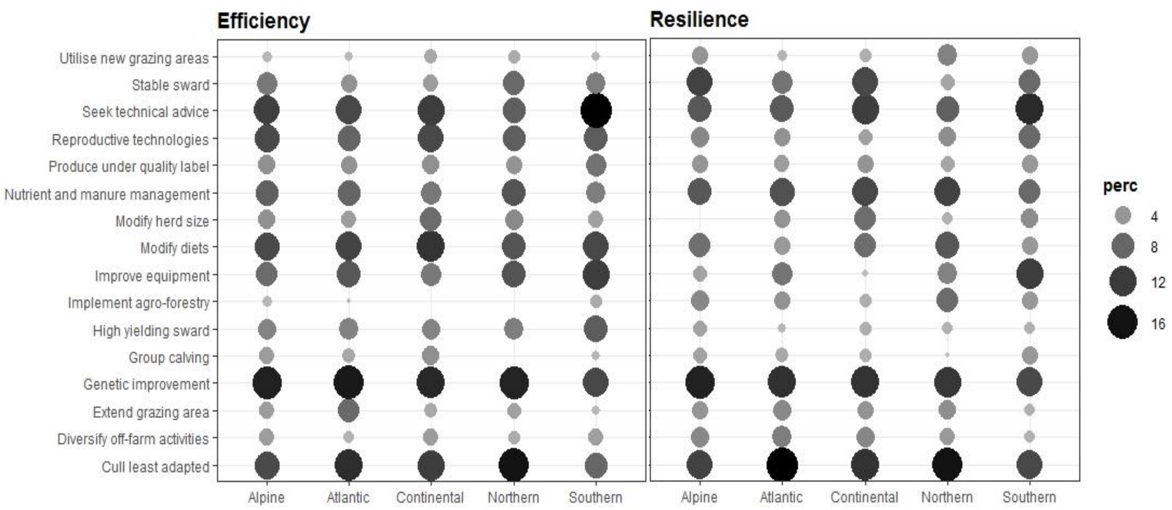


Figure 8 The management options that are considered important by respondents in the context of each efficiency and resilience. From all options, on the vertical axis, each respondent selected the top five for each efficiency and resilience. Only regions with >10 respondents are included. The size and shade of the bubble are scaled according to the percent of respondents selecting an action as in the top five.

2.1.8. Beef systems

For maintaining efficient beef production, as can be seen in Figure 9, the most important actions in Atlantic systems were to seek technical advice and the use of genetic improvement tools. Also important were culling the least adapted animals and utilising group calving patterns. In Southern beef systems, for maintaining efficient production, there was generally less consensus on the options that represent the most important actions. However, seeking technical advice, improving equipment and modifying diets were all seen as highly important. For resilient production, again in Southern systems, there was generally less consensus on the most important options, but culling the least adapted animals, seeking technical advice and using a stable grass sward were all seen as important. For Atlantic production, culling the least adapted animal, effective nutrient and manure management, and using a stable grass sward were all highly favoured.

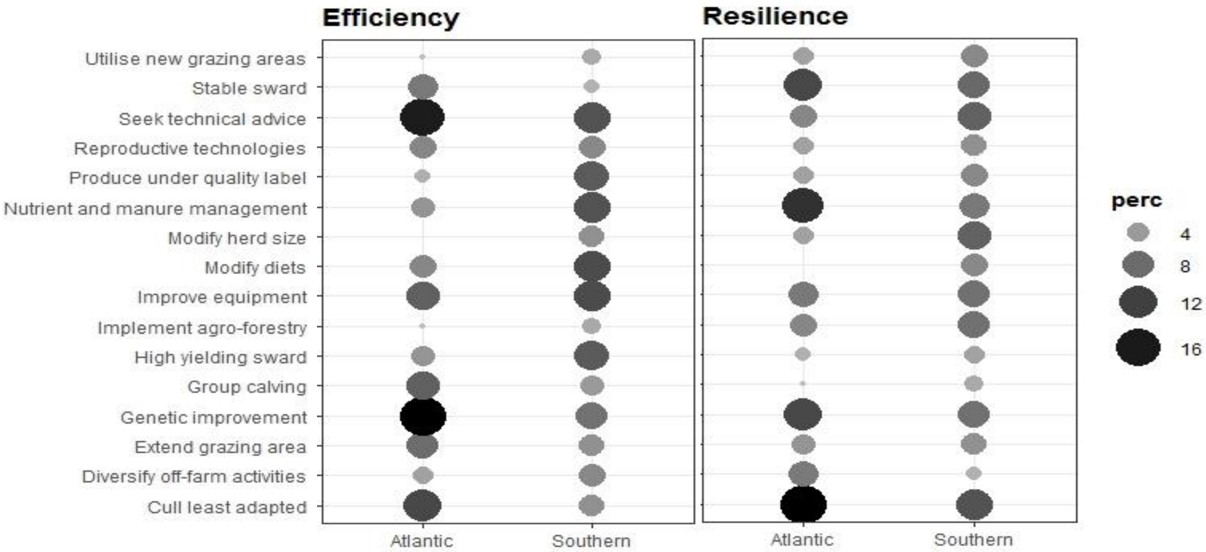


Figure 9 The management options that are considered important by respondents in the context of each efficiency and resilience. From all options, on the vertical axis, each respondent selected the top five for each efficiency and resilience. Only regions with >10 respondents are included. The size and shade of the bubble are scaled according to the percent of respondents selecting an action as in the top five.

2.2. Spanish cattle farmer survey

Beef cattle farms have undergone major changes in size and management in the last decades, most of them as strategies to adapt to the changing socioeconomic environment. In the Spanish Central Pyrenees, as in the rest of Europe, the total number of mountain farms is decreasing. Among those remaining, there is a wide diversity in technical management and economic performance, influenced by both internal (labour availability, feed self-sufficiency, etc.) and external factors (political, socioeconomic and environmental context). There is also genetic diversity associated to the use of different breeds, usually with a strong territorial link, and to the animal types. The existing animal types are the result of selection carried out by individual farmers and under breed-specific selection programs. In beef cattle breeds, most of these programs focus on traits related to calving ease and calf growth during lactation and fattening, chosen because of their economic importance, easy measurement and adequate heritability to allow for genetic improvement via classical breeding programs. However, other traits can also play a major role on cow lifetime productivity and therefore determine long-term performance of the farms.

These differences, both at the animal and the farm scale, may be behind their further adaptability to uncertain situations, like those related to climate variability or to global market dynamics affecting the prices of inputs and outputs.

In order to determine the factors contributing to efficiency (at the cow and the farm levels), the resilience of suckler cattle farming systems in Mediterranean mountain areas and their long-term evolution, a survey was conducted in three valleys of the Central Spanish Pyrenees (Broto, Baliera-Barrabés and Benasque). With the aim of analysing the dynamics of these farms, a constant sample of cattle farms located in the valleys was surveyed in 1990 (101 farms), 2004 (71 farms) and 2018 (54 remaining farms). Data were obtained by means of direct interviews with farmers, using a fully structured questionnaire in which detailed information on farm structure, family composition and labour, management (grazing, indoor feeding, reproduction) and economic performance in a 1-year production cycle was gathered.

To gain knowledge on the general perceptions of farmers about the efficiency of their cows and the resiliency of their farms, the questionnaire included two specific sections addressing these issues. Regarding animal efficiency, farmers were presented with a set of traits and asked to score their relative importance in order to define the efficiency of their cows, by using a 1-5 Likert scale (1. Unimportant, 2. Of little Importance, 3. Moderately Important, 4. Important, 5. Very Important). The traits considered were age at first calving, calving ease, fertility, cumulative number of weaned calves, calf weight at birth, at 90 days and at weaning, calf carcass conformation, cow size, cow udder conformation, feet and legs morphology, docility and use of low quality feedstuffs (and others if considered necessary). Farmers were also asked if they actually registered these traits, and if they provided the information to any breeder association. The results were analysed according to herd size, comparing data from farms with < 65 vs. > 65 cows (49% and 51%, respectively), type of marketed product (weaned vs.

fattened calf (75% and 25% of the farms, respectively) and predominant cow breed (autochthonous and imported, 91% vs. 9%, respectively) (Casasús et al., 2018).

Regarding farm resilience, as a first approach we collected the spontaneous perception of farmers (open questions without predetermined set of choices) on how they would face two types of adverse circumstances: 1. two consecutive drought years, or 2. strong increase in input prices. Then, farmers were asked to score how different adaptations in their production systems may increase their coping ability with both theoretical situations. A 1-5 Likert scale was used (1. Unimportant, 2. Of little Importance, 3. Moderately Important, 4. Important, 5. Very Important). The adaptations implied changes in the management of reproduction (group calving in specific periods; using reproductive technologies; applying specific heifer management programs), health (intensifying control programs; eliminating the worst adapted animals), feeding (extending the grazing period; using new pasture areas; modifying indoors diets; searching for feedstuff self-sufficiency), general management (modifying herd size; introducing new breeds; updating facilities or equipment; seeking for technical advice) or commercialization and diversification (change product type and fatten calves; produce under quality labels; collective commercialization of calves; diversify the activity within agriculture; diversify the activity off-farm).

2.2.1. Farm current structure

With a large diversity, the average farm size was 76 ha UAA (Utilised Agricultural Area, that is, arable land and permanent grasslands), of which 92% were meadows located mostly at valley bottoms. The herd also grazed on an average of 467 ha high mountain ranges (managed collectively) and 26 ha intermediate altitude pastures (mainly shrub and forest pastures). The average herd consisted of 87 dams, 3 bulls and 8 replacement heifers. Only 13% of the farms fattened their calves up to slaughter, and these had on average 56 fattening calves (in larger farms of 146 dams, on average). The average labour input per farm was 1.5 Working Units (WU).

Technical management will not be described in detail here. The herds typically grazed throughout the vegetative season on different pastures under low intensity systems and were housed during the winter, when they received a diet consisting of preserved grass (hay or silage) and concentrates. Except for the breeding-fattening farms, calves were generally weaned at 200 kg weight and sold to fattening operations in lowland areas.

2.2.2. Farm dynamics 1991-2004-2018

In the time elapsed between the different surveys, the structure of the farms involved in this constant sample has changed significantly, both in the first period, before and after the 1992 CAP reform (1991-2004; García-Martínez et al., 2009), and after the mid-term CAP review (2004-2018).

The total number of farms decreased significantly in both periods. The cease of operation from 2004 to 2018 (20% of the farms) was mostly due to retirement (85% of the cases), with animals sold and land rented to other farmers. With some differences among valleys, despite the decreasing number of farms, the total number of cows managed by this constant sample of farmers was maintained or increased, while the total used agricultural area was constant or decreased (Figure 10). The latter could be ascribed to land urbanisation or the abandonment of the less productive grasslands and their conversion into shrub and forest pastures. This could specially be the fate of some of the land formerly belonging to retiring farmers, while the remaining farmers would only rent their more productive pastures.

At the farm level, an increase in herd size of almost three-fold was observed in all valleys (33 cows per farm in 1991, 56 in 2004 and up to 87 in 2018), while the Used Agricultural Area per farm did not increase at the same rate (49, 66 and 76 ha/farm, respectively) (Figure 11). Therefore, an intensification in the use of foraging areas was observed (from 1.3 to 1.8 cows/ha UAA), as they were dedicated to the provision of preserved forage for the winter period, while there was an increased extensive use of forest and grassland pastures by a larger herd throughout the year.

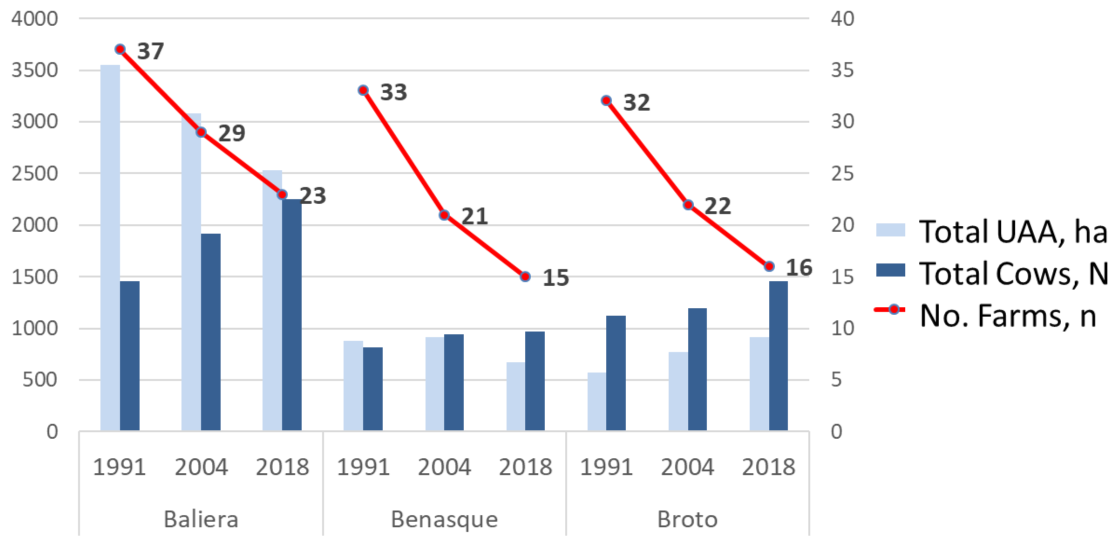


Figure 10. Trends observed in total number of farms, cattle census (adult cows) and used agricultural area (UAA) in three valleys of the Central Spanish Pyrenees in a constant sample of farms surveyed in 1991, 2004 and 2018.

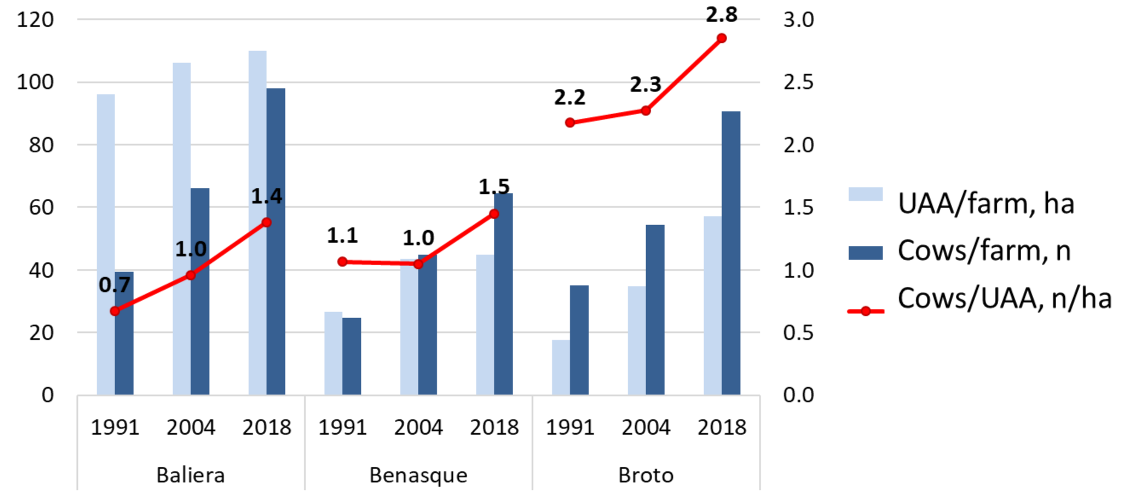


Figure 11 Trends observed in farm size in terms of adult cows and used agricultural area (UAA), and intensity of land use (cows/ha UAA) in three valleys of the Central Spanish Pyrenees during 1991, 2004 and 2018.

Concerning the farm orientation, García-Martínez et al. (2009) already observed a change of productive orientation from mixed beef-dairy to pure beef production in the first phase, with calves being fattened either individually or in a cooperative way by a large share of the farms (nearly 50%). The proportion of on-farm fattened calves increased from 4% in 1991 to 30% in 2004, but then decreased again to 10% in 2018 (Figure 12). Apparently, it was an interesting option in the 2000s due to the associated CAP premiums (slaughter and beef special premiums), but the current payment schemes and high concentrate feeding costs in mountain areas reduced its profitability. However, in the case of Broto Valley, where it was associated to a quality label, it was still common practice in 2018 in 21% of the farms.

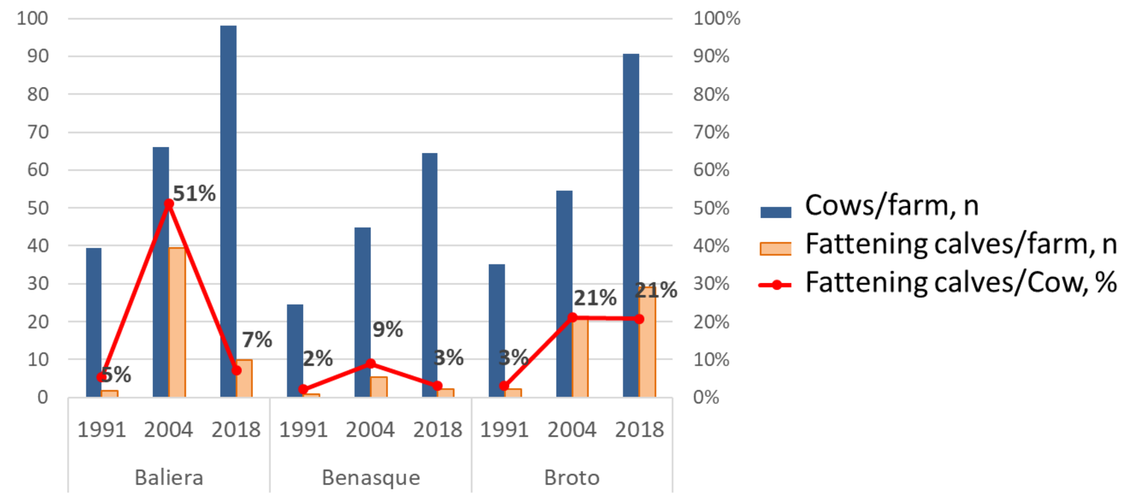


Figure 12 Trends observed in on-farm size calf fattening (% fattened calves per adult cow) in three valleys of the Central Spanish Pyrenees during 1991, 2004 and 2018.

Finally, the number of annual working units per farm has remained fairly constant over the study period (1.7 WU/farm in 1991, 1.4 in 2004 and 1.5 in 2018) (Figure 13). As a consequence of the changes in farm size, the labour intensity has increased significantly, both in terms of cows (19 cows/WU in 1991, 43 in 2004 and 59 in 2018) and agricultural area managed per worker (28 ha UAA/WU in 1991, 48 in 2004 and 51 in 2018). This trend matches that observed by Veysset et al. (2015) in French beef cattle farms for the period 1990 to 2012.

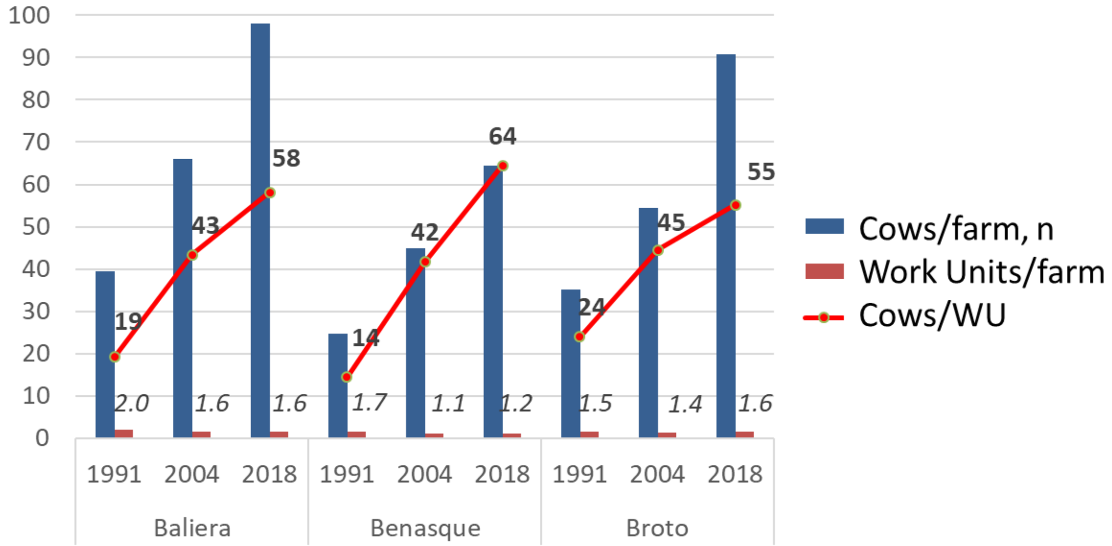


Figure 13 Trends observed in labour inputs (Working Units, WU) per farm and intensity (cows/WU) in three valleys of the Central Spanish Pyrenees during 1991, 2004 and 2018.

2.2.3. Farmers' perceptions on parameters defining suckler cow efficiency and farm resilience

Our results indicate that despite 85% of the farmers belonged to breeder associations only 21% of them delivered data for their breeding programmes. In fact, data were registered by relatively few farmers (age at first calving by 51%, fertility and calf birth weight by 32%, calving ease by 30%, calf weaning weight by 9%), mainly in large farms (> 65 cows) but irrespectively of major cow breed (autochthonous vs. imported specialized beef breed) or type of marketed product (weaned or fattened calf) (Table 10).

Despite the low recording rates, most of these traits were regarded as important or very important to determine cow efficiency, with the highest scores given to calving ease (4.9), fertility (4.6) and docility, udder conformation and cumulative number of weaned calves (4.3). Adult leg (4.2) and calf birth weight and beef conformation (4.0) were also considered important. Surprisingly, calf weight at 90 days (3.7, related to dam's milk yield) at weaning (3.6) were scored lower, and the less important trait was cow size (2.9). Some scores differed according to farm size (large farms rated cow size and docility higher) or predominant breed (higher rates for calving ease in farms with autochthonous breeds), but the type of marketed product was not significant.

Table 10 Recording rates and importance assigned by farmers to different traits.

	Registered (yes/no)	Importance (1-5)
Calving ease	30%	4.9
Fertility	32%	4.6
Udder Conformation	4%	4.3
Docility	2%	4.3
No. calves weaned in the cow's life	21%	4.3
Feet and leg morphology	2%	4.2
Carcass conformation	4%	4.0
Calf weight at birth	28%	4.0
Age at first calving	51%	3.9
Calf weight at weaning	9%	3.6
Efficient use of low quality resources	0%	3.4
Calf weight at 90 days	2%	3.1
Cow Size	2%	2.9

(1. Unimportant, 2. Of little Importance, 3. Moderately Important, 4. Important, 5. Very Important)

The relative scores and registration rates of the different traits has interesting implications for the expected success of breeding programs. Some of the most important traits were recorded and included in breeding schemes (calving ease, calf birth weight). However, some traits were considered important but not recorded even if they are needed in the current schemes (cow udder, feet and leg conformation, docility, calf carcass conformation). Other traits showed that the interests of farmers were not fully met by the breeding schemes, either because they were regarded as important but not considered in the programmes (fertility, lifetime productivity, age at first calving) or because they were included in breeding schemes but regarded by farmers as less important (calf weight at 90 days and weaning). The latter were particularly surprising, since most of the interviewed farmers sold weaned calves as their main farm product, but it could be explained by the fact that calves are sold to cattle dealers and prices are agreed on a group basis rather than for each individual calf, and therefore the relative importance of individual weaning weight is diluted.

We concluded that in order to include these important but not currently addressed traits in the breeding goals, participatory approaches including stakeholders' views should be implemented. This ought to be coupled with the development of easy measuring protocols and the facilitation of on-farm data recording and delivery, and the systemic use of the available official databases.

2.2.4. Farmers' perceptions on strategies defining farm resilience

When farmers were asked about how they would face two adverse hypothetical scenarios (two consecutive drought years, strong increase in input prices), their spontaneous responses affected mainly the livestock census and the origin of the feedstuffs. In the event of *two consecutive drought years*, farmers would mainly rely on purchased feedstuffs (44%) and adjusting their herd size (33%), mostly by selling older or less productive cows (Table 11). Other options were changing indoor feeding (adapting diet composition and quantity) and pasture management (type of pastures, length of the grazing period) and some even considered transhumance with part of their herds to other areas with higher forage availability. Some farmers considered the combination of several options, in a complementary way.

Table 11 Farmers' spontaneous strategies to cope with a scenario of two consecutive drought years.

Adaptation strategy	% responses
purchase feedstuffs	44%
sell cows	33%
change pasture management	5%
change indoor feeding management	4%
transhumance	4%
other	5%
no opinion	5%

When faced with a potential *strong increase in input prices*, some farmers declared to be unaffected because they were self-sufficient (19%) (Table 12). Among the rest, most would decrease their herd size by selling cows, and reduce their dependence on purchased feedstuffs, in some cases by abandoning the fattening of their calves based on high-concentrate diets. Changes in indoor feeding and increasing the relative contribution of grazed pasture to the annual diets were also considered.

Once they had expressed their preferred strategies to cope with these theoretical situations, they scored the relevance for this purpose of a given set of practices involving the reproduction, health and feeding management of the herd, farm structure and commercialization/diversification strategies. With some differences between scenarios, they stated that the most relevant areas on which they could act to face these circumstances were feeding and health management of their animals (moderately to very important) (Table 13).

Table 12 Farmers' spontaneous strategies to cope with a scenario of a strong increase in commodity prices.

Adaptation strategy	% responses
sell cows	26%
purchase feedstuffs	11%
change indoor feeding management	9%
change pasture management	9%
cease fattening	4%
transhumance	4%
no opinion	19%
not affected (self-sufficient)	19%

Table 13 Average relevance (1-5) of practices concerning different areas of the farm management to cope with hypothetical scenarios of two consecutive drought years and a strong increase in commodity prices.

Scenario	Two consecutive drought years	Increase in commodity prices
Areas		
Feeding	4.1	3.2
Health	3.4	3.4
Commercialization and diversification	3.0	3.0
General management	2.6	2.5
Reproduction	2.6	2.6

(1. Unimportant, 2. Of little Importance, 3. Moderately Important, 4. Important, 5. Very Important)

Most of the strategies presented were of similar relevance for both scenarios (Table 14), particularly those considered "of little importance" in both cases, like changing breed or product type, which are quite fixed for a given production system/environment, or updating facilities and equipment, which require an unlikely investment under uncertain circumstances such as the ones hypothesized.

Some of the adaptation strategies were regarded as "important" in both scenarios, like detection and culling of the worst adapted animals and the search for feed self-sufficiency. Others were scored as "moderately important", like seasonal calving and the modification of indoor diets. These were followed by strategies associated to increasing their product value, like commercializing calves collectively (as weanlings or finished animals) or under a quality label (only for fattened calves). Finally, some practices were considered less relevant for adaptability in either scenario, like the adoption of specific health and reproduction programs; consequently, farmers only scored their need for technical advice with 2.5.

Since both scenarios compromised not only cattle farming but also other livestock or agricultural activities, farmers did not consider diversifying their activity within agriculture. However, they considered the possibility of diversifying economic activities off-farm, which could be "important" for a better performance of their household under these conditions.

Table 14 Relevance (1-5) of a given set of actions involving different areas of the farm management to cope with scenarios of two consecutive drought years and a strong increase in commodity prices.

	Two drought years	Increase in commodity prices
Reproduction	Average importance (1-5)	Average importance (1-5)
Group calving in specific periods	3.0	3.1
Specific heifer management program	2.4	2.5
Use reproductive technology	2.3	2.3
Health		
Eliminate the worst adapted animals	4.1	4.2
Intensify control programs	2.7	2.7
Feeding		
Extend the grazing period	2.7	4.3
Use new grazable areas	3.4	4.1
Search for feedstuff self-sufficiency	3.6	3.8
Modify indoors diets	3.3	3.4
General management		
Modify herd size	3.3	3.5
Seek for technical advice	2.4	2.5
Update facilities or equipment	1.8	1.8
Introduction of new breeds	1.7	1.8
Commercialization and Diversification		
Commercialize calves collectively	2.8	2.8
Produce under quality labels	2.5	2.6
Change product type	1.8	1.7
Diversify activity within agriculture	2.3	2.2
Diversify activity off-farm	3.8	3.7

(1. Unimportant, 2. Of little Importance, 3. Moderately Important, 4. Important, 5. Very Important)

Overall, feeding management (both indoors and on pasture) was the most relevant area in which actions could be taken to improve the resilience of their farms under adverse circumstances (Muñoz-Ulecia et al, 2019). In the case a strong increase in the prices of purchased inputs, the extension of the grazing season and the use of new pastures (sometimes by means of transhumance to lowland areas) were envisaged and considered as "important", both regarded as the pathway towards increased feed self-sufficiency. In the event of a persistent drought that would impair pasture availability, the relevance of both practices was reduced.

3. Farm efficiency and resilience data analysis

3.1. Database construction

Alongside the stakeholder surveys, an analysis of farm efficiency and resilience using economic and production data was undertaken using a newly generated farm production environment dataset. This dataset was created by combining Farm Accountancy Data Network (FADN) (EC, 2019a) and Gridded Agro-Meteorological Data in Europe (AGRI4CAST) (EC, 2019b) at a NUTS 2 (EC, 2019c) region spatial scale. The data was processed and stored in two cattle system databases (dairy and beef), as averages for a wide range of variables at a NUTS2 scale. (Only average values for a farm sample =>15 farms can be circulated or published). Other databases were considered, such as from Multisward or Dairyman projects, but this data was only available for a limited number of countries and would have been difficult to construct a consistent database. The use of FADN and AGRI4CAST within a newly formed database allowed consistency for enhanced analysis.

Production and economic data: Detailed FADN data (anonymised individual farm data) was requested for all ruminant and mixed farm types, over 10 a year period and for the most recent data available at request (2004-2013). Following receipt of the data (~250k farms) this was compiled into two consistent datasets, one for dairy farms (141,961) and one for beef farms (54,417). Each dataset comprised some values directly from the FADN data, but also additional calculated variables as necessary, to quantify dairy or beef enterprise performance at per animal, per output product unit or per enterprise allocated hectare. These values were calculated according to the respective dairy and beef enterprise allocation methodologies described by FADN (EC, 2016 and EC, 2013).

Climatic variables and defining environmental zones: For each farm within the dataset, the structural, production and economic data from the FADN data was supplemented with the addition of meteorological data. The daily meteorological data was downloaded from the AGRI4STAT database web portal (part of the Joint Research Center) at NUTS 2 scale. Daily weather data was downloaded separately for each of the 237 nuts2 regions present in the FADN database and from 2004 to 2013. The requested variables were as follows:

- Grid_no: Location of the weather station
- Temperature_max: Maximum air temperature (°C)
- Temperature_min: Minimum air temperature (°C)
- Temperature_avg: Mean air temperature (°C)
- Vapourpressure: Vapour pressure (hPa)
- Precipitation: Sum of precipitation (mm/day)

Data from each NUTS 2 regions were then combined into one consistent dataset, containing more than 45 million of observations. Each NUTS 2 region has an average of data from 52 weather stations, with around 191,416 observations per NUTS 2 region for 10 years (c.a. 19, 142 per year). This large dataset was processed through scripts in STATA software to generate annual and monthly values for a wide range of climatic variables.

Initially, **annual climatic statistics** were calculated to generate mean values for daily maximum, minimum and average temperature, both the daily vapour pressure and precipitation level, as well as the standard deviation of these variables was calculated annually at weather station level in each NUTS 2 region and at two altitude levels (above and below or equal to 600 meters). Subsequently, these further variables were computed:

- Number of days with precipitation below 1mm/day, on the year
- Number of days with a maximum temperature above 25°c, on the year
- Number of days with a maximum temperature above 5 degrees (vegetation growth)
- Number of days with a mean temperature above 5 degrees (vegetation growth)
- Number of days with THI1 above 55, on the year
- Number of days with THI1 above 60, on the year
- Number of days with THI2 above 55, on the year
- Number of days with THI2 above 60, on the year
- Annual extra heat THI1 60: ∑ [(daily THI1)-60]
- Annual extra heat THI2 60: ∑ [(daily THI2)-60]

Furthermore, two annual THI indices (first and second version) were calculated:

- THI1_year = ((0.15*Td_c_year+0.85*tpavg_year)*1.8+32);
- THI2_year = (1.8*tpavg_year+32)-((0.55-0.0055*RHI_2_year)*(1.8* tpavg_year-26));

Where Td_c is the dew point at temperature Td; tpavg_year is the annual average temperature; and RHI_2_year is the annual relative humidity.

This was allowed by calculating:

- Td_c_year =240.7263/(7.591386/(log10(avg_vapourpressure_year/6.116441))-1);
- RHI_2_year=10^(7.591386*((Td_c_year/(Td_c_year+240.73))-(tpavg_year/(tpavg_year+240.73))));

Where avg_vapourpressure_year is the annual average vapour pressure in Pa.

The above annual variables were then extrapolated at NUTS 2 level annually for the two altitude levels. Therefore, averages and calculation were first computed at station level in each region, prior to calculating average values at NUTS 2 level. The second stage, computed **monthly climatic variables,** following the same process as per annual data except that monthly variables were combined with year at every step, allowing analysis of months in years.

The climatic data were then merged with the FADN dataset (dairy and beef) from 2004 to 2013 and released as a project milestone. Occasionally the climatic dataset did not include lowland or upland weather station data for a specific region with FADN data. For this situation, the climatic variables were derived using a step by step procedure, depending on data availability:

Firstly, the missing value at NUTS 2 level is derived by using the percentage difference between low and high altitude taken at the larger NUTS 1 level for the given year. Alternatively, the same process is applied but using the 10 year average difference. A third step uses the difference between lowland and upland at the region level. Should all previous steps fail to generate a value, the value in the other altitude zone in the same NUTS 2 region is taken.

3.2. Defining climatic zones/regions

As meteorological conditions vary considerably across Europe and given their effect on pastures, forage production as well as on health and productivity of dairy and beef cows, it was decided to split the whole of Europe into areas of similar climate conditions (regions or zones). This allowed for further analysis of efficiency and resilience of cattle systems by comparing performance under specific conditions, and were further divided into different farm types.

Climatic zones have previously been developed, e.g. Metzger (2005), but these types of classifications can be applied as GIS layers, and the FADN data only provides an approximate geographical location for each farm (the NUTS 2 region). Therefore in order to assign farms to climatic classes and given the absence of a climatic zone classification for NUTS 2 regions in the literature, a Latent Class Analysis (LCA) was performed to assign a climate class to each NUTS 2 region, using the following continuous variables:

- ✓ Maximum summer temperature
- ✓ Minimum winter temperature
- ✓ Standard deviation of average temperature
- ✓ Number of dry days (0 to 1 mm/day)
- ✓ Rainfall (average precipitation level expressed in mm/day)

LCA was performed separately for lowland and upland NUTS 2 regions using climatic averages over the ten year period (2004-2013). LCA is a method to classify data that represent the same class overall, into a set of subclasses of more homogeneous groups (Williams and Kibowski 2016). Each NUTS 2 region was assigned to a class, depending on the probabilistic assessment of the likelihood to belong to a group (Williams and Kibowski 2016). It is usually appropriate for use when samples are >=100 observations (Nylund, Asparouhov et al. 2007), and with 239 observations for lowland and 153 observations for upland NUTS 2 regions, there was sufficient statistical power.

However, LCA faces the limitation that the identified subclasses may not necessarily refer to existing groups in the population. In other words, the statistical classification may not always represent well the reality (Bauer, 2004). To the purpose of our classification, variables were carefully selected to try to represent the reality at best. Extreme weather variables like the maximum and minimum temperature in summer and winter, respectively, were selected to reach a better discrimination between groups. Comparison with the geographical classification by Metzger et al. (2005) based on climatic and soil data demonstrates a high consistency of the environmental subclasses we defined.

The distribution of the variables used in the model was first checked using the **hist** (histogram) command, and as they all appeared to follow a normal distribution, no logarithmic transformation was needed. The Stata command **gsem** (generalised structural equation modelling) was used with the **lclass() option** to fit both the lowland and upland model with latent variables. The **nonrtolerance** option was also used to allow convergence, meaning that the maximizer reached an apparent maximum in a non-concave space. Structural equation modelling encompasses a broad set of models ranging from linear models to simultaneous equations. The number of latent classes was defined manually in a way that the number of classes could be minimised while obtaining acceptable samples size and a low BIC (Bayesian information criterion) score. The BIC is a popular measure for comparing maximum likelihood models (see e.g. Raftery, 1995)

Using 6 iterations, six lowland and three upland classes appeared to be the most appropriate using continuous climatic variables. Table 15 shows weather statistics for the nine climatic zones identified using two separate LCA models (lowland and upland). Figure 14 provides a visual overview of the lowland European climatic regions defined using the LCA method.

Table 15 Characteristics of climatic zones in Europe.

Name	Description	Max summer temp	Min winter temp	sd avg temp	Dry days (0-1mm)	Rainfall (mm/d)
North Atlantic	Cool and wet, with less temperature variation (NUTS 2 from IE, West UK)	18	2.7	4.7	206.1	2.8
West Atlantic	Moderate temperature, with warmer summers, cooler winters, drier (NUTS 2 from BE, DE, DK, ES, FR, LU, NE, PT, UK)	21	1.7	6.1	241.2	2.1
Boreal	Very cold winters, moderate summer, dry (NUTS 2 from FI, SE)	18	-9.6	9.4	252.2	1.7
Central Europe	Warm summers, cold winters (NUTS 2 from AT, CZ, DE, EE, FR, IT, LT, LV, PL, SE SK)	23	-2.6	8.0	252.0	2.0
Southern Central Europe	Warm summers, cool winters (NUTS 2 from AT, EL, ES, FR, HU, IT, SI, SK)	27	-0.9	8.1	279.4	2.0
Mediterranean	Hot summer, warm winter, dry (NUTS 2 from CY, EL, ES, FR, IT, MT, PT)	29	5.3	6.6	301.7	1.6
Atlantic Mountain	Cool and wet with less seasonal variation (NUTS 2 from BE, DE, FR, IE, LU, UK)	17	1.3	4.8	186.3	2.8
Central Mountain (Alpine)	Warmer summers but colder winters, moderate rainfall (NUTS 2 from AT, CZ, DE, ES, FI, FR, HU, IT, PL, SE, SI, SK)	20	-4.2	7.7	239.3	2.5
Mediterranean Mountain	Mild winters and warm summers, with lower rainfall (NUTS 2 from CY, EL, ES, FR, IT, PT)	27	1.3	6.9	286.9	1.9

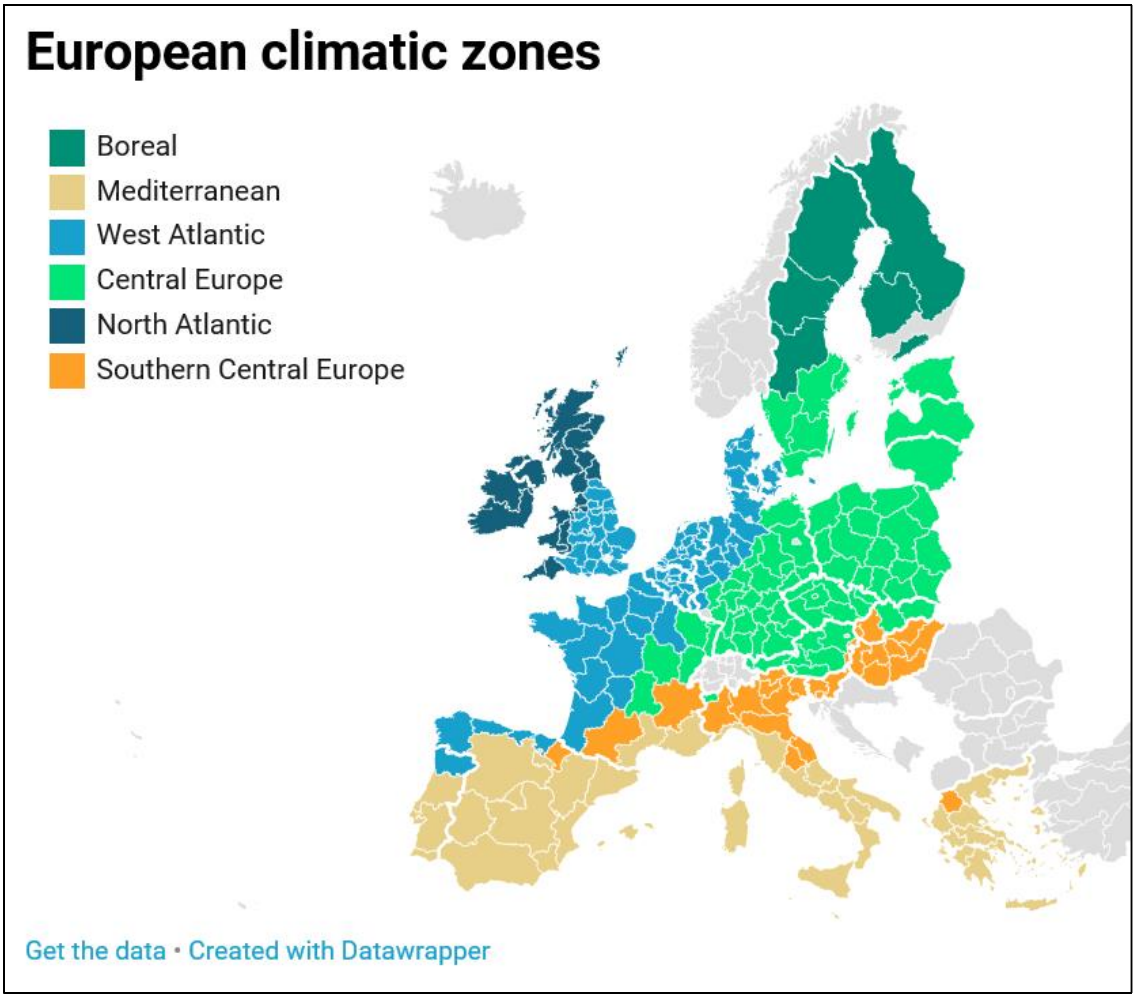


Figure 14 European lowland climatic regions (defined at NUTS 2 scale)

Table 16 and Table 17 indicate the number of farms and observations in the FADN database within each climatic region.

Table 16 Dairy farms and observations within climatic regions

Climatic region	Farms			Observations		
	Freq.	Percent	Cum.	Freq.	Percent	Cum.
North Atlantic	1,304	4.05	4.05	6,988	4.92	4.92
West Atlantic	8,952	27.79	31.84	38,770	27.31	32.23
Boreal	676	2.1	33.93	4,110	2.9	35.13
Central Europe	13,869	43.05	76.98	60,826	42.85	77.97
Southern Central Europe	2,428	7.54	84.52	9,576	6.75	84.72
Mediterranean	1,512	4.69	89.21	5,345	3.77	88.49
Atlantic Mountain	42	0.13	89.34	244	0.17	88.66
Central Mountain (Alpine)	2,570	7.98	97.32	12,492	8.8	97.46
Mediterranean Mountain	863	2.68	100	3,610	2.54	100
Total	**32,216**	**100**		**141,961**	**100**	

Table 17 Beef farms and observations within climatic regions

Climatic region	Farms			Observations		
	Freq.	**Percent**	**Cum.**	**Freq.**	**Percent**	**Cum.**
North Atlantic	2,609	17.71	17.71	11,383	20.92	20.92
West Atlantic	4,104	27.87	45.58	15,767	28.97	49.89
Boreal	177	1.2	46.78	917	1.69	51.58
Central Europe	3,365	22.85	69.63	10,970	20.16	71.74
Southern Central Europe	1,277	8.67	78.3	4,079	7.5	79.23
Mediterranean	1,236	8.39	86.69	3,789	6.96	86.2
Atlantic Mountain	34	0.23	86.92	138	0.25	86.45
Central Mountain (Alpine)	708	4.81	91.73	2,446	4.49	90.94
Mediterranean Mountain	1,218	8.27	100	4,928	9.06	100
Total	**14,728**	**100**		**54,417**	**100**	

3.3. Defining farm types

Within each environmental region the large database of farms highlights the variation between farms. To allow for this variation we explored the use of LCA to define farm types, but often the groups were very irregular in size, preventing statistical analysis, therefore a decision tree basis for determining the "farm types" within each environmental region was adopted. We defined a farm typology based on the stocking rate and forage proportion of the farm.

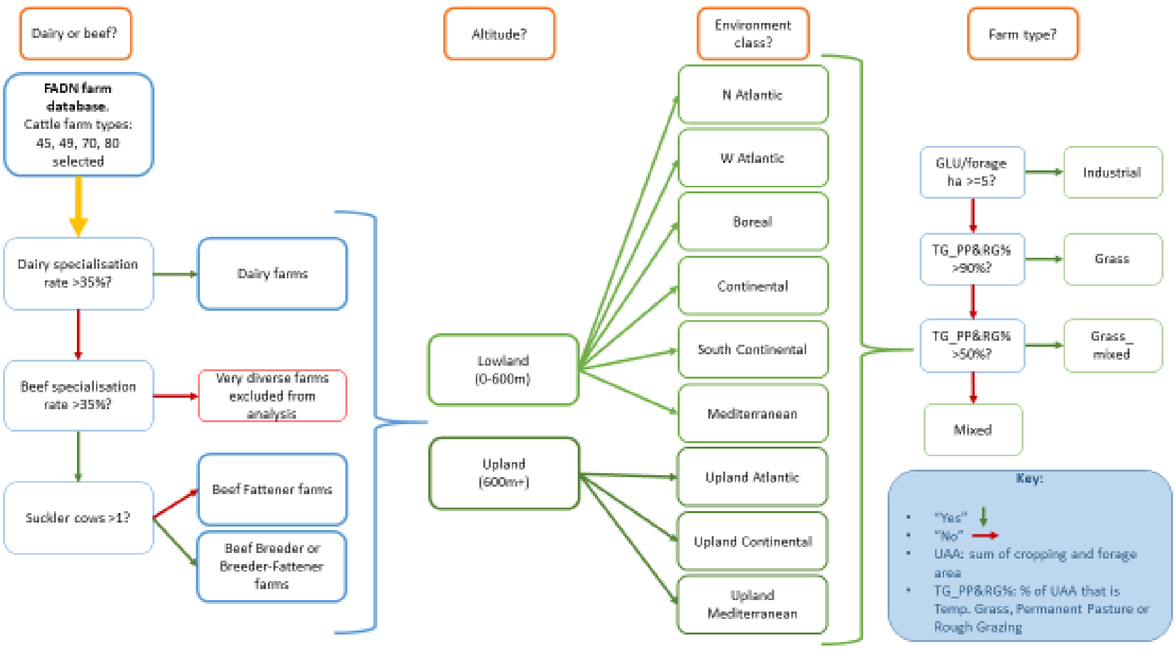


Figure 15 Farm typology decision tree

The farm types are specified throughout the report as indicated in Table 18.

Table 18 Farm types

Farm type	Code	Definition
Grass	GRS	>90% grassland
Grass Mixed	GMX	>50% grassland
Mixed	MIX	<50% grassland
Industrial/Intensive	IND	>5 GLU/Forage hectare
Mountain/Upland	MNT	Altitude >600m

3.4. Efficiency assessment method

Efficiency is an important factor to look at when it comes to assessing the performance of a company or farm and reflects how well the inputs are converted into measurable outputs. Thus, it gives indications on the potential to improve productivity given the state of technology and inputs available (Abdulai and Tietje 2007). Technical efficiency is a popular measure that has been extensively used in the area of agriculture, especially on crops and dairy enterprises. However, it has rarely been used for beef enterprises (Barnes 2008, Ceyhan and Hazneci 2010).

Efficiency measurement can significantly vary depending on the method used. Several methods have been used to measure efficiency, including the popular Data Envelopment Analysis (DEA) and Stochastic Frontier Method (SF),that proved to be the most reliable (Meeusen and van Den Broeck 1977, Charnes, Cooper et al. 1978). SF relies on econometric techniques while DEA uses a linear mathematical programming (Aigner, Lovell et al. 1977, Charnes, Cooper et al. 1978). Many authors in economic literature have dealt with the two approaches and comprehensive reviews can be found e.g. in Kumbhakar and Lovell (2000), Coelli, Rao and Battese (2005), and Cooper et al. (2000). DEA was not selected for this study since the noise in the data is not taken into account, meaning that all deviances from the frontier would account for technical inefficiency (Johansson 2005). On the other hand, SF requires the distribution functional form to be defined, which can lead to measurement errors in case it is specified wrongly (Johansson 2005). However, Coelli (1995) recommends the use of SF in the area of agriculture due to potential measurement errors, data inconsistency, and given the influence of the exogenous weather conditions. Although FADN data are standardised, a few inconsistencies and missing values or variables can still be found.

Functional forms that can be used in SF include among others the Cobb-Douglas, the translog, and the Leontief functions (Abdulai and Huffman 2000). We first calculated efficiency scores by specifying a Cobb-Douglas function, which is the most popular in the literature. It was already tested by Charles Cobb and Paul Douglas in 1928 (Tan 2008). This function assumes constant returns to scale meaning that if all inputs units increase by 10%, the physical output should also increase by 10%. The Translog function (logarithmic transcendental), which is a flexible generalisation of the Cobb-Douglas form, was then used as a comparison. It is a second order form, which is linear in the parameters (Coelli, Rao et al. 2005). Furthermore, this function does not assume a priori restriction to returns to scale and substitution elasticities between inputs (Christensen, Jorgenson et al. 1973). It has been widely used in the literature to measure efficiency (Martin and Page 1983), productivity growth and technical change (May and Denny 1979).

To compute efficiency scores using the Cobb-Douglas production function, the Stata command **frontier** was used with an exponential distribution. The **nontolerance** option was also specified to allow convergence of the model. The variables used into the models were first transformed into logarithmic values. The output considered is the revenue (or turnover) expressed in € per dairy cow or beef livestock unit. Therefore, the technical efficiency measures here the ability of the farm to generate a given revenue while using the smallest possible quantity of inputs (Johansson 2005). As the requested FADN data from 2004 to 2013 comprised almost exclusively economic variables and given the lack of consistent data from Eurostat on the price of agricultural inputs over years and country wise, only economic values were used into the models to account for output and all inputs. The independent variables included in the model are as follows:

- ✓ Feed cost per dairy cow or beef: includes the coarse fodder, non-fodder and concentrate cost;
- ✓ Forage cost per dairy cow or beef: includes the seed, fertilisers, and crop protection cost that are allocated to either the dairy or beef enterprise (ratio of dairy of beef livestock units by total livestock units);
- ✓ Machinery and building upkeep cost per dairy cow of beef;
- ✓ Other livestock specific costs per dairy cow or beef;
- ✓ The year, used as a fixed effect to control for price changes in inputs and outputs

Once the efficiency scores were computed, extreme outliers, or those with null efficiency were withdrawn from the dataset. Then, to identify which regions or farm types or intensities were performing significantly better, an ÂNOVA analysis was performed

For the purpose of farm data assessment, the efficiency was measured in each of those three specific climatic regions but also by different farm types within each region. They are therefore two different levels of analysis: (1) climatic region, and (2) farm type within each region.

On top of those three levels of analysis, the analysis was conducted by assuming two different assumptions on the stochastic frontier, respectively.

The first assumption tested is that each of the different level of analysis (climatic regions, farm types) run under the same frontier. By looking for instance at the first level of analysis (climatic regions), this assumption means that all climatic regions across Europe have the same underlying technology and potential in terms of revenue generated from the inputs invested.

The second assumption tested is that each farm type within each region runs under a specific frontier. Therefore, this means that each of those farm types has a different underlying technology and a different potential.

3.5. Identifying challenges and determinants of efficiency

In a second step and in order to identify and analyse challenges to efficiency, the determinants of technical efficiency (using economic values) were identified using a linear interactive model. The variables used to explain efficiency and the corresponding hypothesis are as follows:

- ✓ Farm size (in ha): Larger farms are assumed to be more economically efficient due to economies of scale;
- ✓ Renewal cost per dairy cow or beef livestock unit: Higher renewal costs are presumed to be a sign of inefficiency;
- ✓ Feed cost per dairy cow or beef: Higher feed cost could lower efficiency due to a decreasing return;
- ✓ Forage cost per dairy cow or beef: As above;
- ✓ Stocking density (grazing livestock unit/forage area): Higher stocking density may decrease efficiency as livestock compete more with each other on pasture;
- ✓ Specialisation rate [(dairy or beef economic output/total economic output)*100]: a higher specialisation is presumably in favour of efficiency due to more optimisation, specialised machinery and specific knowledge;
- ✓ Share of forage maize area on the total surface: Higher energy and DM yield/ha may result in higher efficiency;
- ✓ Share of grass area on the total surface: A higher share may indicate less productive land;
- ✓ Annual extra heat, ∑ [(daily THI2)-60]: the heat is presumed to negatively affect efficiency of dairy cows and beef animals due to heat stress;
- ✓ Number of dry days (0 to 1mm) in spring: Drought could negatively affect efficiency of the dairy and beef systems due to a shortage of forage;
- ✓ Number of dry days (0 to 1mm) in summer: As above.

Determinants to efficiency are expressed in marginal effect given the presence of interactions into the model. This means that the coefficient obtained for an independent variable represents its marginal effect (i.e. of adding one unit of that variable) on the efficiency level. For the dairy analysis, the milk price was controlled for as it could positively affect the efficiency score. In general, small sample sizes could not be calculated (~<250 farms) and are excluded from the reporting.

3.6. Resilience assessment method

The economic resilience was estimated based on the margin difference (€) from one year to the next from 2005 to 2013. The annual margin difference was calculated for each farm individually, meaning each individual farm was compared from one year to the other. Averages were computed at climatic region and farm type level within each climatic region. The annual margin difference was analysed over the period from 2005 to 2013 but also in 2009 and 2010 for the dairy sector as the price of milk significantly decreased in 2009 (from 10 to 24% depending on the climatic region).

In a second step and in order to identify and analyse challenges to resilience, a linear interactive model was developed. The independent variables on “shock” measurement were first computed for identical farms from one year to the other, and expressed into a percentage difference. The variables used to explain the annual margin difference are as follows:

- ✓ Shock (%) in milk price: Shock in the price of milk (decreased price) is presumably in disfavour of economic resilience (no price data available for beef);
- ✓ Shock (%) in the feed cost: Shock in the feed cost (increased cost) is presumably in disfavour of economic resilience;
- ✓ Shock (%) in the heat: Difference in the annual extra heat, ∑ [(daily THI2)-60]: the heat is presumably affecting negatively the farm system resilience due to its potential effect on dairy cows and beefs but also on the grass and crops;
- ✓ Shock (%) in the number of dry days (0 to 1mm) in spring: Drought is presumed to negatively affect the resilience of dairy and beef systems due to forage shortages;
- ✓ Shock (%) in the number of dry days (0 to 1mm) in summer: As above;
- ✓ Farm size (in ha): bigger farms are presumably more economically resilient due to economies of scale;
- ✓ Shock (%) in purchased concentrates costs per dairy cow or beef;
- ✓ Stocking density (grazing livestock unit/forage area): Higher stocking density presumably has a negative impact on resilience;
- ✓ Deciles of intensity level based on the feed and forage cost per dairy cow or beef; more intensive farms may be less resilient as they usually have a higher level of production (e.g. any change on milk price would potentially have a higher impact);
- ✓ Specialisation rate [(dairy or beef economic output/total economic output)*100]: A higher specialisation is presumably in favour of resilience due to more optimisation, specialised machinery and specific knowledge;
- ✓ Suckler cow specialisation rate [(number of suckler livestock units /BLU)*100]: Optimisation, specialised machinery and specific knowledge;
- ✓ Dependency on purchased concentrated expressed as the percentage of the purchased concentrate cost on the feed cost per dairy cow, on average from entire period (if the farm remains 10 years in the dataset, otherwise on a shorter period);

The other variables used only for interactions into the model are as follows:

- ✓ Technical efficiency (Cobb-Douglas), on average from 2004 to 2013 on the farm (if the farm remains 10 years in the dataset, otherwise on a shorter period)
- ✓ Dry spring: number of dry days (0 to 1mm) in spring
- ✓ Dry summer: number of dry days (0 to 1mm) in spring
- ✓ Rainfall during spring (mm) in the actual year
- ✓ Rainfall during summer (mm) in the actual year

Therefore, the model identifies the explanatory factors of variability in the annual margin over time; which can be economic (shock in the price), meteorological, or more structural like the specialisation rate. In case, the annual margin difference is only explained by the economic and/or meteorological factors, the structural factors have no effect.

Challenges or drivers to economic resilience are expressed in marginal effect given the presence of interactions into the model. This means that the coefficient obtained for an independent variable represents its marginal effect (i.e. of adding one unit of that variable) on the annual margin difference. In general, small sample sizes could not be calculated (~<250 farms) and are excluded from the reporting.

4. Results: Dairy sector

The European dairy sector is spread across the continent, but when Europe is considered to be uniformly efficient for the production of milk (a common frontier), Figure 16 shows that whilst North Atlantic and mountain/upland systems are the most economically efficient, dairy farming in all EU regions is very efficient (>=90%).

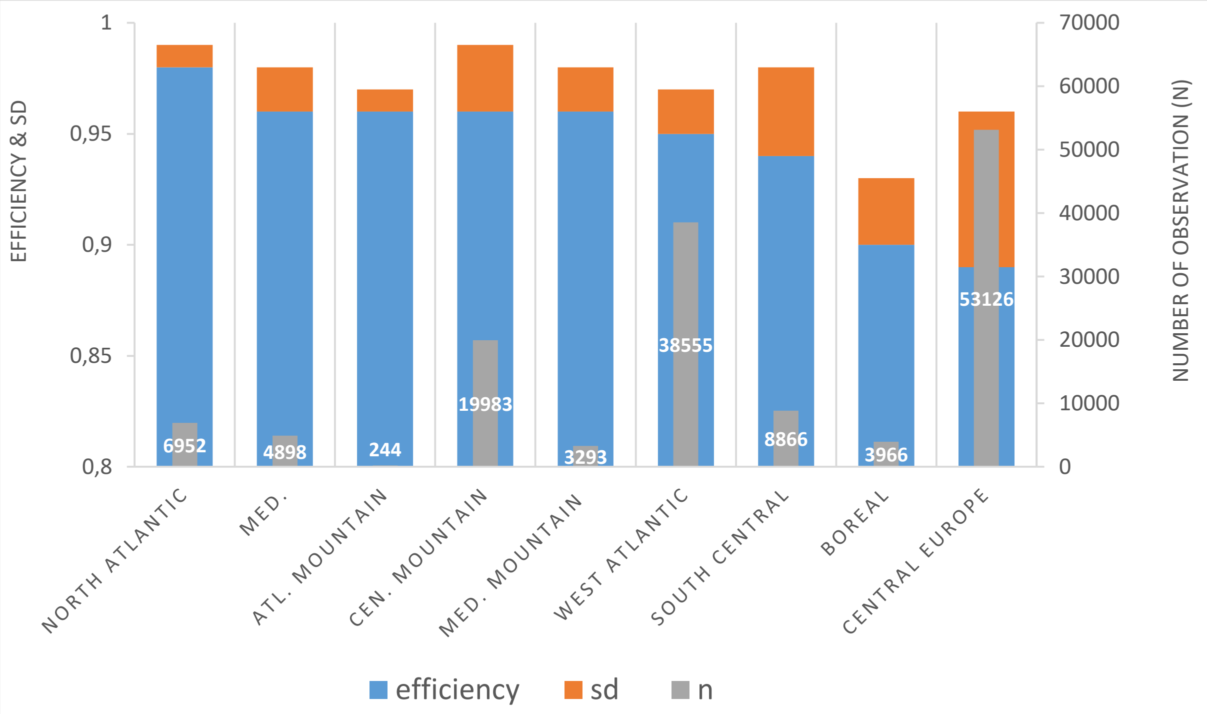
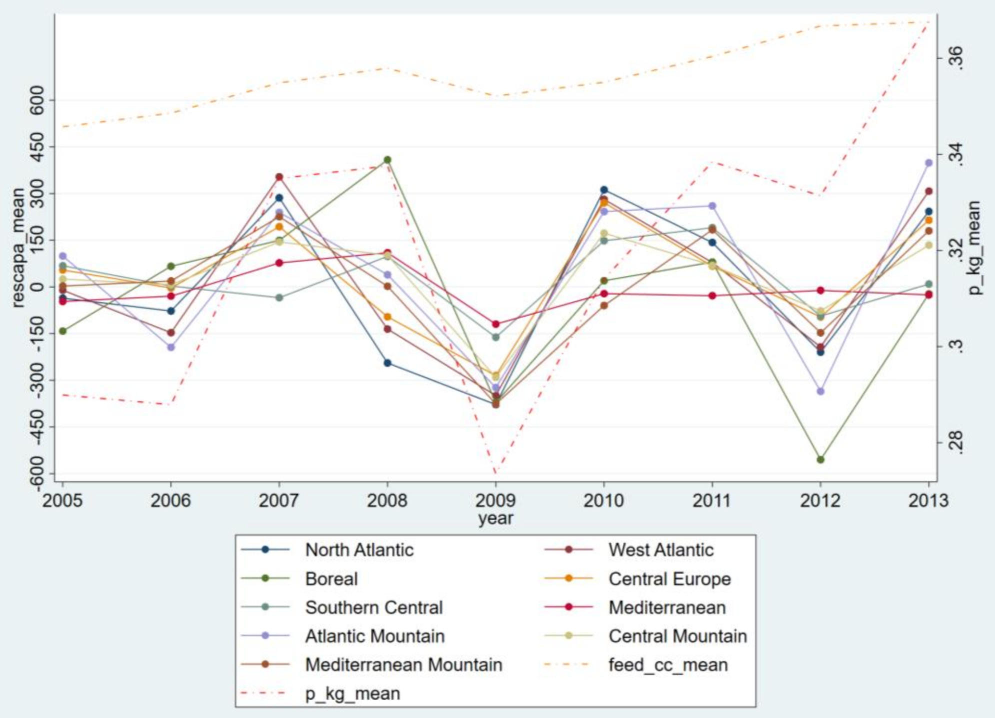


Figure 16 – Dairy farm efficiency of climatic regions on a common frontier

However, when regions are compared under the same frontier, it is implicitly assumed that these regions can achieve the same performance, which is a relatively strong assumption given that climatic and other factors are very different across Europe. Therefore there is a need to assess the regions individually, which begins on page 51 with the Atlantic zone.

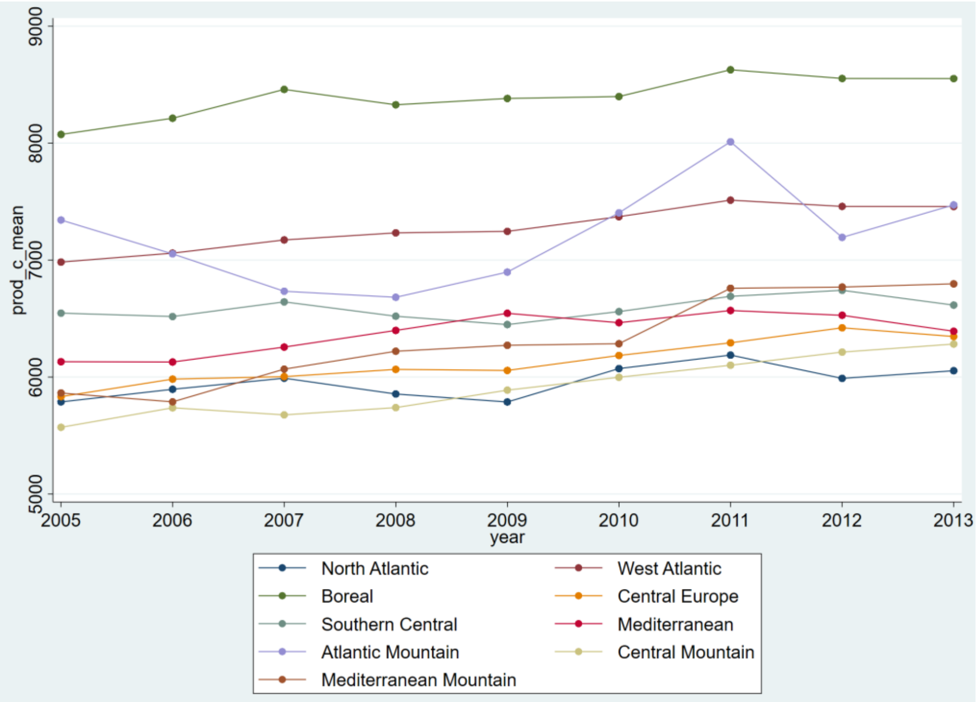
When resilience is considered, Figure 17 and Figure 18 indicate the evolution of the margin difference annually as well as the trend in milk production per cow, respectively. When considered at the enterprise or systems level, clearly, the main issue in terms of resilience is of an economic nature. Overall, the margin seems to strongly correlate with the price of milk, whilst production is quite stable over time and increases steadily.

In the following sections, dairy farm efficiency will be examined on a regional basis, and further refined through analysis at farm type or intensity level (including organic farm differentiation). An economic resilience is then performed at climatic region level.



(n=93,922; minimum group size=180)

Figure 17 – Dairy farm economic resilience of climatic regions over from 2005 to 2013



(n=118,275: ; minimum group size=218)

Figure 18 – Dairy cow production resilience of climatic regions over from 2005 to 2013

4.1. Atlantic zone results

4.1.1. Atlantic dairy efficiency

The efficiency score is very high when assuming that all climatic regions can achieve the same across Europe (common frontier); in this case we obtain a score of 0.98 (out of 1) in North Atlantic, 0.95 in West Atlantic, and 0.96 in Atlantic Mountain; with a very low standard deviation (sd) for all of those regions (see Table 19). The North Atlantic region has the highest efficiency score in the Atlantic region, indicating a greater economic return compared to the cost of inputs, possibly as a result of an ideal climate for grassland production and relatively mild winters. When assuming a specific frontier for each climatic region, the efficiency scores in North Atlantic and West Atlantic are still high but significantly lower, while it remains quite similar in the Atlantic Mountain region, indicating a higher heterogeneity within the North Atlantic and West Atlantic regions compared to the Atlantic Mountain one.

Table 19 Atlantic zone dairy farm efficiency on common and specific frontiers

Climatic region	Value	Common frontier	Specific frontier	Milk yield /cow (kg)	Revenue /cow (€)	Feed cost/ cow (€)	Forage cost/ cow (€)	Margin/ cow (€)	n
North Atlantic	mean	0.98	0.89	5932	1736	520	115	826	6952
	sd	0.01	0.07	1457	533	291	50	354	
West Atlantic	mean	0.95	0.86	7227	2340	674	131	1220	38555
	sd	0.02	0.11	1642	644	407	83	507	
Atlantic Mountain	mean	0.96	0.93	7105	2227	569	126	1225	244
	sd	0.01	0.05	1350	538	391	84	470	

When considering changes over time, **Figure 19**, shows differences in terms of efficiency between farm types in North Atlantic, West Atlantic, and Atlantic Mountain, respectively. These graphs assume a common frontier across all farm types within each of the climatic region, allowing for an overall performance comparison.

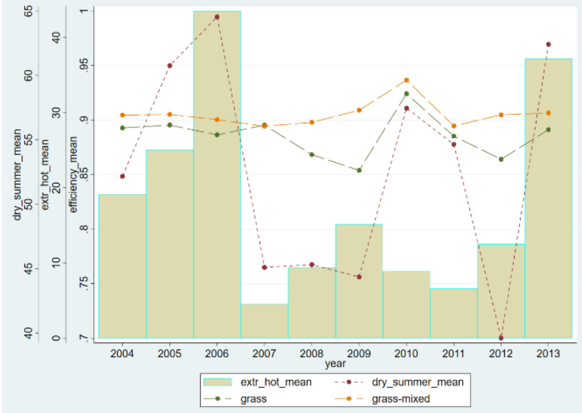
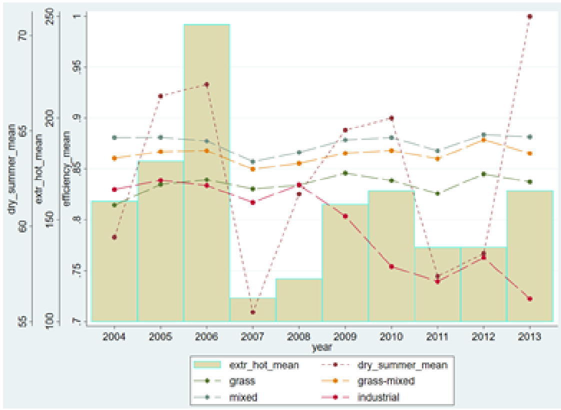
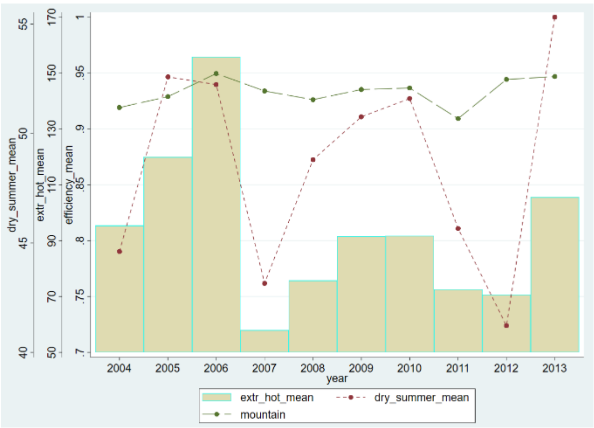
North Atlantic	West Atlantic
	
Atlantic Mountain	
	

Figure 19 Efficiency scores in the Atlantic zone, (common frontier for all farm types)

When each region is further differentiated into farm types, and assessed on a **common frontier** per region Table 20 indicates that in the North Atlantic region, grass farm types were less efficient, whilst grass-mixed and mixed types were almost identical in performance. For the West Atlantic region, all farm types were significantly different, with mixed the most efficient, followed by grass-mixed, grass and then the industrial/intensive farms in last position, probably in part due to their high feed costs relative to production.

When results are considered under a farm type **specific frontier**, it further highlights the range in performance within that type, rather than against another type, so higher standard deviations indicate a greater variance within the type.

Within the Atlantic zone, milk yield is highest within the West Atlantic region, whilst purchased feed costs are greatest for the intensive/industrial farm types. The margin per cow is generally lowest in the Northern Atlantic region, where yields are also the lowest.

Table 20 Atlantic region dairy farm type efficiency scores when assuming a common or specific frontier within each climatic region

Climatic region	Farm type*	Value	Common frontier	Specific frontier	Milk yield/ cow	Revenue /cow (€)	Feed cost/ cow	Forage cost/ cow	Margin /cow (€)	n
North Atlantic	GRS[a]	mean	0.89	0.89	5832	1704	505	113	817	6236
		sd	0.08	0.08	1405	518	282	49	352	
	GMX[b]	mean	0.91	0.89	6821	2023	656	130	907	625
		sd	0.06	0.09	1622	586	327	51	350	
	IND	mean	0.89		6142	1748	617	100	750	21
		sd	0.05		1603	549	248	49	289	
	MIX[b]	mean	0.91	0.96	6805	1978	611	134	895	69
		sd	0.04	0.03	1416	545	347	71	462	
West Atlantic	GRS[a]	mean	0.83	0.86	6653	2185	673	62	1163	8466
		sd	0.12	0.10	1659	662	398	57	512	
	GMX[b]	mean	0.86	0.87	7145	2318	589	137	1276	12306
		sd	0.10	0.09	1590	643	379	63	494	
	IND[c]	mean	0.79	0.83	6871	2271	984	66	937	1879
		sd	0.16	0.11	2099	791	455	67	596	
	MIX[d]	mean	0.88	0.87	7638	2447	703	171	1241	15903
		sd	0.09	0.10	1492	596	405	81	488	
Atlantic Mountain	MNT	mean	0.93	0.93	7095	2221	566	126	1222	243
		sd	0.05	0.05	1345	533	389	84	469	

* Differing letters indicate significantly different farm types

Table 21 indicates the main drivers and challenges within each farm type in the Atlantic regions when assuming a specific frontier. A "+" sign indicates a contribution to greater efficiency, a "-" to lower efficiency, and "ns", highlighting no significant effect.

The stocking density and dairy specialisation appear to be the most important factors in favour of efficiency, whilst other determinants such as farm size and even increased heat (THI), are generally positively significant but the coefficients are extremely small, meaning that they have almost no effect. The drought in spring and summer has a positive effect in North Atlantic and Atlantic Mountain regions, possibly reflecting the increase in solar gain compared to the typically cooler and damp climates of these regions. However, in the West Atlantic region drought in spring and summer has a negative effect. Also and surprisingly, the year has a negative effect on efficiency, indicating a decline in efficiency over time, possibly due to decreasing margins over feed costs, or difficulties in adapting to structural changes over time.

Table 21 Atlantic zone drivers and challenges to dairy farm efficiency within each farm type assuming a specific frontier

Region	Farm type	n	FSIZE	HRC	FEED	FOR	STOCK	SPEC	MAIZE	GRASS	HEAT	DRY_SPR	DRY_SUM	YR
North Atlantic	GRS	6236	+	-	-	+	+	+	+	-	+	+	+	-
	GMX	625	+	ns	-	ns	ns	+	ns	-	-	+	+	-
West Atlantic	GRS	8466	+	+	ns	+	+	+	+	+	+	-	-	-
	GMX	12306	+	-	+	+	+	+	+	-	+	-	-	-
	IND	1879	+	-	+	+	-	+	ns	ns	+	-	ns	-
	MIX	15903	+	-	+	+		+	-	-	+	-	-	-
Atlantic Mountain	MNT	243	+	ns	+	-	+	ns	ns	ns	+	+	+	ns

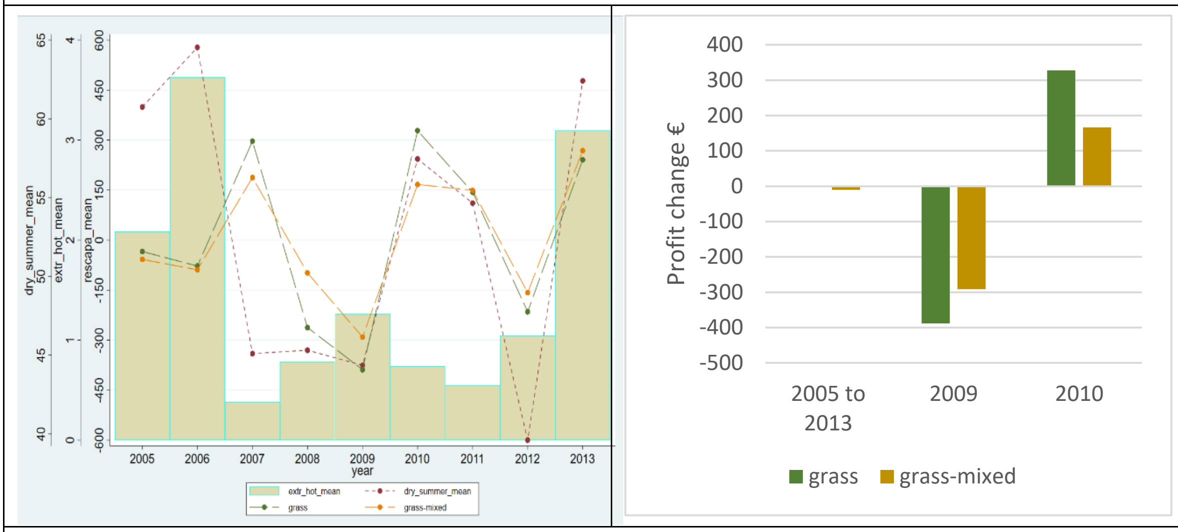
4.1.2. Atlantic dairy resilience

The economic resilience of Atlantic dairy systems is indicated by the change in margin between years (calculated on an individual farm basis), and is shown in Figure 20. Over the ten year period, the annual margin changes considerably with large fluctuations in all regions and for all farm types. The charts also indicate the how the margin decreased considerably in 2009 for all regions due to the dramatic fall in the milk price.

Whilst all farm types saw a large fall in their margins in 2009, the recovery in 2010 varied within the regions and by farm types:

- North Atlantic: Grass farms recovered well in 2010, but grass-mixed and mixed only saw a small improvement to their margin in 2010.
- West Atlantic: The grass system appears to suffer less in 2010, whilst the mixed and systems show a larger reaction in 2009, followed by a strong recovery, however the intensive system fails to recover at the same rate.
- The Atlantic mountain region shows the same overall pattern

North Atlantic region



West Atlantic region

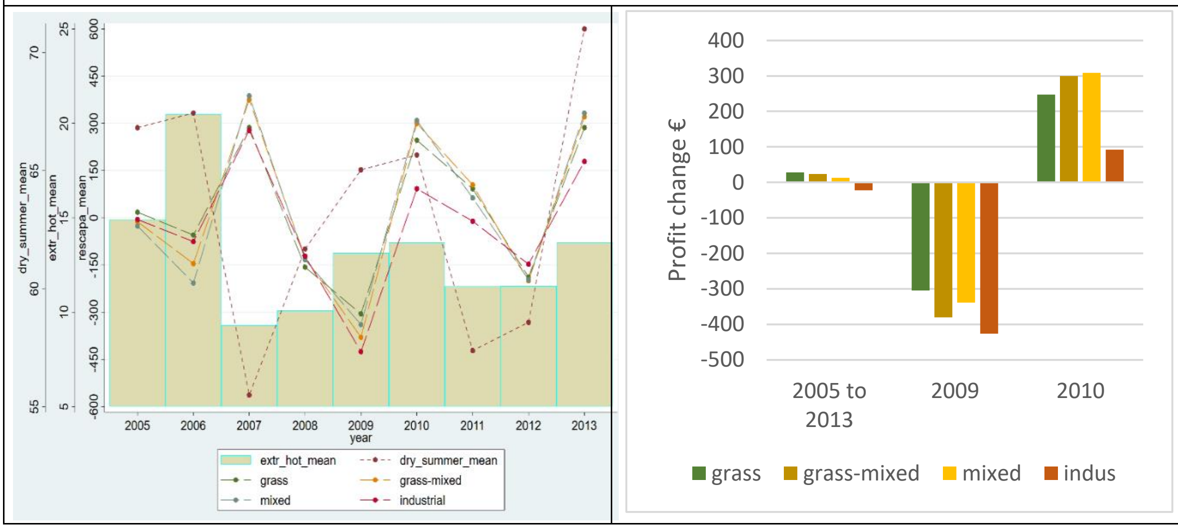


Figure 20 Resilience (overview and margin change in specific years) in N. and W. Atlantic regions

When the drivers of resilience are examined, Table 21 indicates that many factors were not significant. For the North and West Atlantic both milk and feed price shocks, increased intensity, as well as heat caused a negative impact on resilience. On the contrary, increasing specialisation, farm size and a dry spring supported dairy margin resilience.

Table 22 Atlantic region drivers and challenges to dairy resilience

	n	SHOCK_MILK	SHOCK_FEED	FSIZE	STOCK	INT	SHOCK_CONC	SPEC	DEPEND	SHOCK_HEAT	DRY_SPR	DRY_SUM
North Atlantic	5317	-	-	+	ns	-	ns	+	ns	-	+	ns
West Atlantic	27758	-	-	+	-	-		+	+	-	+	+

4.2. Boreal zone/region results

4.2.1. Boreal dairy efficiency

The efficiency score is high when assuming that all climatic regions can achieve the same across Europe (common frontier); though at a score of 0.90 (out of 1) in the Boreal region, it is lower than other regions. When assuming a specific frontier for the Boreal region, the efficiency scores remains very similar; however, the standard deviation increases from 0.03 to 0.10.

The Boreal region shows a high annual milk yield and revenue, though feed costs are also substantial, albeit with a high standard deviation, indicating variance between farms. In general, costs have increased much more than the price the farmers are paid for the milk. For Swedish dairy farmers 2006-2007 were very difficult years with high feed costs (high price of cereal) and 2009 the milk price was really low. Also 2013 was a very though year. In an interview study that year 100% off the Swedish dairy farmers said profitability was low or very low. The low profitability increase the speed of structural changes - many dairy farmers with small herds slaughter the animals and close the barn. Due to low profit the rate of investments in buildings and equipment is low and maintenance is postponed. Many farmers also decrease the speed of paying back on loans. The active farmers say, when interviewed, that they like their job, but many of them would not recommend their daughters and sons to become farmers.

Table 23 Boreal region dairy farm efficiency on common and specific frontiers

Climatic region	Value	Common frontier	Specific frontier	Production /cow (kg)	Revenue /cow (€)	Feed cost/ cow (€)	Forage cost/ cow (€)	Margin /cow (€)	n
Boreal	mean	0.90	0.89	8353	3193	1043	151	1532	3966
	sd	0.03	0.10	1353	658	523	87	666	

When considering changes over time, **Figure 21** shows differences in efficiency between farm types in the Boreal region between 2004 and 2013. This graph assume a common frontier across all farm types within the Boreal region, allowing for an overall performance comparison instead of looking at the heterogeneity within each farm type in each climatic region.

Results in Table 24 under a **common frontier** indicate that mixed farms were significantly more efficient than grass-mixed, that were superior to purely grass based farms.

The milk yield level is similar between the farm types, whilst feed costs were highest for the grassland based farms, which also showed the lowest margins, probably reflecting the high cost of purchasing externally sourced feeds with poorer land quality or climatic restrictions.

Table 25 examines the drivers and challenges within each farm type in the Boreal region, assuming a specific frontier. A “+” sign indicates a contribution to greater efficiency, a “-“ to lower efficiency, and “ns”, highlighting no significant effect.

The stocking density and dairy specialisation appear to be the most important factors in favour of efficiency, but the stocking density has no significant effect in the grass system. The heat is positively significant whilst a drought in spring and summer has only a significant negative effect in the mixed system. As with the Atlantic zone, the year also has a quite strong negative effect on efficiency across all farm types.

Boreal region

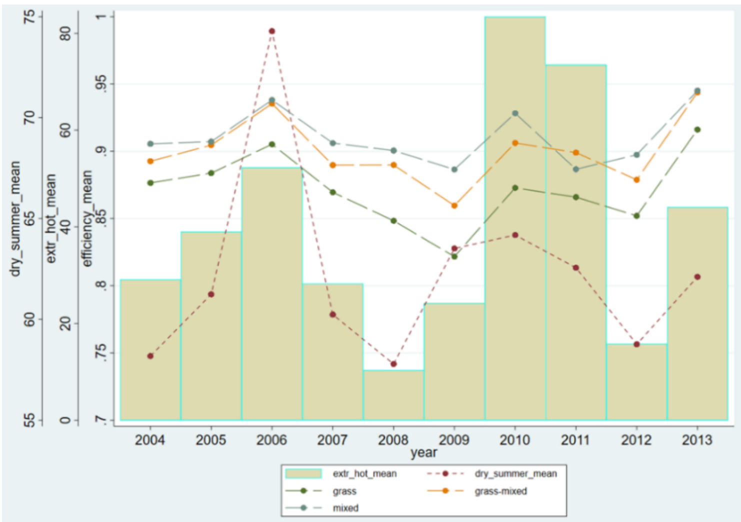


Figure 21 – Efficiency score in the Boreal region, (common frontier for all farm types)

Table 24 Boreal region dairy farm type efficiency scores when assuming a common or specific frontier within each climatic region

Climatic region	Farm type*	Value	Common frontier	Specific frontier	Milk yield/ cow (kg)	Revenue /cow (€)	Feed cost/ cow (€)	Forage cost/ cow (€)	Margin /cow (€)	n
Boreal	GRS[a]	mean	0.87	0.89	8228	3106	1145	155	1196	1270
		sd	0.12	0.12	1450	688	545	101	715	
	GMX[b]	mean	0.90	0.90	8407	3226	1007	152	1452	2000
		sd	0.09	0.09	1333	648	522	82	639	
	MIX[c]	mean	0.91	0.90	8427	3257	958	138	1522	696
		sd	0.07	0.08	1206	616	448	69	566	

* Differing letters indicate significantly different farm types

Table 25 Boreal region drivers and challenges to dairy farm efficiency within each farm type assuming a specific frontier

Region	Farm type	n	FSIZE	HRC	FEED	FOR	STOCK	SPEC	MAIZE	GRASS	HEAT	DRY_SPR	DRY_SUM	YR
Boreal	GRS	1270	+	ns	+	ns	ns	+	ns	-	+	ns	ns	-
	GMX	2000	ns	-	+	ns	+	+	ns	ns	+	ns	ns	-
	MIX	696	ns	ns	+	+	+	+	ns	ns	+	ns	-	-

4.2.2. Boreal dairy resilience

The economic resilience of Atlantic dairy systems is indicated by the change in margin between years (calculated on an individual farm basis), and is shown in **Figure 22**. During the 10 year time period shown the margin showed a generally negative trend, with a severe fall in margins in 2009, with a small recovery in 2010, but another negative impact in 2012. The data indicates that climatic effects do not seem to influence the change in margin, with price changes for milk and feed causing the largest impacts.

Boreal region

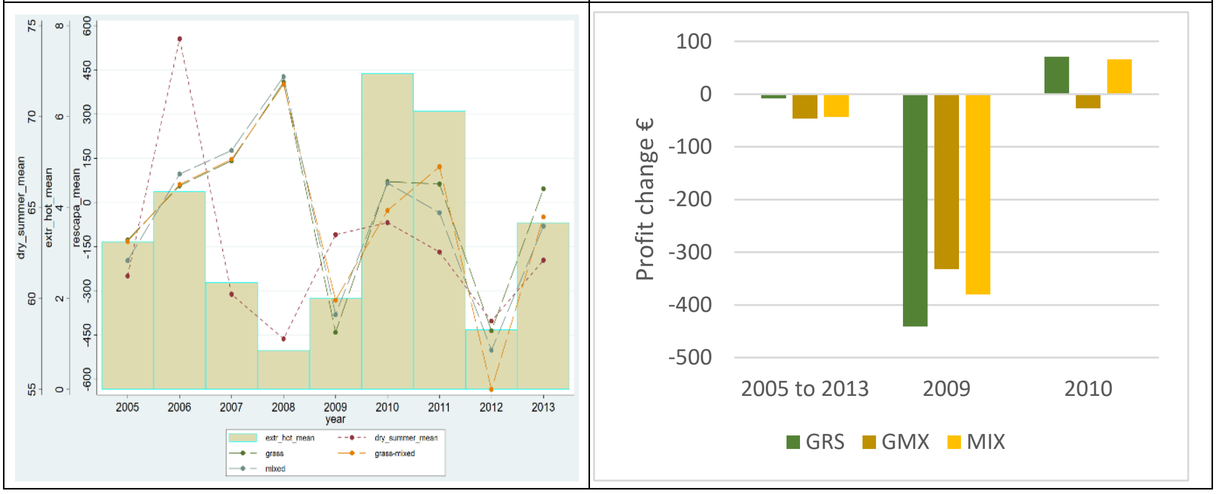


Figure 22 – Resilience (overview and margin change in specific years) in the Boreal region

When the drivers of resilience are examined, Table 26 shows that economic factors caused a negative impact on margin resilience, whilst increasing specialisation and a dry spring exerted a positive effect.

Table 26 Boreal region drivers and challenges to dairy resilience

	n	SHOCK_MILK	SHOCK_FEED	FSIZE	STOCK	INT	SHOCK_CONC	SPEC	DEPEND	SHOCK_HEAT	DRY_SPR	DRY_SUM
Boreal	3179	-	-	ns	ns	-	-	+	ns	ns	+	ns

4.3. Continental Europe zone results

4.3.1. Continental dairy efficiency

The efficiency scores are high when assuming that all climatic regions can achieve the same across Europe (common frontier), especially for the Central Mountain region where the efficiency score is even excellent When assuming a specific frontier for each climatic region, the efficiency scores in Central Europe and Central Mountain are still high but a little lower, indicating some heterogeneity within the farms of each region.

Table 27 Continental region dairy farm efficiency on common and specific frontiers

Climatic region	Value	Common frontier	Specific frontier	Milk yield /cow (kg)	Revenue /cow (€)	Feed cost/ cow (€)	Forage cost/ cow (€)	Margin /cow (€)	n
Central Europe	mean	0.89	0.87	6102	1808	544	103	926	53126
	sd	0.07	0.10	1724	725	335	75	498	
Central Mountain	mean	0.96	0.89	5879	2083	655	54	1093	10983
	sd	0.03	0.08	1679	740	442	62	595	

When considering changes over time, Figure 23 indicates differences in terms of efficiency between farm types in Central Europe and Central Mountain. These charts assume a common frontier across all farm types within each of the climatic region, allowing for an overall performance comparison instead of looking at the heterogeneity within each farm type in each climatic region.

Central Europe	Central Mountain

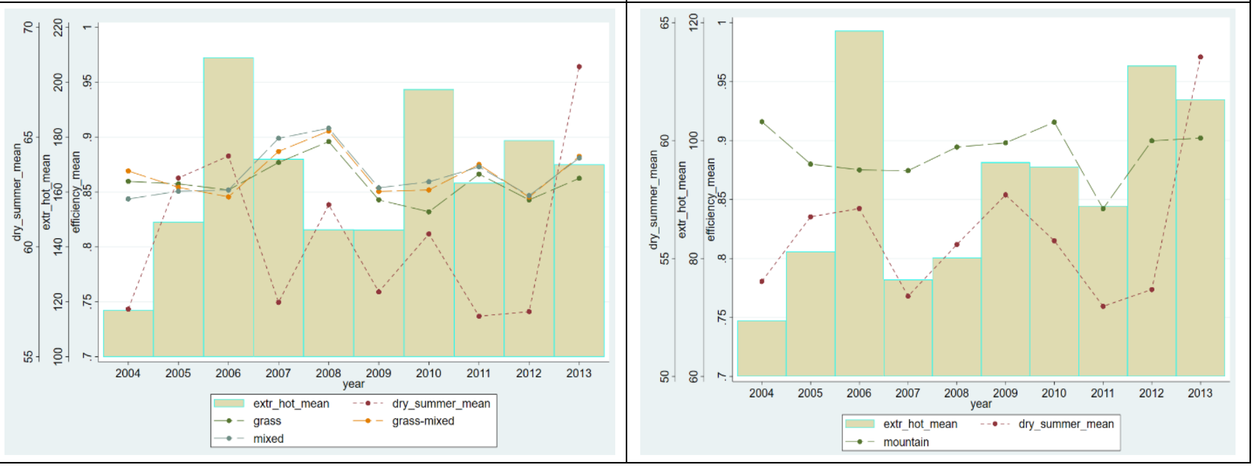


Figure 23 Efficiency score in Central Europe, (common frontier for all farm types)

When each region is further differentiated into farm types and assessed under a **common frontier** per region, Table 28 indicates that in the Central Europe (lowland) region grass farms were the least efficient, with intensive/industrial farms showing the highest efficiency and mixed farms in the middle range. Milk yields were lower on the industrial farms, and similar between the other farm types, while feed costs were highest for grass farms. The margin per cow was greatest on the grass-mixed and mixed farms and lowest on the industrial types (though also a small sample compared to the other types).

In the Central Mountain (Alpine) region the mountain farm type achieved efficiency of 0.89 and an average milk yield of almost 5900 kgs per cow. The small sample of intensive/industrial farms in this region probably have limited grazing land or share common grazing areas, but achieved a low yield of around 4000kgs of milk per cow and the lowest margin in the Continental Europe zone due to high feed costs and low milk yield.

Table 28 Continental region dairy farm type efficiency scores when assuming a common or specific frontier within each climatic region

Climatic region	Farm type*	Value	Common frontier	Specific frontier	Milk yield/ cow (kg)	Revenue /cow (€)	Feed cost/ cow (€)	Forage cost/ cow (€)	Margin/cow (€)	n
Central Europe	GRS[a]	mean	0.86	0.86	5963	1819	621	52	880	7432
		sd	0.12	0.12	1753	751	402	55	558	
	GMX[b]	mean	0.87	0.86	6039	1821	551	95	939	14463
		sd	0.10	0.10	1689	735	369	65	512	
	IND[c]	mean	0.91	0.92	5654	1617	577	35	850	72
		sd	0.07	0.05	1891	654	328	46	514	
	MIX[b]	mean	0.87	0.89	6166	1800	523	119	932	31155
		sd	0.09	0.08	1730	714	295	78	476	
Central Mountain	IND[a]	mean	0.81	0.79	4039	1747	887	2	674	70
		sd	0.11	0.15	1558	647	381	7	485	
	MNT[b]	mean	0.89	0.89	5891	2085	654	54	1096	10914
		sd	0.08	0.08	1673	740	442	62	595	

* Differing letters indicate significantly different farm types

Table 29 indicates the main drivers and challenges within each farm type in the Continental Europe regions when assuming a common frontier. A "+" sign indicates a contribution to greater efficiency, a "-" to lower efficiency, and "ns", highlighting no significant effect. The industrial/intensive farm type drivers could not be determined due to the small sample sizes.

The specific forage costs, stocking density, dairy specialisation, and the share of maize area appear to be the most important factors in favour of efficiency. The effects of a drought in the spring has a positive or little negative effect in the Central Europe region, but a negative effect in the Central Mountain region. Summer drought only has a significant negative effect in the mixed system in Central Europe as well as for the mountain farms in Central Mountain. As per Atlantic and Boreal zones, time caused a negative impact on margin resilience, though this wasn't seen on the mountain farms.

Table 29 Continental region drivers and challenges to dairy farm efficiency within each farm type assuming a specific frontier

		n	FSIZE	HRC	FEED	FOR	STOCK	SPEC	MAIZE	GRASS	HEAT	DRY_SPR	DRY_SUM	YR
Central Europe	GRS	7432	+	ns	ns	+	+	+	+	+	+	+	ns	-
	GMX	14463	+	ns	-	+	+	+	+	+	-	+	ns	-
	MIX	31155	+	ns	-	+	+	+	+	+	+	-	-	-
Central Mountain	MNT	10914	-	ns	-	ns	+	+	+	+	-	-	-	ns

4.3.2. Continental dairy resilience

The economic resilience of Continental zone dairy systems is indicated by the change in margin between years (calculated on an individual farm basis), and is shown in Figure 24. During the 10 year time period shown, the margin showed a slightly positive trend, with a severe fall in margins in 2009, but a strong small recovery in 2010, followed by a small but further decline in margins in 2012. The data indicates that climatic effects do not seem to influence the change in margin, with price changes for milk and feed causing the impact.

When the drivers of resilience are examined, Table 30 shows that economic factors caused a negative impact on margin resilience, whilst increasing specialisation has a positive effect. In the Central lowland region extra heat and a dry spring also exerted a positive effect.

Central Europe region

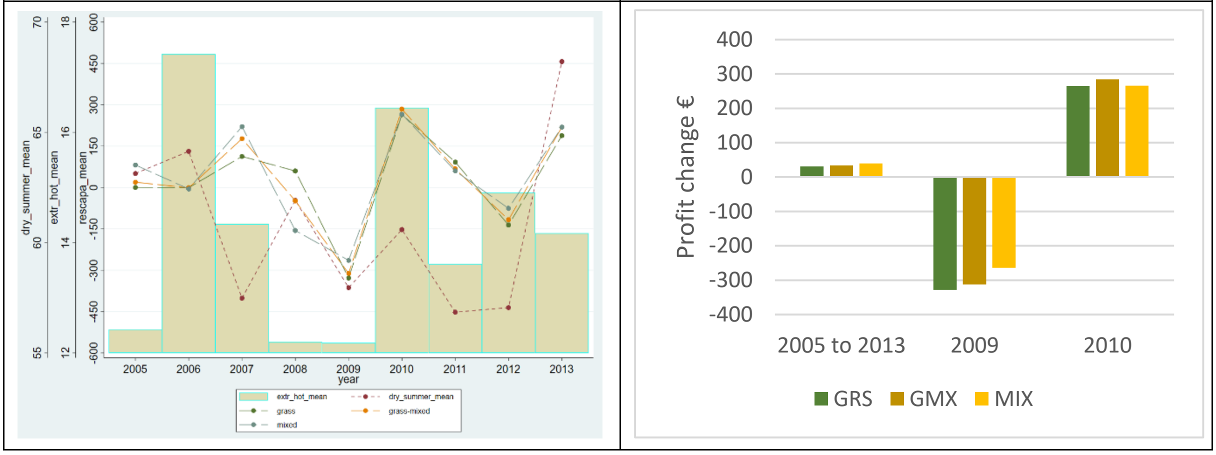


Figure 24 – Resilience (overview and margin change in specific years) in Central Europe region

Table 30 Atlantic region drivers and challenges to dairy resilience

	n	SHOCK_MILK	SHOCK_FEED	FSIZE	STOCK	INT	SHOCK_CONC	SPEC	DEPEND	SHOCK_HEAT	DRY_SPR	DRY_SUM
Central Europe	38043	-	-	+	ns	-	-	+	+	+	+	-
Central Mountain	7991	-	-	ns	ns	ns	-	+	ns	ns	-	ns

4.4. Southern Europe zone results

4.4.1. Southern dairy efficiency

The efficiency score is very high when compared on a common frontier with other regions in Europe (common frontier); with Southern Central achieving 0.94, Mediterranean at 0.96 and 0.96 in the Mediterranean Mountain region. All regions shows a very low standard deviation , and even when assuming a specific frontier to assess for heterogeneity within a specific climatic region, the efficiency scores are a little lower and the standard deviations slightly higher.

Table 31 Mediterranean region dairy farm efficiency on common and specific frontiers

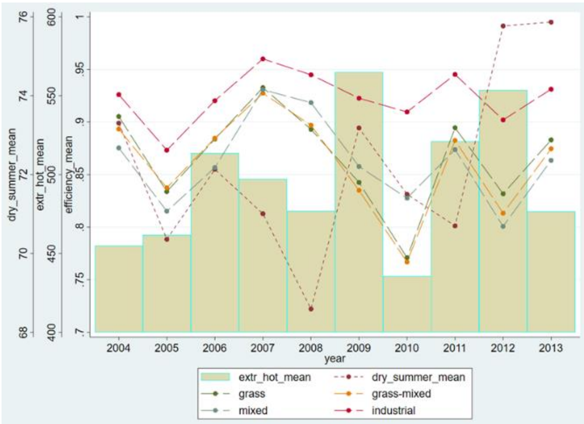
Climatic region	Value	Common frontier	Specific frontier	Milk yield /cow (kg)	Revenue /cow (€)	Feed cost/ cow (€)	Forage cost/ cow (€)	Margin /cow (€)	n
Southern Central Europe	mean	0.94	0.87	6556	2307	990	93	1024	8866
	sd	0.04	0.10	1884	921	511	79	750	
Mediterra-nean	mean	0.96	0.92	6330	2281	1102	61	963	4897
	sd	0.02	0.05	2130	860	604	73	683	
Mediterran ean Mountain	mean	0.96	0.91	6223	2132	897	55	1003	3292
	sd	0.02	0.06	1881	788	463	56	669	

When considering changes over time, **Figure 25** highlights differences in terms of efficiency over time between farm types in Southern Central, Mediterranean, and Mediterranean Mountain, respectively. These charts assume a common frontier across all farm types within each of the climatic regions, allowing for an overall performance comparison.

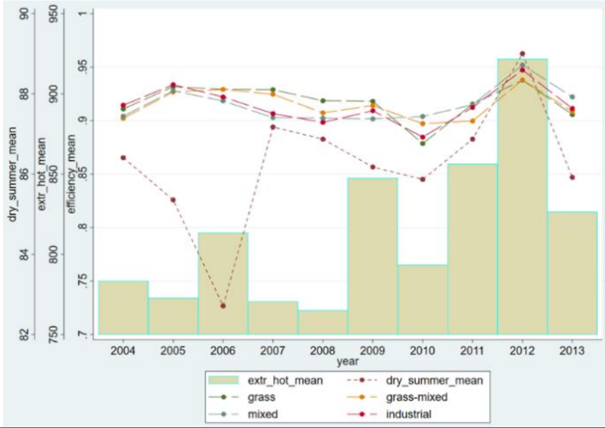
When each region is further differentiated into farm types, and assessed on a **common frontier** per region Table 32 indicates that in the Southern Central region, industrial/intensive farm types achieved the highest efficiency, whilst grass and grass-mixed and mixed types were almost identical in performance, and mixed and grass-mixed also significantly different to the other farm types. For the Mediterranean region, grass and grass-mixed formed one group, whilst grass-mixed, mixed and industrial formed another significantly different group. For the Mediterranean Mountain region the mountain farms were more efficient than the industrial ones, When results are considered under a farm type **specific frontier**, it further highlights the range in performance within that type, rather than against another type, so higher standard deviations indicate a greater variance within the type.

Within the Southern Europe zone, milk yield is highest on the mixed and intensive farms, but they also incur the highest feed costs. The margin per cow is generally lowest on the mixed Mediterranean farms and highest on the industrial types which are more common in this zone than the other climatic zones.

Southern Central region



Mediterranean region



Mediterranean Mountain region

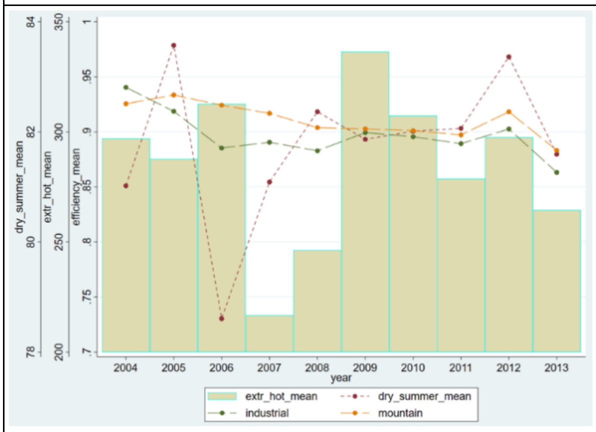


Figure 25 Efficiency scores in the Mediterranean regions, (common frontier for all farm types)

Table 32 Mediterranean region dairy farm type efficiency scores when assuming a common or specific frontier within each climatic region

Climatic region	Farm type*	Value	Common frontier	Specific frontier	Milk yield/ cow	Revenue /cow (€)	Feed cost/ cow	Forage cost/ cow	Margin /cow (€)	n
Southern Central	GRS[a]	mean	0.87	0.88	6174	2283	998	58	1024	1875
		sd	0.11	0.11	1880	1034	562	60	804	
	GMX[ab]	mean	0.86	0.89	6364	2189	899	108	973	2197
		sd	0.11	0.10	1752	878	502	71	713	
	IND[c]	mean	0.92	0.91	7026	2693	1143	44	1327	1034
		sd	0.05	0.06	1989	934	500	40	739	
	MIX[b]	mean	0.86	0.87	6727	2280	996	115	970	3755
		sd	0.11	0.11	1882	854	480	87	725	
Mediterranean	GRS[a]	mean	0.92	0.89	5942	2058	861	40	1047	764
		sd	0.05	0.07	2030	760	464	59	639	
	GMX[ab]	mean	0.92	0.94	5808	2165	906	63	1078	617
		sd	0.05	0.05	2053	897	503	63	728	
	IND[b]	mean	0.91	0.91	6609	2372	1212	41	947	1849
		sd	0.05	0.07	2095	812	634	59	642	
	MIX[b]	mean	0.92	0.92	6394	2326	1164	92	899	1665
		sd	0.06	0.05	2183	916	614	83	719	
Mediterranean Mountain	IND[a]	mean	0.89	0.90	6710	2325	1004	23	1105	281
		sd	0.07	0.07	1860	917	529	33	740	
	MNT[b]	mean	0.91	0.92	6175	2110	887	58	990	3008
		sd	0.06	0.06	1876	766	455	56	655	

* Differing letters indicate significantly different farm types

Table 33 indicates the main drivers and challenges within each farm type in the Southern Europe regions when assuming a specific frontier. A "+" sign indicates a contribution to greater efficiency, a "-" to lower efficiency, and "ns", highlighting no significant effect.

The farm size and dairy specialisation appear to be the most important factors in favour of efficiency, as well as increased heat (THI) and a spring drought in some farm types. Some negative impacts appear to be an increasing area of grassland – possibly linked to land quality, whilst many factors were not significant for most farm types. For Southern region and Mediterranean mountain farm types the year was a negative effect, whilst in the Mediterranean area there was no significant year effect.

Table 33 Mediterranean region drivers and challenges to dairy farm efficiency within each farm type assuming a specific frontier

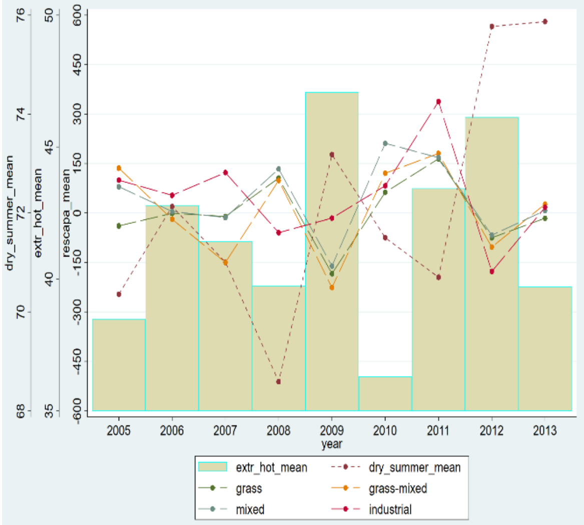
		n	FSIZE	HRC	FEED	FOR	STOCK	SPEC	MAIZE	GRASS	HEAT	DRY_SPR	DRY_SUM	YR
Southern central	GRS	1875	+	ns	-	+	+	+	ns	-	+	-	-	-
	GMX	2197	ns	ns	ns	+	ns	+	+	-	+	+	-	-
	IND	1034	+	ns	ns	ns	ns	+	ns	ns	+	ns	+	-
	MIX	3755	ns	+	ns	+	ns	+	-	-	+	+	ns	-
Mediterranean	GRS	764	+	ns	ns	ns	ns	+	-	-	+	+	ns	ns
	GMX	617	+	+	ns	ns	+	ns	ns	-	+	-	-	ns
	IND	1849	ns	ns	+	ns	ns	+	+	+	ns	-	-	ns
	MIX	1665	+	ns	+	ns	+	+	ns	ns	+	ns	-	ns
Mediterranean Mountain	IND	281	+	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
	MNT	3008	+	ns	ns	+	+	+	-	-	-	+	-	-

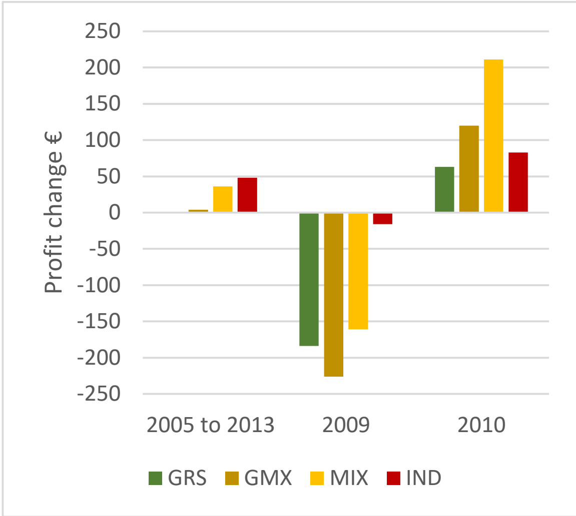
4.4.2. Southern dairy resilience

The economic resilience of Southern zone dairy systems is indicated by the change in margin between years (calculated on an individual farm basis), and is shown in Figure **26**. Over the ten year period, the annual margin changes considerably with large fluctuations in all regions and for all farm types, with a small overall increase in margins for some farm types such as industrial types in the Southern region.

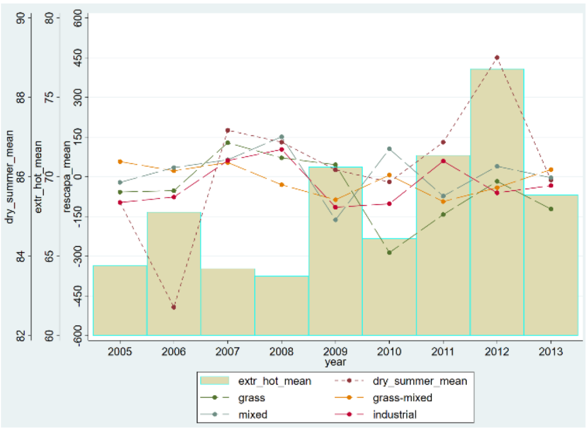
The charts also indicate variable patterns in margin changes during the time period assessed. In the Southern region most farm types see the common decline in margins in 2009 due to the milk market crisis, but the industrial farm type group does not suffer such a severe impact, but appears to have a more severe margin decline in 2012. In the Mediterranean region the margin decline in 2009 of other regions is not really reflected and e.g. grass types even increase their margin in 2009, but then suffer a severe fall in 2010. The Mediterranean Mountain region data fits more with the other zones, with a large margin decline in 2009, but also further losses in 2010, and then a further margin decline in 2012.

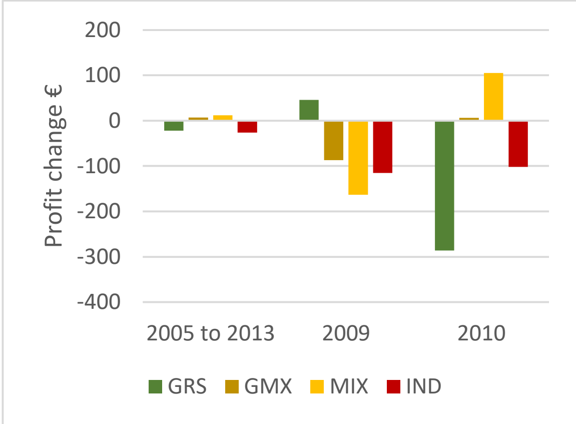
Southern Central region



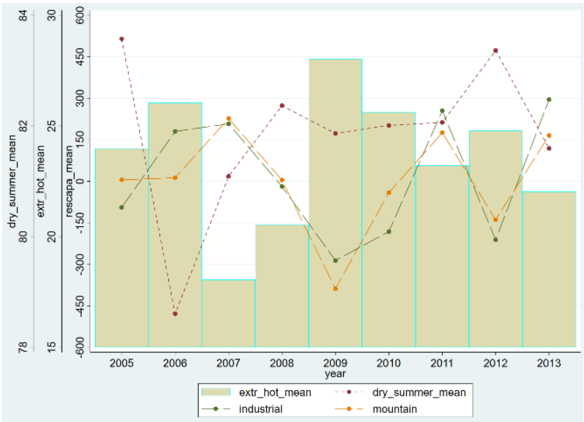


Mediterranean region





Mediterranean Mountain region



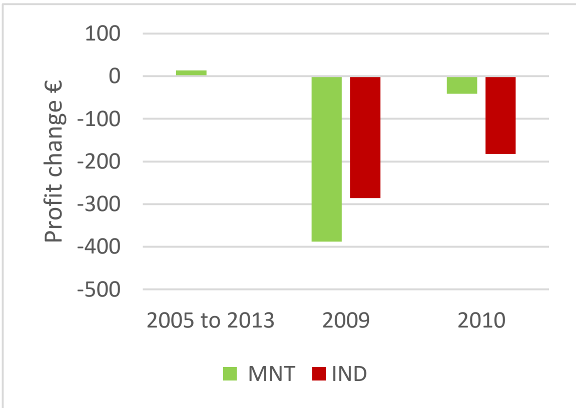


Figure 26 Resilience (overview and margin change in specific years) in the Mediterranean regions

When the drivers of resilience are examined, Table 34 shows that economic factors caused a negative impact on margin resilience, whilst only increasing in specialisation exerted a positive effect. Many factors showed no significant impact on the resilience of margins, especially climatic factors.

Table 34 Southern region drivers and challenges to dairy resilience

	n	SHOCK_MILK	SHOCK_FEED	FSIZE	STOCK	INT	SHOCK_CONC	SPEC	DEPEND	SHOCK_HFAT	DRY_SPR	DRY_SUM
Southern Central	5933	-	-	+	ns	-		+	ns	ns	ns	ns
Mediterranean	3253	-	-	ns	ns	ns	-	+	-	ns	ns	ns
Mediterranean Mountain	2268	-	-	ns	ns	-	ns	+	-	ns	ns	ns

5. Results: Beef sector

European beef production is spread right across the continent, but when it is considered to be uniformly possible to produce beef (a common frontier), Figure 27 and Figure 28 show that for both suckler (breeder) beef and beef finishing systems, the North Atlantic and Boreal regions are the least efficient with a relatively high standard deviation. However, the efficiency level remains relatively high in the different regions, especially for beef finisher systems, though the finisher sample sizes are quite often small compared to the suckler beef data.

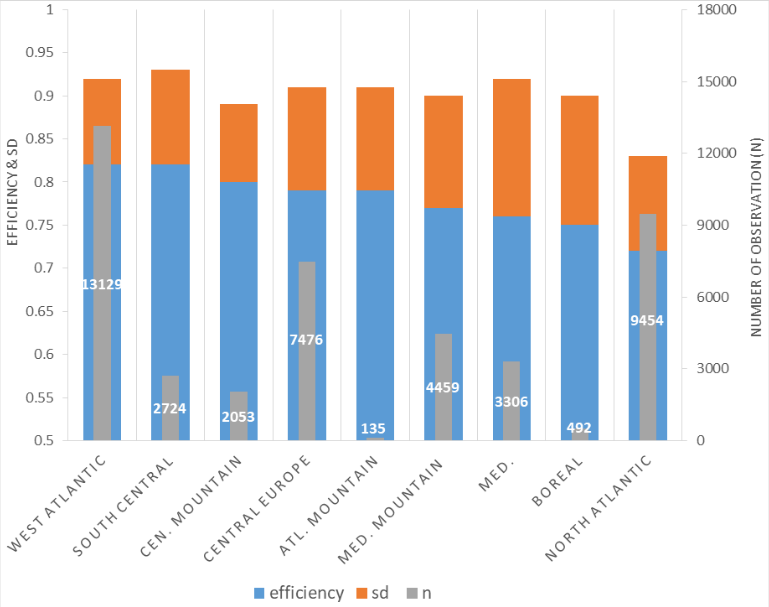


Figure 27 – Suckler beef farm efficiency of climatic regions on a common frontier

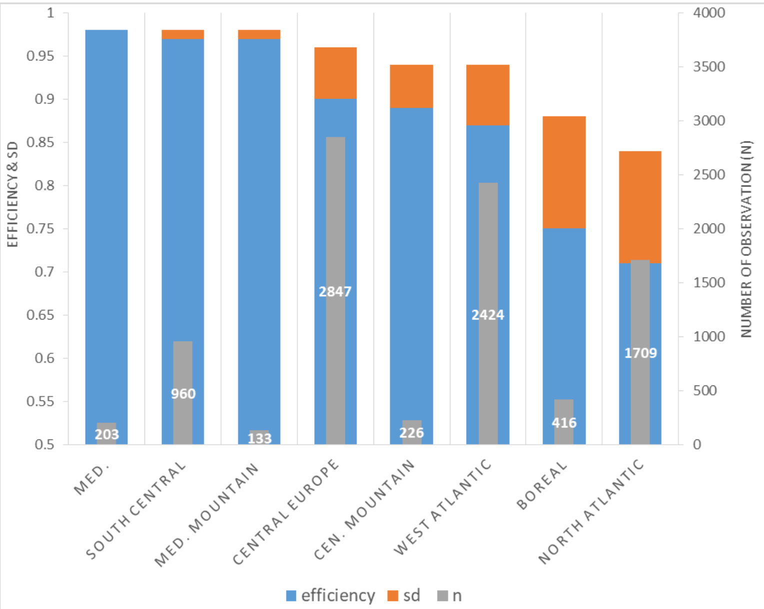
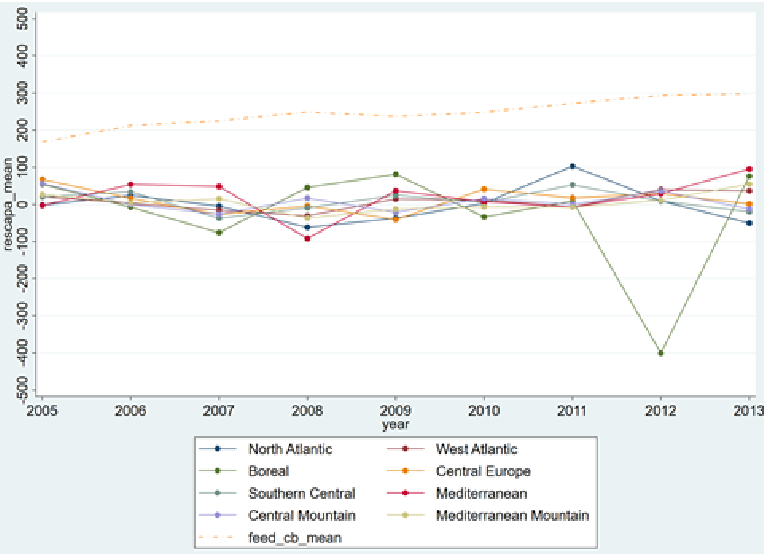


Figure 28 – Finishers beef farm efficiency of climatic regions on a common frontier

However, when regions are compared under the same frontier, it is implicitly assumed that these regions can achieve the same performance; a relatively strong assumption, so there is therefore a need to assess the regions on their own for the two beef systems.

When assessing the regional system resilience, Figure 29 and Figure 30 indicate respectively the evolution of the margin difference annually for the suckler cow and finisher systems. It is obvious from both system charts that the level of variability is limited, especially compared to the sharp changes in the dairy margin during 2009 and 2012.



(n=29,534: minimum sample size=360)

Figure 29 – Suckler beef farm economic resilience of climatic regions over from 2005 to 2013

(n=5,016 minimum sample size=328)

Figure 30 – Finishers beef farm economic resilience of climatic regions over from 2005 to 2013

In the following sections, dairy farm efficiency will be examined on a regional basis, and further refined through analysis at farm type or intensity level (including organic farm differentiation). An economic resilience assessment is then performed at climatic region level.

5.1. Atlantic zone results

5.1.1. Atlantic suckler beef efficiency

The efficiency score is lower when compared to the dairy sector, and when assuming that all climatic regions can achieve the same across Europe (a common frontier); efficiency scores of 0.72 in North Atlantic, 0.82 in West Atlantic, and 0.79 in Atlantic Mountain are obtained. Contrary to the dairy sector, the North Atlantic region has the lowest efficiency score in the Atlantic region but also more generally across Europe. When assuming a specific frontier for each climatic region, the efficiency scores in North Atlantic and Atlantic Mountain are higher while it remains quite similar in the West Atlantic region. This shows that the different climatic regions are actually quite homogenous, especially in the North Atlantic and Atlantic Mountain regions.

Table 35 Atlantic region suckler beef farm efficiency on common and specific frontiers

Climatic region	Value	Common frontier	Specific frontier	Revenue /BLU (€)	Feed cost/BLU (€)	Forage cost/BLU (€)	Margin/ BLU(€)	n
North Atlantic	mean	0.72	0.83	555	188	101	114	9454
	sd	0.11	0.10	216	120	60	187	
West Atlantic	mean	0.82	0.80	776	227	93	322	13129
	sd	0.10	0.13	311	179	68	267	
Atlantic Mountain	mean	0.79	0.88	700	171	97	263	135
	sd	0.12	0.14	312	90	80	246	

When considering changes over time, Figure 31 show differences in terms of efficiency over time between farm types in North Atlantic, West Atlantic, and Atlantic Mountain regions. These chartss assume a common frontier across all farm types within each of the climatic regions, allowing for an overall performance comparison instead of looking at the heterogeneity within each farm type in each climatic region.

When each region is further differentiated into farm types and assessed under a **common frontier** per region, Table 36 indicates that efficiency varied considerably between farm types. In the North Atlantic region mixed and grass-mixed farms were more efficient, whilst in the West Atlantic region all farm types achieved significantly different levels of efficiency, with mixed farms the most efficient and industrial/intensive farms the least. The Atlantic mountain farms achieved a high level of efficiency for the beef sector of 0.88.

North Atlantic region	West Atlantic region

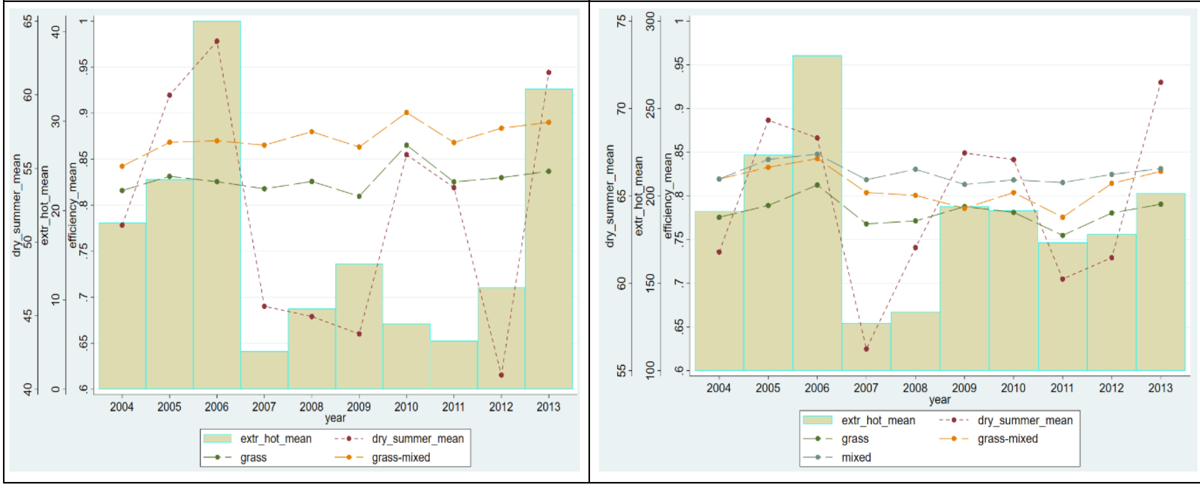


Figure 31 – Efficiency scores in the North Atlantic region, (common frontier for all farm types)

Table 36 Atlantic region suckler beef farm type efficiency scores when assuming a common or specific frontier within each climatic region

Climatic region	Farm type*	Value	Common frontier	Specific frontier	Revenue /BLU (€)	Feed cost /BLU (€)	Forage cost /BLU (€)	Margin /BLU (€)	n
North Atlantic	GRS[a]	mean	0.83	0.83	543	182	98	111	8519
		sd	0.10	0.10	208	115	59	185	
	GMX[b]	mean	0.87	0.90	661	236	129	144	790
		sd	0.07	0.05	242	155	64	201	
	MIX[b]	mean	0.86	0.81	717	246	127	158	140
		sd	0.07	0.14	281	136	67	230	
West Atlantic	GRS[a]	mean	0.78	0.78	719	205	64	321	6173
		sd	0.14	0.14	294	171	58	253	
	GMX[b]	mean	0.81	0.82	787	211	121	323	4361
		sd	0.12	0.12	289	151	62	263	
	IND[c]	mean	0.75	0.74	847	321	43	387	161
		sd	0.21	0.18	462	242	45	313	
	MIX[d]	mean	0.83	0.85	898	307	122	317	2434
		sd	0.11	0.10	337	214	67	301	
Atlantic Mountain	MNT	mean	0.88	0.88	700	171	97	263	134
		sd	0.14	0.14	312	90	80	246	

* Differing letters indicate significantly different farm types

Revenue from beef sales was generally highest on mixed and industrial farms, though they also encountered the highest feed costs. The lowest margins were achieved by grass based farms in the northern Atlantic region and highest in the West Atlantic industrial systems. Table 37 indicates the main drivers and challenges within each farm type in the Atlantic regions when assuming a specific frontier. A “+” sign indicates a contribution to greater efficiency, a “-“ to lower efficiency, and “ns”, highlighting no significant effect.

Multiple factors appear to contribute to a positive margin resilience, including farm size, increasing feed costs, the specialisation rate, as well as additional heat in some regions. A dry spring or summer appear to have a negative or no significant effect on resilience, whilst the grass and maize proportions both appear to results in a negative effect on the margin resilience, possibly linked to the economic advantages of more mixed farm system indicated in the efficiency analysis. In contrast to the dairy sector the year had a positive or no effect on suckler beef resilience.

Table 37 Atlantic region drivers and challenges to suckler beef farm efficiency within each farm type assuming a specific frontier

		n	FSIZE	HRC	FEED	FOR	STOCK	SPEC	SCOW	MAIZE	GRASS	HEAT	DRY_SPR	DRY_SUM	YR
North Atlantic	GRS	8519	+	+	+	+	+	+	-	ns	-	ns	ns	+	ns
	GMX	790	+	ns	+	ns	ns	+	ns	-	ns	-	ns	ns	ns
West Atlantic	GRS	6173	+	+	+	+	+	+	-	ns	-	+	-	-	+
	GMX	4361	+	ns	+	+	+	+	+	-	-	+	-	-	ns
	MIX	2434	+	ns	+	+	+	+	ns	-	ns	+	-	-	+

*Different letters indicate significantly different farm type groups

5.1.2. Atlantic finisher beef efficiency

The efficiency score is considerably lower for the North Atlantic region than the West Atlantic region, when assuming that all climatic regions can achieve the same across Europe (a common frontier); with efficiency scores of 0.71 in North Atlantic and 0.87 in West Atlantic (the sample was too small in the Atlantic Mountain region). When assuming a specific frontier for each climatic region, the efficiency scores in North Atlantic region increase and reduce slightly in the West Atlantic region.

Table 38 Atlantic region beef finisher farm efficiency on common and specific frontiers

Climatic region	Value	Common frontier	Specific frontier	Revenue /BLU (€)	Feed cost/BLU (€)	Forage cost/BLU (€)	Margin /BLU(€)	n
North Atlantic	mean	0.71	0.79	594	254	96	132	1709
	sd	0.13	0.13	307	193	68	207	
West Atlantic	mean	0.87	0.83	906	405	112	267	2424
	sd	0.07	0.10	361	255	77	301	

Considering changes over time, **Figure 32** shows differences in terms of efficiency over time between farm types in North Atlantic and West Atlantic regions. These graphs assume a common frontier across all farm types within each of the climatic region, allowing for an overall performance comparison instead of looking at the heterogeneity within each farm type in each climatic region.

North Atlantic region	West Atlantic region

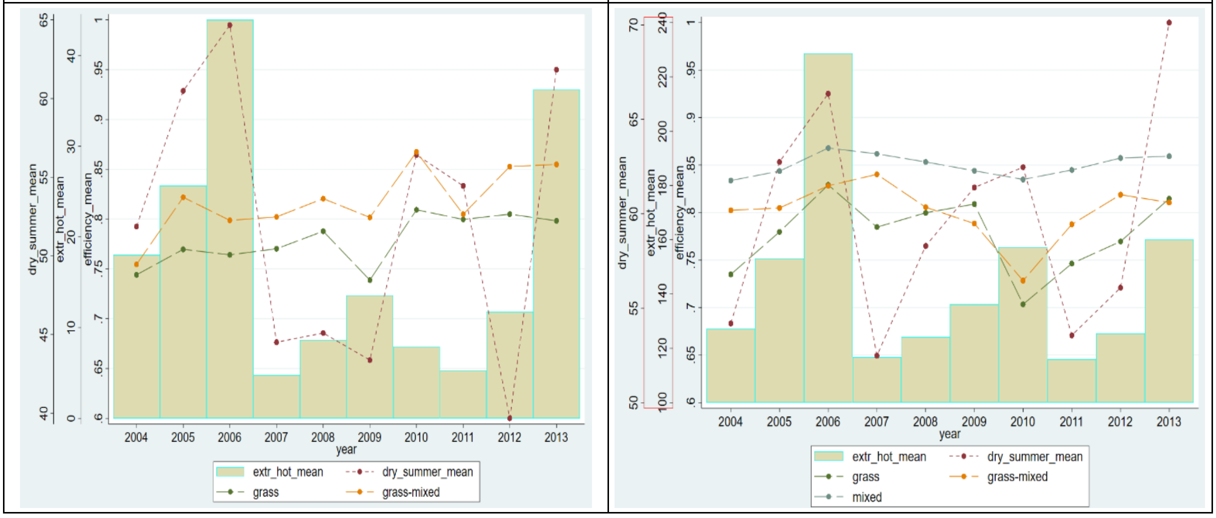


Figure 32 Efficiency scores in the Atlantic region, (common frontier for all farm types)

When each region is further differentiated into farm types, and assessed on a **common frontier** per region Table 39 indicates that in the North Atlantic region, grass farm types were less efficient, whilst grass-mixed and mixed types were similar in efficiency. For the West Atlantic region, grass types were again the least efficient, with industrial and grass-mixed at a higher level of efficiency, whilst mixed farms were the most efficient.

When results are considered under a farm type **specific frontier**, it further highlights the range in performance within that type, rather than against another type, so higher standard deviations indicate a greater variance within the type, though for most types the sd remains the same.

Within the Atlantic zone, beef revenues were highest on industrial and mixed farms and lowest on grass based systems, but costs also reflect their intensity, with high feed costs. However, margins per beef livestock unit were considerably higher on the industrial units, and lowest in the North Atlantic region

Table 39 Atlantic region beef finisher farm type efficiency scores when assuming a common or specific frontier within each climatic region

Climatic region	Farm type*	Value	Common frontier	Specific frontier	Revenue /BLU (€)	Feed cost /BLU (€)	Forage cost /BLU (€)	Margin /BLU (€)	n
North Atlantic	GRS[a]	mean	0.78	0.77	562	228	92	133	1298
		sd	0.14	0.14	293	156	69	203	
	GMX[b]	mean	0.87	0.87	641	282	107	135	299
		sd	0.07	0.07	289	182	55	200	
	MIX[b]	mean	0.83	0.83	846	489	113	108	111
		sd	0.12	0.12	381	372	81	255	
West Atlantic	GRS[a]	mean	0.81	0.81	675	233	70	236	251
		sd	0.11	0.11	371	165	53	290	
	GMX[b]	mean	0.86	0.86	755	294	123	198	444
		sd	0.08	0.08	298	179	70	210	
	IND[b]	mean	0.75	0.75	1001	500	61	331	115
		sd	0.20	0.20	552	274	50	489	
	MIX[c]	mean	0.87	0.87	976	455	119	286	1614
		sd	0.08	0.08	328	261	79	304	

*Different letters indicate significantly different intensity level groups within a region

Table 40 indicates the main drivers and challenges within each farm type in the Atlantic regions when assuming a specific frontier. A "+" sign indicates a contribution to greater efficiency, a "-" to lower efficiency, and "ns", highlighting no significant effect.

The sample sizes for some farm types were too small to calculate drivers and challenges, but in general, an increasing stocking density had a positive impact, as does farm size for some types. The drought in spring and summer had quite a strong negative effect on mixed farms in West Atlantic, whilst summer drought had quite a positive effect in the grass system in North Atlantic. The time has quite a strong positive effect in both the grass-mixed system in North Atlantic and the mixed system in West Atlantic, however, many factors were not significant.

Table 40 Atlantic region drivers and challenges to beef finisher farm efficiency within each farm type assuming a specific frontier

		n	FSIZE	FEED	FOR	STOCK	SPEC	MAIZE	GRASS	HEAT	DRY_SPR	DRY_SUM	YR
North Atlantic	GRS	1298	+	+	ns	+	ns	ns	ns	-	ns	+	ns
	GMX	299	+	ns	ns	+	ns	ns	ns	+	ns	ns	+
West Atlantic	GRS	251	ns	ns	ns	+	ns	ns	ns	ns	ns	ns	ns
	GMX	444	-	ns	ns	ns	+	ns	-	ns	ns	ns	ns
	MIX	1614	ns	+	+	ns	+	-	-	+	-	-	+

5.1.3. Atlantic suckler beef resilience

The economic resilience of Atlantic suckler beef systems is indicated by the change in margin between years (calculated on an individual farm basis), and is shown in Figure 33. Over the ten year period, the annual margin does not change considerably with a small peak in 2011 in the North Atlantic region, but few other changes, especially in the West Atlantic region. The sample size for the Atlantic Mountain region was too small for presentation (<15 farms)

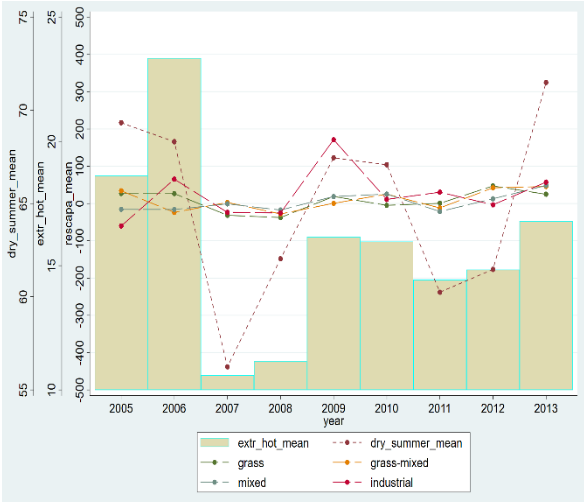
North Atlantic region	West Atlantic region
	

Figure 33 – Resilience in the Atlantic regions

When the drivers of resilience are examined, Table 41 shows that feed costs, increasing suckler cow numbers and increasing intensity caused a negative impact on margin resilience, whilst only increasing in specialisation exerted a positive effect. Many factors showed no significant impact on the resilience of margins, though heat and a dry spring had a negative impact on North and West Atlantic regions respectively.

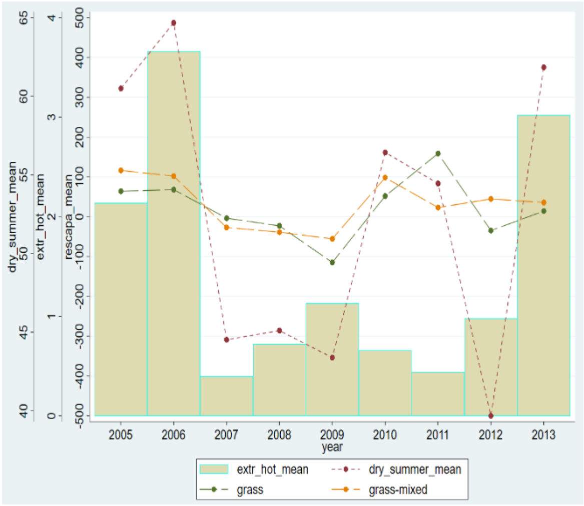
Table 41 Atlantic region drivers and challenges to suckler cow resilience

	n	SHOCK_FEED	FSIZE	STOCK	INT	SHOCK_CONC	SPEC	SCOW	DEPEND	SHOCK_HEAT	DRY_SPR	DRY_SUM
North Atlantic	8377	-	ns	ns	-	ns	+	-	ns	-	ns	-
West Atlantic	11813	-	ns	ns	-	ns	+	-	ns	ns	-	ns

5.1.4. Atlantic finisher beef resilience

The economic resilience of Atlantic finisher beef systems is indicated by the change in margin between years (calculated on an individual farm basis), and is shown in Figure 34. Over the ten year period, the annual margin does not change considerably with a small peak in 2011 in both the Atlantic regions displayed.

North Atlantic region



West Atlantic region

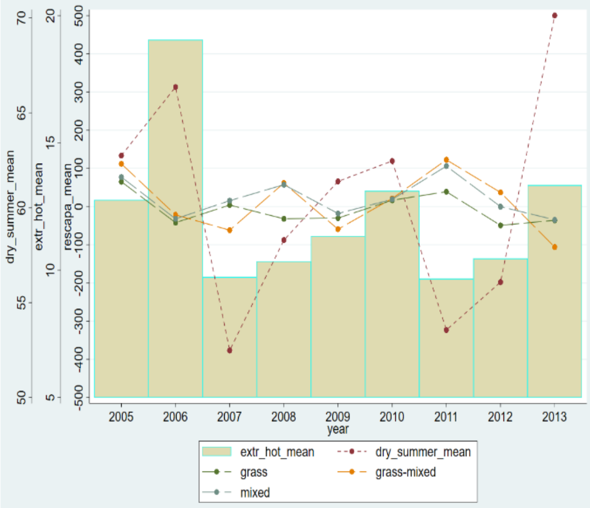


Figure 34 – Resilience in the Atlantic regions

When the drivers of resilience are examined, Table 42 shows very limited effects on the beef finisher margin resilience, with a negative effect for feed price changes and a positive impact from increasing specialisation in West Atlantic, and only two negative impacts in the North Atlantic region from intensity or a dry spring.

Table 42 Atlantic region drivers and challenges to beef finisher resilience

	n	SHOCK_FEED	FSIZE	STOCK	INT	SHOCK_CONC	SPEC	DEPEND	SHOCK_HEAT	DRY_SPR	DRY_SUM
North Atlantic	1531	ns	ns	ns	-	ns	ns	ns	ns	-	ns
West Atlantic	2194	-	ns	ns	ns	-	+	ns	ns	ns	ns

5.2. Boreal zone/region results

5.2.1. Boreal suckler beef efficiency

The efficiency score is quite low (0.75) when compared to the dairy sector, and when assuming that all climatic regions can achieve the same across Europe (a common frontier). When assuming a specific frontier for each climatic region, the efficiency score in the Boreal region is almost unchanged.

The revenue is relatively low, and with quite high feed costs, the Boreal region shows a negative margin, but with quite a high standard deviation. Beef production in Sweden is very heterogeneous in all possible ways; herd size, feeding and management, breeds, crosses, slaughter age etc. Therefore it's difficult to describe general patterns or trends. During the last years the beef price paid to the farmers from the slaughter houses has increased quite a lot, but that positive trend started after 2013. Many beef farmers have other jobs (the husband or the wife or both) outside the farm and that is how they get an income. The room for suckler cows is increasing as the number of dairy cows decreases. An important income from production systems with grazing animals is public money for keeping pastures (i.e. biodiversity in an 'open' landscape).

Table 43 Boreal region suckler beef farm efficiency on common and specific frontiers

Climatic region	Value	Common frontier	Specific frontier	Revenue /BLU (€)	Feed cost /BLU (€)	Forage cost /BLU (€)	Margin /BLU(€)	n
Boreal	mean	0.75	0.74	659	318	112	-45	492
	Sd	0.15	0.16	311	330	84	375	

Figure 35 indicates differences in terms of efficiency over time between farm types in the Boreal region. This graph assume a common frontier across all farm types within the Boreal region, allowing for an overall performance comparison.

Boreal region

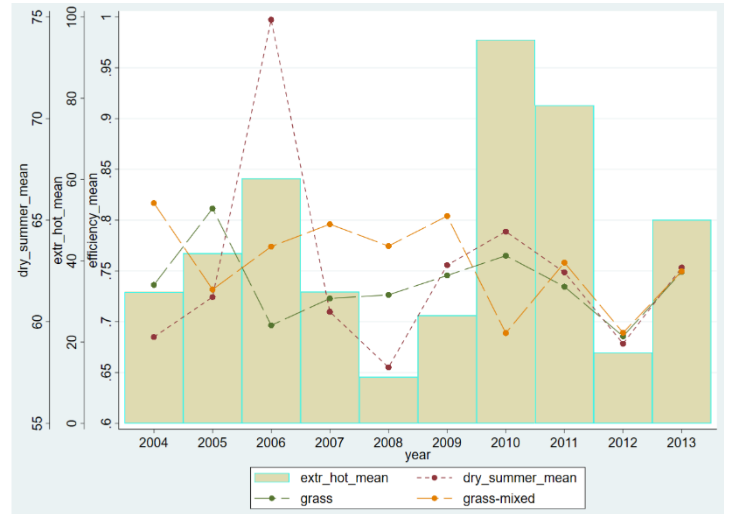


Figure 35 Efficiency score in the Boreal regions, (common frontier for all farm types)

When each region is further differentiated into farm types and assessed under a **common frontier** per region, Table 44 indicates that efficiency did not vary considerably between farm types. However, when results are considered under a farm type specific frontier the mixed farm types appear to show a higher level of efficiency and a low standard deviation, indicating a consistent system.

Revenue from beef sales was generally similar, as were feed costs, despite the considerably differing land usage of the three farm types. With similar revenue and costs the overall margin was also similar between farm types, and was negative for all types.

Table 44 Boreal region suckler beef farm type efficiency scores when assuming a common or specific frontier within each climatic region

Climatic region	Farm type*	Value	Common frontier	Specific frontier	Revenue /BLU (€)	Feed cost /BLU (€)	Forage cost /BLU (€)	Margin /BLU (€)	n
Boreal	GRS a	mean	0.73	0.73	640	327	104	-49	247
		sd	0.17	0.17	339	320	83	382	
	GMX a	mean	0.76	0.77	675	306	118	-37	190
		sd	0.15	0.16	268	287	80	361	
	MIX a	mean	0.75	0.96	680	320	133	-57	54
		sd	0.13	0.03	319	260	100	395	

*Different letters indicate significantly different intensity level groups

In Table 45 below, we then look at the drivers and challenges within each farm type in the Boreal region, assuming a specific frontier. The grass-mixed and mixed system were not assessed due to the small sample sizes. For the grass based systems the heat seems to have quite a strong positive effect on efficiency, possibly due to the low temperatures in some periods of the year.

Table 45 Boreal region drivers and challenges to suckler beef farm efficiency within each farm type assuming a specific frontier

		n	FSIZE	HRC	FEED	FOR	STOCK	SPEC	SCOW	MAIZE	GRASS	HEAT	DRY_SPR	DRY_SUM	YR
Boreal	GRS	247	ns	ns	+	ns	ns	ns	ns	ns	ns	+	ns	ns	ns

* Symbol code: + = significant positive coefficient; - = significant negative coefficient; ns = not significant

5.2.2. Boreal finisher beef efficiency

The efficiency score is relatively low for the Boreal region, when assuming that all climatic regions can achieve the same across Europe (a common frontier). When assuming a specific frontier for each climatic region, the efficiency scores in region remained identical.

Table 46 Boreal region beef finisher farm efficiency on common and specific frontiers

Climatic region	Value	Common frontier	Specific frontier	Revenue /BLU (€)	Feed cost /BLU (€)	Forage cost /BLU (€)	Margin /BLU(€)	n
Boreal	mean	0.75	0.75	836	611	80	-22	416
	sd	0.13	0.16	351	343	58	380	

Considering changes over time, Figure 36 shows differences in terms of efficiency over time for the grass farm type in the Boreal region. These chart assumes a common frontier across all farm types within each of the climatic region, allowing for an overall performance.

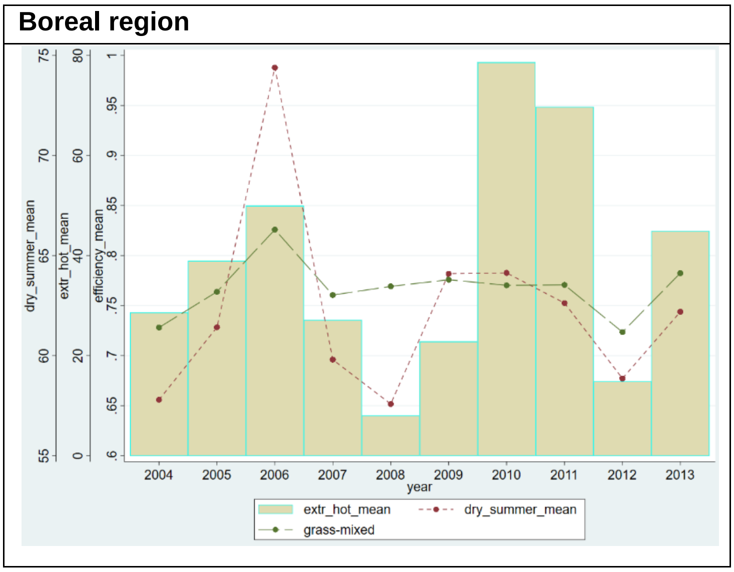


Figure 36 Efficiency score in the Boreal region, (common frontier for all farm types)

When the region is further differentiated into farm types, and assessed on a **common frontier** per region Table 47 indicates that farm types were not significantly different.

When results are considered under a farm type **specific frontier** some of the samples are too small for analysis, but efficiency falls, indicating a wide range in performance between farms.

As per the suckler data, within the Boreal zone, beef revenues were similar between the two systems compared, as were the costs. The grass-mixed systems achieved a slightly positive margin, but both were very low or negative.

Table 47 Boreal region beef finisher farm type efficiency scores when assuming a common or specific frontier within each climatic region

Climatic region	Farm type*	Value	Common frontier	Specific frontier	Revenue /BLU (€)	Feed cost /BLU (€)	Forage cost /BLU (€)	Margin /BLU (€)	n
Boreal	GRS	mean	0.73		772	639	83	-101	92
		sd	0.18		331	388	80	425	
	GMX	mean	0.77	0.78	860	595	79	27	187
		sd	0.15	0.14	370	293	44	329	
	MIX	mean	0.75	0.66	846	615	79	-37	137
		sd	0.17	0.23	336	374	58	405	

* Differing letters indicate significantly different farm types

5.2.3. Boreal suckler beef resilience

The economic resilience of Boreal suckler beef systems is indicated by the change in margin between years (calculated on an individual farm basis), and is shown in Figure 37. Over the ten year period, the annual margin does not change considerably, except for a dip in margin in 2012, which reverses in 2012.

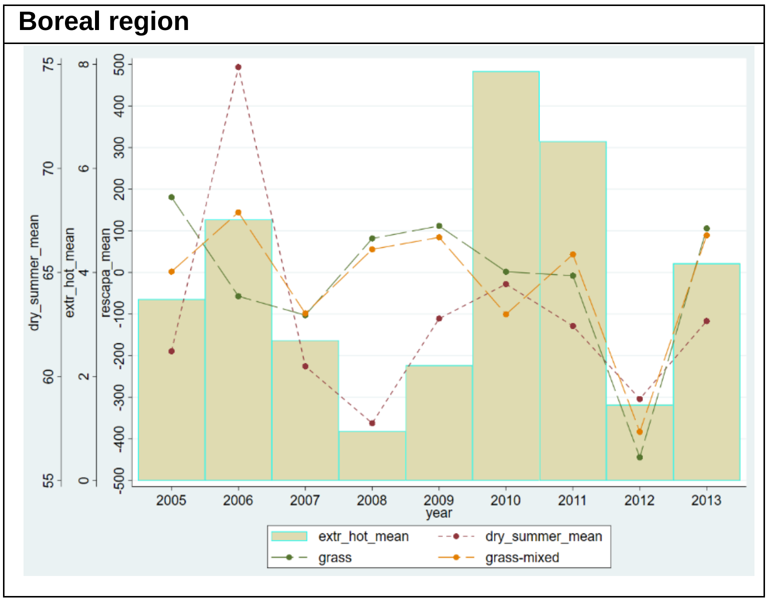


Figure 37 – Resilience in the Boreal region

Table 48 Boreal region drivers and challenges to dairy resilience

	n	SHOCK_FEED	FSIZE	STOCK	INT	SHOCK_CONC	SPEC	SCOW	DEPEND	SHOCK_HEAT	DRY_SPR	DRY_SUM
Boreal	461	-	ns	ns	-	ns	ns	-	ns	ns	ns	ns

5.2.4. Boreal finisher beef resilience

The economic resilience of Atlantic finisher beef systems is indicated by the change in margin between years (calculated on an individual farm basis), and is shown in Figure 38. Over the ten year period, the annual margin appears to decline, and shows some correlation with the weather patterns, but due to the small sample sizes this can be confirmed.

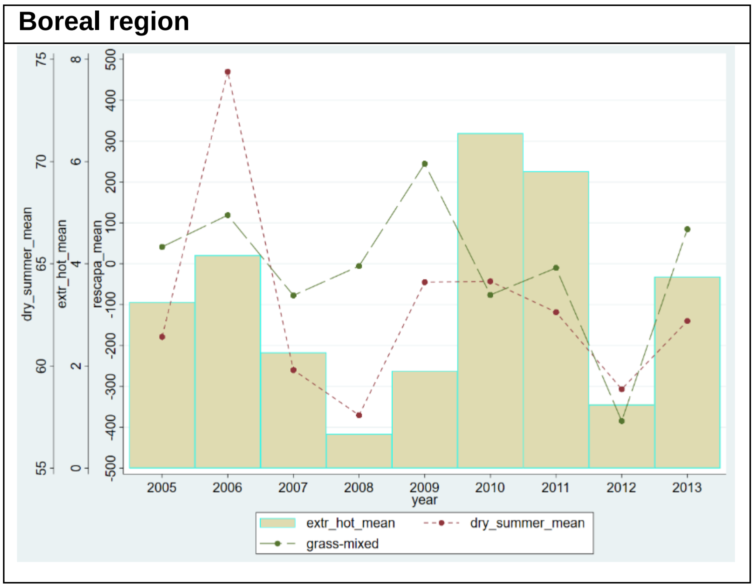


Figure 38 – Resilience in the Boreal region

When the drivers of resilience are examined, Table 49 Boreal region drivers and challenges to dairy resilience indicates very limited effects on the beef finisher margin resilience, with a negative effect for feed price changes and a positive impact from a warmer summer. All other factors were not significant.

Table 49 Boreal region drivers and challenges to dairy resilience

	n	SHOCK_FEED	FSIZE	STOCK	INT	SHOCK_CONC	SPEC	DEPEND	SHOCK_HEAT	DRY_SPR	DRY_SUM
Boreal	377	-	ns	ns	ns	ns	ns	ns	+	ns	ns

5.3. Continental Europe zone results

5.3.1. Continental suckler beef efficiency

The efficiency score is quite high when assuming that all climatic regions can achieve the same across Europe (common frontier). In this case we obtain a score of 0.79 in Central Europe and 0.80 in Central Mountain. When assuming a specific frontier for each climatic region, the efficiency scores are significantly higher in the Central Mountain region and slightly higher in Central Europe. This shows a certain homogeneity within those climatic regions.

Table 50 Continental region suckler beef farm efficiency on common and specific frontiers

Climatic region	Value	Common frontier	Specific frontier	Revenue /BLU (€)	Feed cost /BLU (€)	Forage cost /BLU (€)	Margin /BLU(€)	n
Central Europe	mean	0.79	0.81	630	224	62	216	7476
	sd	0.12	0.13	260	191	61	280	
Central Mountain	mean	0.80	0.87	662	216	53	258	2053
	sd	0.09	0.11	253	163	57	264	

Figure 39 indicates differences in terms of efficiency over time between farm types in Central Europe and Central Mountain, respectively. These graphs assume a common frontier across all farm types within each of the climatic region, allowing for an overall performance comparison instead of looking at the heterogeneity within each farm type in each climatic region.

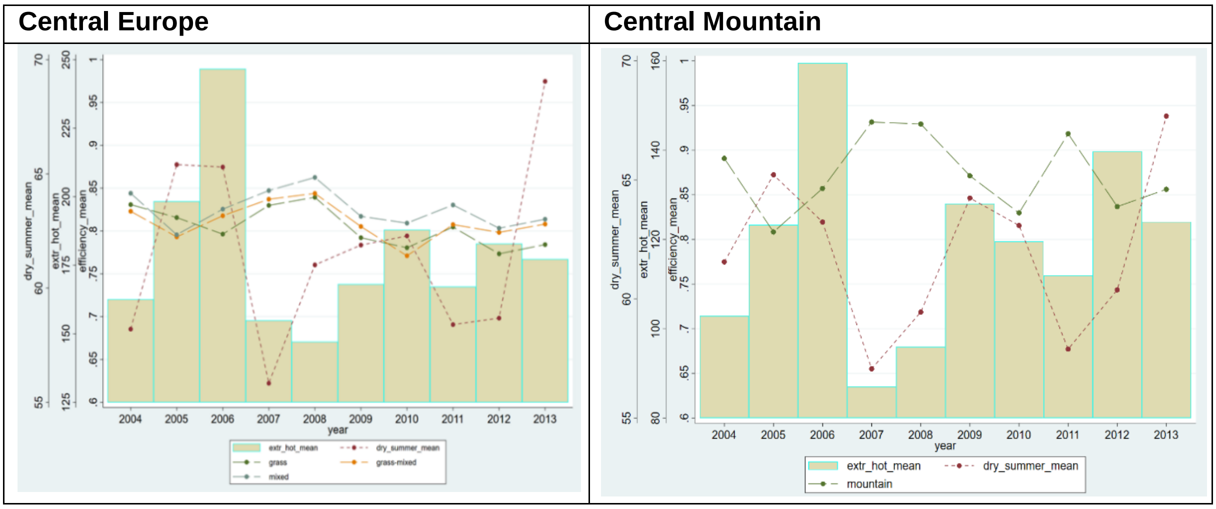


Figure 39 Efficiency scores in Central Europe, (common frontier for all farm types)

When each region is further differentiated into farm types and assessed under a **common frontier** per region, **Table 51** indicates that efficiency did not vary considerably between grass and grass-mixed farm types, but mixed farms achieved a significantly higher efficiency.

However, when results are considered under a farm type specific frontier the mixed farm types appear to show a higher level of efficiency.

Revenue from beef sales was generally similar, as were feed costs, despite the considerably differing land usage of the three farm types. With similar revenue and costs the overall margin was also similar between farm types, and was negative for all types.

Table 51 Continental region suckler beef farm type efficiency scores when assuming a common or specific frontier within each climatic region

Climatic region	Farm type*	Value	Common frontier	Specific frontier	Revenue /BLU (€)	Feed cost /BLU (€)	Forage cost /BLU (€)	Margin /BLU (€)	n
Central Europe	GRS [a]	mean	0.80	0.80	613	236	42	201	4120
		sd	0.15	0.15	263	204	48	299	
	GMX [a]	mean	0.81	0.83	639	217	85	212	2178
		sd	0.12	0.12	251	182	65	256	
	MIX[b]	mean	0.82	0.82	672	195	90	278	1176
		sd	0.11	0.11	260	158	68	243	
Central Mountain	MNT	mean	0.87	0.87	662	216	54	258	2047
		sd	0.11	0.11	253	163	57	264	

*Different letters indicate significantly different intensity level groups within a region

In **Table 52** below, the drivers and challenges within each farm type in the Central Europe and Central Mountain region are highlighted, assuming a specific frontier. The rationale is that we would like to know why farms in a specific group (here farm type) perform better or less than the others, and also the level of heterogeneity within those groups.

The specific forage costs, stocking density, dairy specialisation appear to be the most important factors in favours of efficiency. The drought in spring and summer has an ambivalent effect in central Europe and, surprisingly, a positive effect in the Central Mountain region. Surprisingly, the time has quite a negative effect on efficiency but only in the central Europe region in the grass and grass-mixed systems.

Table 52 Continental region drivers and challenges to suckler beef farm efficiency within each farm type assuming a specific frontier

		n	FSIZE	HRC	FEED	FOR	STOCK	SPEC	SCOW	MAIZE	GRASS	HEAT	DRY_SPR	DRY_SUM	YR
Central Europe	**GRS**	4120	+	ns	+	+	+	+	-	ns	+	+	+	-	-
	GMX	2178	+	ns	+	+	+	+	ns	ns	+	+	+	ns	-
	MIX	1176	ns	ns	ns	+	+	+	-	-	ns	+	ns	-	ns
Central Mountain	**MNT**	2047	+	ns	-	+	+	+	-	ns	-	-	+	+	ns

5.3.2. Continental finisher beef efficiency

The efficiency score is almost identical for both regions, with similar standard deviations for the common frontier, though an increasing sd value for Central Europe on the specific frontier, indicating some heterogeneity.

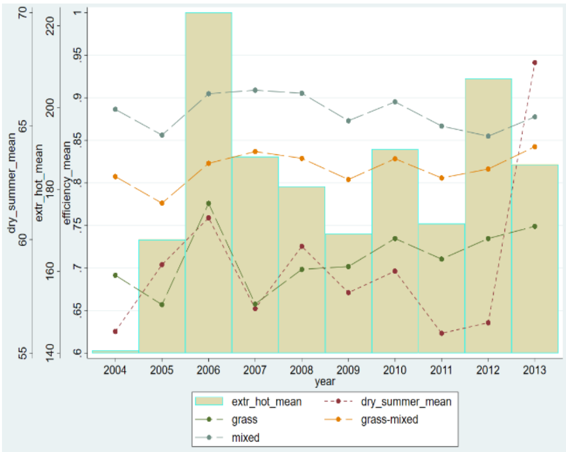
Revenue is slightly higher for the mountain farms, as are feed costs, but the overall margin remains slightly higher than the lowland Central Europe region.

Table 53 Continental region beef finisher farm efficiency on common and specific frontiers

Climatic region	Value	Common frontier	Specific frontier	Revenue /BLU (€)	Feed cost /BLU (€)	Forage cost /BLU (€)	Margin /BLU (€)	n
Central Europe	mean	0.90	0.86	914	357	95	357	2847
	sd	0.06	0.12	351	200	64	308	
Central Mountain	mean	0.89	0.94	1062	417	77	428	224
	sd	0.05	0.03	670	343	77	597	

Figure 40 indicates differences in terms of efficiency over time between farm types in Central Europe and Central Mountain, respectively. These graphs assume a common frontier across all farm types within each of the climatic region, allowing for an overall performance comparison instead of looking at the heterogeneity within each farm type in each climatic region.

Central Europe



Central Mountain

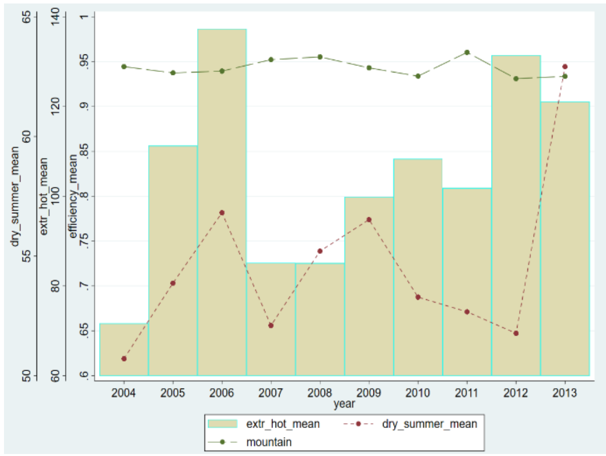


Figure 40 – Efficiency scores in Central Europe, (common frontier for all farm types)

When the regions are further differentiated into farm types, and assessed on a **common frontier** per region **Table 54** indicates that in the Central Europe region, farm types were all significantly different.

When results are considered under a farm type **specific frontier** the efficiency scores converge.

As per the suckler beef data, the mountain region shows a higher revenue level, but also the highest feed costs. Overall, the margin is highest in the mountain and mixed farm types and lowest for the grass farms.

Table 54 Continental region beef finisher farm type efficiency scores when assuming a common or specific frontier within each climatic region

Climatic region	Farm type*	Value	Common frontier	Specific frontier	Revenue /BLU (€)	Feed cost /BLU (€)	Forage cost /BLU (€)	Margin /BLU (€)	n
Central Europe	GRS [a]	mean	0.71	0.87	616	378	58	84	169
		sd	0.18	0.12	329	232	94	326	
	GMX [b]	mean	0.82	0.86	823	335	96	274	473
		sd	0.15	0.12	329	198	63	321	
	MIX[c]	mean	0.88	0.86	957	361	98	396	2196
		sd	0.09	0.10	343	198	60	289	
Central Mountain	MNT	mean	0.94	0.93	1040	408	79	416	219
		sd	0.03	0.03	642	340	77	579	

*Different letters indicate significantly different intensity level groups within a region

In **Table 55** below, we then look at the drivers and challenges within each farm type in the Central Europe region, assuming a specific frontier (the Central Mountain sample was too small for analysis). The rationale is that we would like to know why farms in a specific group (here farm type) perform better or less than the others, and also the level of heterogeneity within those groups.

The most important factors in favour of efficiency in Central Europe were the farm size and higher feed expenditure, as well as warmer summers, but the year was a negative factor for both farm types shown below. The mountain sample size was too small to analyse.

Table 55 Continental region drivers and challenges to beef finisher farm efficiency within each farm type assuming a specific frontier

		n	FSIZE	FEED	FOR	STOCK	SPEC	MAIZE	GRASS	HEAT	DRY_SPR	DRY_SUM	YR
Central Europe	**GMX**	473	+	+	ns	+	ns	ns	+	+	ns	ns	-
	MIX	2196	+	+	+	ns	+	ns	-	+	+	ns	-

5.3.3. Continental suckler beef resilience

The economic resilience of Continental suckler beef systems is indicated by the change in margin between years (calculated on an individual farm basis), and is shown in Figure 41. Over the ten year period, the annual margin does not change considerably with a slight decline in the earlier years, and a small peak in 2011.

Central Europe region	**Central Mountain region**

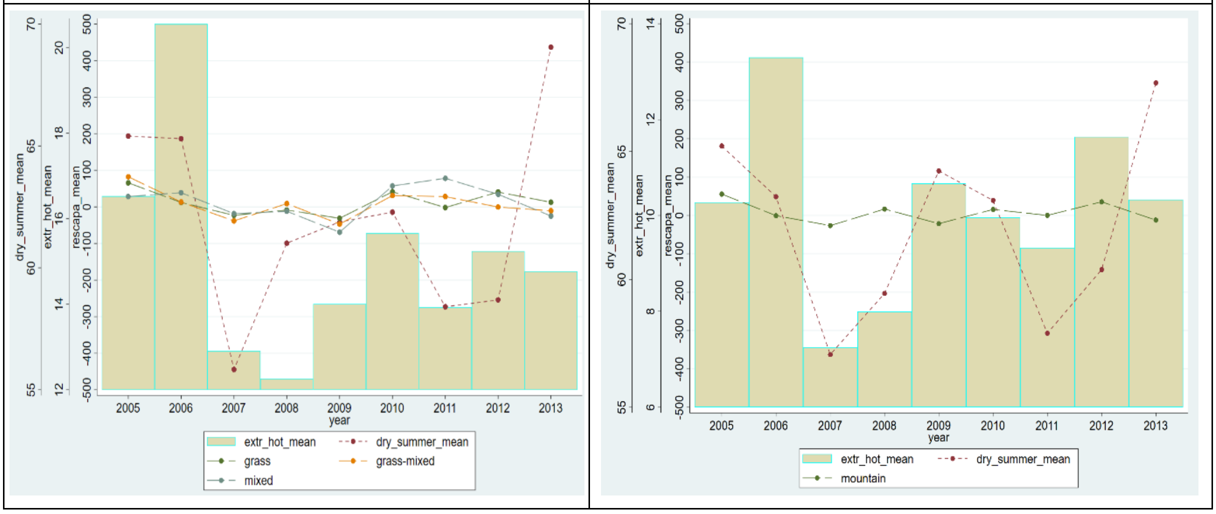


Figure 41 Resilience in the Central Europe regions

When the drivers of resilience are examined, Table 56 indicates very limited effects on the beef suckler margin resilience, with a negative effect from feed price changes and increasing suckler cow numbers in the lowland region, but a positive effect from increasing specialisation. Most other factors were not significant.

Table 56 Continental region drivers and challenges to beef suckler resilience

	n	SHOCK_FEED	FSIZE	STOCK	INT	SHOCK_CONC	SPEC	SCOW	DEPEND	SHOCK_HEAT	DRY_SPR	DRY_SUM
Central Europe	6915	ns	ns	ns	ns	-	+	-	ns	ns	-	ns
Central Mountains	1893	-	ns	ns	ns	ns	+	ns	ns	ns	ns	ns

5.3.4. Continental finisher beef resilience

The economic resilience of Continental finisher beef systems is indicated by the change in margin between years (calculated on an individual farm basis), and is shown in Figure 42. Over the ten year period, the annual margin does not change considerably in the Central Europe region, but is a little more erratic in the Central Mountain region, with a dip in 2008 and 2010, and a peak in 2011/2012.

Central Europe region	**Central Mountain region**

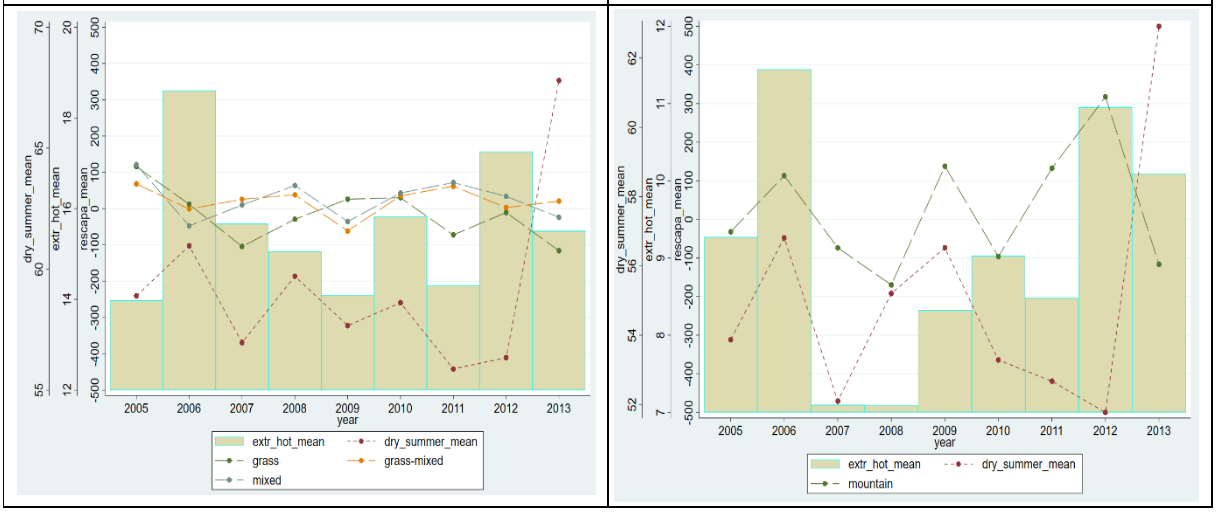


Figure 42 – Resilience in the Central Europe regions

The drivers of resilience are shown in Table 57, and highlight a positive impact from increasing specialisation, but two negative impacts from feed price increases and increasing intensity.

Table 57 Continental region drivers and challenges to beef fattener resilience

	n	SHOCK_FEED	FSIZE	STOCK	INT	SHOCK_CONC	SPEC	DEPEND	SHOCK_HEAT	DRY_SPR	DRY_SUM
Central Europe	2657	-	ns	ns	-	ns	+	ns	ns	ns	ns

5.4. Southern Europe zone results

The efficiency score is not very high compared to dairy when assuming that all climatic regions can achieve the same across Europe (common frontier); with a score of 0.82 in Southern Central, 0.76 in Mediterranean, and 0.77 in Mediterranean Mountain. When assuming a specific frontier for each climatic region, the efficiency scores and standard deviations in the different regions are similar.

Beef revenue is highest in the Southern Central area, and despite higher forage costs, a higher margin is achieved. The mountain region has the highest feed costs and the lowest margin per beef livestock unit.

5.4.1. Southern suckler beef efficiency

Table 58 Mediterranean region suckler beef farm efficiency on common and specific frontiers

Climatic region	Value	Common frontier	Specific frontier	Revenue /BLU (€)	Feed cost /BLU (€)	Forage cost /BLU (€)	Margin /BLU (€)	n
Southern Central Europe	mean	0.82	0.81	793	324	74	289	2724
	sd	0.11	0.14	377	218	68	345	
Mediterranean	mean	0.76	0.74	634	286	33	256	3306
	sd	0.16	0.16	381	197	57	302	
Mediterranean Mountain	mean	0.77	0.79	636	337	35	173	4459
	sd	0.13	0.13	282	174	58	254	

Figure 43 indicates differences in terms of efficiency over time between farm types in Southern Central, Mediterranean, and Mediterranean Mountain, respectively. These charts assume a common frontier across all farm types within each of the climatic region, allowing for an overall performance comparison instead of looking at the heterogeneity within each farm type in each climatic region.

When each region is further differentiated into farm types and assessed under a **common frontier** per region, Table 59 indicates that in the Southern Central region, the industrial and mixed farms achieved a higher level of efficiency than the grass, which was more efficient than the grass-mixed farms. In the Mediterranean region the industrial farm types were the least efficient, with grass and mixed farms at a similar level. In the mountain region, the industrial farms were also less efficient. However, when the results are considered under a farm type specific frontier, some of the efficiency scores change, especially when sample sizes are small, so results should be examined cautiously, especially when the standard deviation indicates a high level of heterogeneity.

Beef revenue varied considerably between the regions and farm types, but was highest in the Southern Central region, whilst feed costs were more uniform across the regions and farm types. Margins were highest on Southern Central mixed farms, and lowest in the mountains and on some industrial farm types.

Southern Central region	**Mediterranean region**

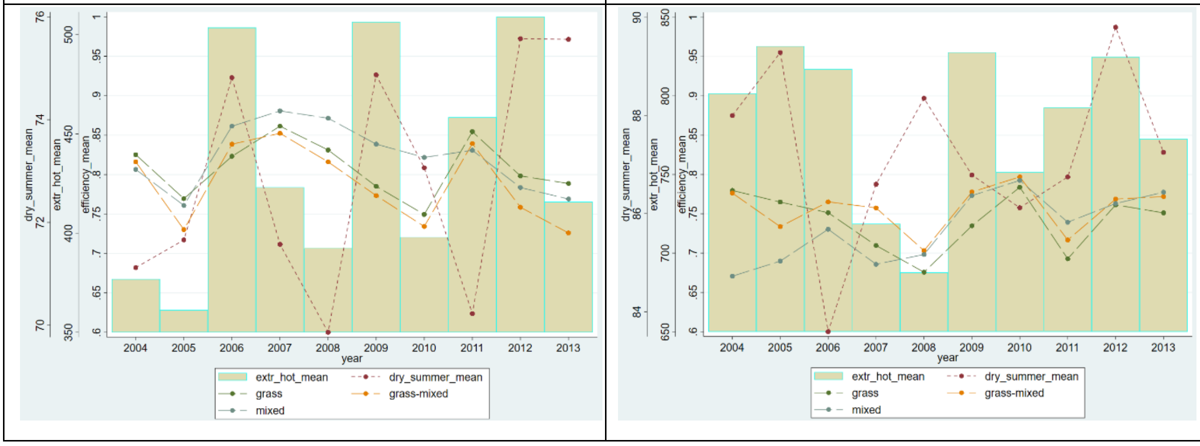


Figure 43 Efficiency score in the Mediterranean regions, (common frontier for all farm types)

Table 59 Mediterranean region suckler beef farm type efficiency scores when assuming a common or specific frontier within each climatic region

Climatic region	Farm type*	Value	Common frontier	Specific frontier	Revenue /BLU (€)	Feed cost /BLU (€)	Forage cost /BLU (€)	Margin /BLU (€)	n
Southern Central	GRS[a]	mean	0.81	0.79	730	299	56	263	1211
		sd	0.13	0.14	293	205	55	293	
	GMX[b]	mean	0.79	0.82	767	310	94	260	869
		sd	0.15	0.15	341	217	73	328	
	IND[c]	mean	0.86	0.67	900	347	26	365	60
		sd	0.09	0.27	572	247	30	398	
	MIX[c]	mean	0.83	0.82	952	394	88	379	584
		sd	0.14	0.15	494	231	75	434	
Mediterranean	GRS[ab]	mean	0.74	0.72	605	278	15	256	1950
		sd	0.16	0.19	332	188	33	264	
	GMX[ab]	mean	0.76	0.79	702	320	49	274	483
		sd	0.14	0.16	386	194	57	324	
	IND[c]	mean	0.66	0.81	488	309	24	120	118
		sd	0.21	0.14	363	254	44	290	
	MIX[b]	mean	0.74	0.83	688	281	71	266	752
		sd	0.15	0.12	473	207	82	371	
Mediterranean Mountain	IND[a]	mean	0.76	0.73	603	346	7	195	190
		sd	0.18	0.18	327	188	14	248	
	MNT[b]	mean	0.79	0.79	638	337	36	172	4269
		sd	0.13	0.13	280	173	59	254	

*Different letters indicate significantly different intensity level groups within a region

In Table 60 below, we then look at the drivers and challenges within each farm type in Southern Central, Mediterranean, and Mediterranean Mountain, assuming a specific frontier. The rationale is that we would like to know why farms in a specific group (here farm type) perform better or less than the others, and also the level of heterogeneity within those groups.

The stocking density and beef specialisation appear to be the most important factors in favour of efficiency across the different farm types and regions. Negative impacts are seen with higher suckler cow proportions and also increasing grass proportions in some regions. The drought has an ambivalent effect in the southern central region, but clearly has a negative effect in the Mediterranean and Mediterranean Mountain regions and for almost all farm types.

Table 60 Mediterranean region drivers and challenges to suckler beef farm efficiency within each farm type assuming a specific frontier

Climatic region		n	FSIZE	HRC	FEED	FOR	STOCK	SPEC	SCOW	MAIZE	GRASS	HEAT	DRY_SPR	DRY_SUM	**YR**
Southern Central	GRS	1211	+	ns	+	+	+	+	-	-	-	ns	ns	ns	ns
	GMX	869	ns	ns	ns	ns	+	+	-	ns	-	+	+	-	-
	MIX	584	ns	ns	ns	+	+	+	-	-	-	+	+	ns	-
Mediterranean	GRS	1950	ns	ns	+	+	ns	+	ns	ns	ns	+	-	-	ns
	GMX	483	ns	ns	ns	-	ns	+	-	-	ns	+	ns	-	ns
	MIX	752	-	ns	+	ns	ns	ns	ns	-	ns	+	-	-	ns
Mediterranean Mountain	IND	190													-
	MNT	4269	+	+	+	+	+	+	-	-	-	+	-	-	ns

5.4.2. Southern finisher beef efficiency

The efficiency score is excellent when assuming that all climatic regions can achieve the same across Europe (common frontier); with a score of 0.97 in Southern Central, 0.98 in Mediterranean, and 0.97 in Mediterranean Mountain; with a very low standard deviation for all of those regions. When assuming a specific frontier for each climatic region, the efficiency scores in the different regions are a little lower, especially in the Mediterranean Mountain region but still high.

Revenue is highest in the mountain region, though purchased feed costs are also high, but the region maintains the highest margin, with the Southern region achieving a much lower margin.

Table 61 Mediterranean region beef finisher farm efficiency on common and specific frontiers

Climatic region	Value	Common frontier	Specific frontier	Revenue /BLU (€)	Feed cost /BLU (€)	Forage cost /BLU (€)	Margin /BLU (€)	n
Southern Central Europe	mean	0.97	0.91	1223	629	67	442	959
	sd	0.01	0.10	700	322	69	611	
Mediterranean	mean	0.98	0.87	1510	685	61	667	204
	sd	0.00	0.11	906	473	83	816	
Mediterranean Mountain	mean	0.97	0.83	1774	861	34	784	132
	sd	0.01	0.15	1114	618	53	869	

Figure 44 indicates differences in terms of efficiency over time between farm types in Southern Central, Mediterranean, and Mediterranean Mountain, respectively. These charts assume a common frontier across all farm types within each of the climatic region, allowing for an overall performance comparison instead of looking at the heterogeneity within each farm type in each climatic region.

Results under a **common frontier** indicate that grass-mixed was the least efficient, with grass and mixed farms at a medium level and the industrial farms achieving the highest efficiency. In the Mediterranean region there were no significant differences.

The Mediterranean and mountain region had the highest beef revenues per beef livestock unit, though their feed costs were also higher, especially in the mountains. Margins were quite variable between the farm types and regions, though the sample sizes are quite small for some groups.

Southern Central region

Figure 44 Efficiency scores in the Mediterranean regions, (common frontier for all farm types)

Table 62 Mediterranean region beef finisher farm type efficiency scores when assuming a common or specific frontier within each climatic region

Climatic region	Farm type*	Value	Common frontier	Specific frontier	Revenue /BLU (€)	Feed cost /BLU (€)	Forage cost /BLU (€)	Margin /BLU (€)	n
Southern Central	GRS[ac]	mean	0.89	0.84	1218	578	49	502	74
		sd	0.12	0.17	795	312	51	743	
	GMX[a]	mean	0.85	0.82	1045	607	75	285	134
		sd	0.12	0.11	709	352	59	654	
	IND[b]	mean	0.95	0.94	1236	619	28	507	192
		sd	0.03	0.04	731	296	31	622	
	MIX[c]	mean	0.91	0.91	1260	642	82	451	557
		sd	0.09	0.10	669	324	77	573	
Mediterranean	GRS	mean	0.86	0.93	1320	674	14	529	44
		sd	0.08	0.07	686	508	29	557	
	GMX	mean	0.89	0.87	1802	696	76	914	28
		sd	0.08	0.17	1365	484	73	1257	
	IND	mean	0.86		1183	657	41	419	43
		sd	0.15		661	490	46	693	
	MIX	mean	0.87	0.81	1685	714	89	779	86
		sd	0.11	0.16	889	446	104	797	
Mediterranean Mountain	MNT	mean	0.84	0.84	1801	889	35	779	124
		sd	0.14	0.15	1087	625	55	834	

*Different letters indicate significantly different intensity level groups within a region

In Table 63 below, we then look at the drivers and challenges to efficiency within each farm type in Southern Central, assuming a specific frontier, though only mixed farms can be shown due to small sample sizes. The rationale is that we would like to know why farms in a specific group (here farm type) perform better or less than the others, and also the level of heterogeneity within those groups.

The most important factors in favour of efficiency in Central Europe were surprisingly warmer summers, and dry weather in both spring and summer, though the effects were very small. The year was a negative factor, as per many other regions.

Table 63 Mediterranean region drivers and challenges to suckler beef farm efficiency within each farm type assuming a specific frontier

Climatic region		n	FSIZE	FEED	FOR	STOCK	SPEC	MAIZE	GRASS	HEAT	DRY_SPR	DRY_SUM	YR
Southern Central	MIX	557	ns	ns	ns	ns	ns	ns	ns	+	+	+	-

5.4.3. Southern suckler beef resilience

The economic resilience of Southern suckler beef systems is indicated by the change in margin between years (calculated on an individual farm basis), and is shown in Figure 45. Over the ten year period, the annual margin does not change considerably with few undulations.

When the drivers of resilience are examined, Table 64 indicates very limited effects on the beef suckler margin resilience, with a positive effect from increasing specialisation. Most other factors were not significant, though increasing intensity and sucker cow proportion in the herd were negative impacts in some regions.

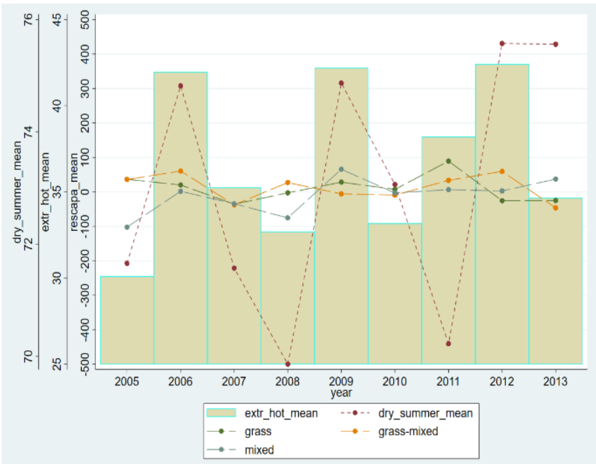
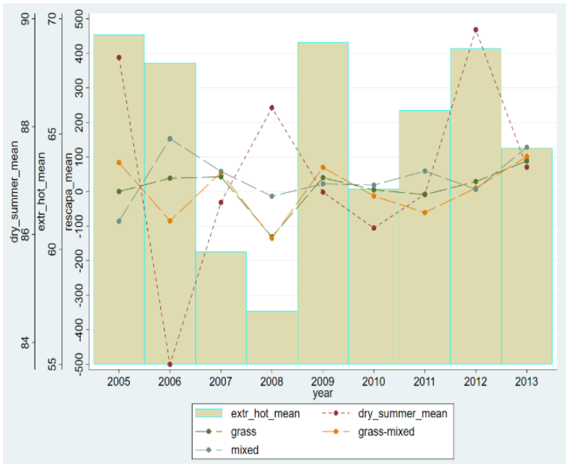
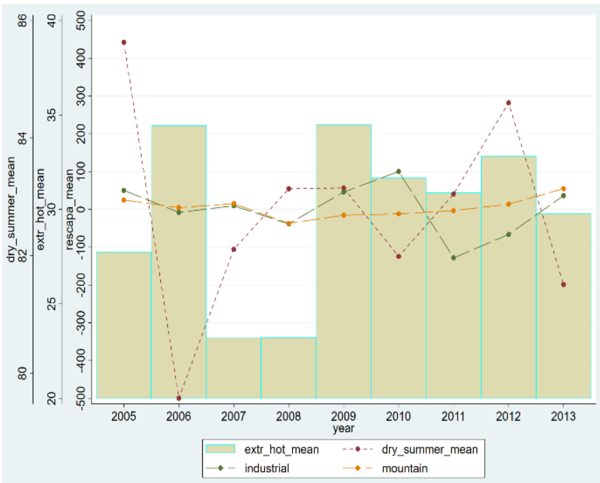
Southern Central region	**Mediterranean region**
	
Mediterranean Mountain regions	
	

Figure 45 – Resilience in the Mediterranean regions

Table 64 Mediterranean region drivers and challenges to beef suckler resilience

	n	SHOCK_FEED	FSIZE	STOCK	INT	SHOCK_CONC	SPEC	SCOW	DEPEND	SHOCK_HEAT	DRY_SPR	DRY_SUM
Southern Central	2563	ns	ns	-	ns	ns	+	ns	ns	ns	ns	ns
Mediterranean	3139	ns	ns	ns	-	-	+	ns	ns	ns	ns	ns
Mediterranean Mountain	4177	ns	ns	ns	-	ns	+	-	ns	-	ns	ns

5.4.4. Southern finisher beef resilience

The economic resilience of Southern zone finisher beef systems is indicated by the change in margin between years (calculated on an individual farm basis), and is shown in **Figure 46**, (though due to small sample sizes only the Southern region mixed farm data can be shown).. Over the ten year period, the annual margin shows some variation with a decline in 2007 followed by a strong recovery in 2008, but followed by a steady decline in subsequent years.

Southern Central region

Figure 46 – Resilience in the Southern Central region

When the drivers of resilience are examined, Table 65 shows very limited effects on the beef finisher margin resilience, with a negative effect from a dry spring and a positive impact from increasing specialisation and warmer summers.

Table 65 Mediterranean region drivers and challenges to beef finisher resilience

	n	SHOCK_FEED	FSIZE	STOCK	INT	SHOCK_CONC	SPEC	DEPEND	SHOCK_HEAT	DRY_SPR	DRY_SUM
Southern Central	933	ns	ns	ns	ns	ns	+	ns	+	-	ns

6. Partners involved in the work

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8. Annexes

8.1. Climate region data

Table 66 Metrological variables obtained from Agri4cast webportal

Category	Variables
Basics (on the **YEAR**)	Max temperature, average on the year
	Min temperature min, average on the year
	Mean temperature, average on the year
	Precipitation (mm) per day, average on the year
Standard deviation (on the **YEAR**)	standard deviation of the temperature, average on the year (from a daily
	standard deviation of the precipitation level, average on the year (from a daily basis)
Number of days in the **YEAR**: for dry periods, warm periods, and positive periods for vegetation growth	Number of days with precipitation below 1mm/day, on the year
	Number of days with temperature max above 25°c, on the year
	Number of days with TH1 above 55, on the year
	Number of days with TH1 above 60, on the year
	Number of days with TH2 above 55, on the year
	Number of days with TH2 above 60, on the year
	Number of days with a max temperature above 5 degrees (may be useful to take account of vegetation growth)
	Number of days with a mean temperature above 5 degrees (may be useful to take account of vegetation growth)
Minimal, maximal, and mean temperature per **MONTH**	Maximum temperature in January
	Maximum temperature in February
	etc (for all month)
	Min temperature in January
	Min temperature in February
	etc (for all month)
	Average temperature in January
	Average temperature in February
	etc (for all month)
Number of days in the **MONTH**: for precipitation, dry periods, warm periods	Precipitation (mm per day) in January
	Precipitation (mm per day) in February
	etc (for all month)

	Number of days with precipitation below 1mm/day in January
	Number of days with precipitation below 1mm/day in February
	etc (for all month)
	Number of days with a maximum temperature above 25°c in January
	Number of days with a maximum temperature above 25°c in February
	etc (for all month)
	Number of days with a TH1 above 55 in January
	Number of days with a TH1 above 55 in February
	etc (for all month)
	Number of days with a TH1 above 60 in January
	Number of days with a TH1 above 60 in February
	Etc (the same for all months)
	Number of days with a TH2 above 55 in January
	Number of days with a TH2 above 55 in February
	etc (for all month)
	Number of days with a TH2 above 60 in January
	Number of days with a TH2 above 60 in February
	etc (for all month)
highest and lowest temperature per **MONTH**	Highest maximum temperature in January
	Highest maximum temperature in February
	etc (for all month)
	Lowest minimum temperature in January
	Lowest minimum temperature in February
	etc (for all month)
highest and lowest temperature per **YEAR**	Highest temperature in the year
	Lowest temperature in the year
Minimal, maximal, and mean temperature per **SEASON**	Mean temperature in spring
	Mean temperature in summer
	Mean temperature in autumn
	Mean temperature in winter
	Minimum temperature in spring
	Minimum temperature in summer
	Minimum temperature in autumn
	Minimum temperature in winter
	Maximum temperature in spring
	Maximum temperature in summer
	Maximum temperature in autumn
	Maximum temperature in winter
Precipitation (total mm) per **SEASON**	Precipitation (mm) in spring
	Precipitation (mm) in summer
	Precipitation (mm) in autumn
	Precipitation (mm) in winter
	Temperature range in January (highest temperature in the month minus

Temperature range **MONTH**	Temperature range in February
	etc (for all month)
Temperature range **YEAR**	Mean Diurnal Range (Mean of monthly (max temp - min temp))
	Annual temperature range: highest temperature in the year minus lowest temperature in the year
	Isothermally [(mean diurnal range/ temperature annual range)*100]
Mean temperature and precipitation in "extreme" **SEASON** (wettest, driest, warmest, coldest)	Mean temperature of the wettest season
	Mean temperature of the driest season
	Mean temperature of the warmest season
	Mean temperature of the coldest season
	Precipitation (total mm) of the wettest season
	Precipitation (total mm) of the driest season
	Precipitation (total mm) of the warmest season
	Precipitation (total mm) of the coldest season

8.2. Resilience evaluation

Dairy

Table 67 resilience for different farm types in North Atlantic on average, in 2009, and 2010

		2005 to 2013						2009						2010					
Farm type	St	n	Res	Prof /Cow (€)	Prod /Cow	Feed/Cow (€)	p**	n	Res	Prof /Cow (€)	Prod /Cow	Feed/ Cow (€)	P**	n	Res	Prof /Cow (€)	Prod /Cow	Feed/Cow (€)	Price €/kg
GRS	mean	4806	1	809	5850	532	0.29	526	-388	436	5650	526	0.23	488	328	746	5935	550	0.28
	sd		329	359	1425	286	0.05		240	280	1456	218	0.03		206	285	1450	233	0.02
GMX	m	449	-10	901	6869	688	0.30	57	-291	664	6850	667	0.26	50	167	839	7222	727	0.28
	sd		289	362	1645	329	0.04		223	348	1688	261	0.03		265	352	1699	278	0.02
IND	m	14						4						1					
	sd																		
MIX	m	48	-43	876	6921	682	0.29	6						4					
	sd		288	492	1375	357	0.04												

Table 68 resilience for different farm types in West Atlantic on average, in 2009, and 2010

		2005 to 2013						2009						2010					
Farm type	St	n	Res	Prof /Cow (€)	Prod /Cow	Feed/Cow (€)	p**	n	Res	Prof /Cow (€)	Prod /Cow	Feed/ Cow (€)	P**	n	Res	Prof /Cow (€)	Prod /Cow	Feed/Cow (€)	Price €/kg
GRS	mean	6056	28	1181	6703	684	0.33	662	-305	951	6645	624	0.29	695	247	1199	6860	645	0.32
	sd		371	518	1657	402	0.06		364	419	1664	370	0.05		334	529	1668	349	0.05
GMX	m	9076	24	1279	7201	612	0.33	1015	-380	958	7152	566	0.28	1049	300	1268	7281	611	0.32
	sd		392	503	1589	387	0.05		338	393	1590	370	0.04		304	498	1610	353	0.04
IND	m	1441	-22	934	6876	995	0.33	157	-426	723	6598	961	0.31	178	92	839	6789	930	0.31
	sd		384	606	2137	460	0.05		354	490	2157	385	0.05		379	591	2205	400	0.04
MIX	m	11185	13	1235	7684	730	0.32	1411	-339	938	7651	664	0.28	1375	309	1254	7755	717	0.32
	sd		413	499	1496	413	0.05		359	420	1523	377	0.03		271	476	1525	363	0.03

Table 69 resilience for different farm types in Atlantic Mountain on average, in 2009, and 2010

		2005 to 2013						2009						2010					
Farm type	St	n	Res	Prof /Cow (€)	Prod /Cow	Feed/Cow (€)	p**	n	Res	Prof /Cow (€)	Prod /Cow	Feed/ Cow (€)	P**	n	Res	Prof /Cow (€)	Prod /Cow	Feed/Cow (€)	Price €/kg
MNT	mean	179	38	1230	7145	583	0.32	24	-324	966	6897	535	0.28	23	242	1208	7404	618	0.31
	sd		441	474	1356	391	0.05		369	372	1384	295	0.06		233	399	1125	256	0.04

Table 70 resilience for different farm types in Boreal on average, in 2009, and 2010

			2005 to 2013						2009						2010				
Farm type	St	n	Res	Prof /Cow (€)	Prod /Cow	Feed/Cow (€)	p**	n	Res	Prof /Cow (€)	Prod /Cow	Feed/ Cow (€)	P**	n	Res	Prof /Cow (€)	Prod /Cow	Feed/Cow (€)	Price €/kg
GRS	mean	992	-8	1196	8257	1169	0.38	99	-441	1300	8306	957	0.37	113	71	1326	8239	922	0.37
	sd		513	731	1455	556	0.06		404	700	1399	322	0.05		403	685	1552	378	0.04
GMX	m	1628	-46	1458	8450	1034	0.39	188	-332	1589	8313	767	0.38	177	-27	1568	8438	822	0.38
	sd		513	652	1330	533	0.05		444	612	1343	282	0.04		342	607	1256	304	0.03
MIX	mean	559	-43	1527	8469	989	0.39	73	-380	1620	8654	824	0.39	55	66	1675	8636	774	0.38
	sd		468	589	1198	459	0.05		342	566	1129	270	0.03		438	532	927	217	0.02

Table 71 resilience for different farm types in Central Europe on average, in 2009, and 2010

			2005 to 2013						2009						2010					
Farm type	**St**	**n**	**Res**	**Prof /Cow (€)**	**Prod /Cow**	**Feed/Cow (€)**	**p****	**n**	**Res**	**Prof /Cow (€)**	**Prod /Cow**	**Feed/ Cow (€)**	**P****	**n**	**Res**	**Prof /Cow (€)**	**Prod /Cow**	**Feed/Cow (€)**	**Price €/kg**
GRS	mean	5330	31	886	5980	629	0.30	571	-328	640	5861	527	0.24	608	265	871	5950	597	0.29
	sd		359	562	1759	408	0.07		349	516	1639	306	0.07		296	541	1676	352	0.07
GMX	mean	10765	34	940	6035	556	0.30	1210	-312	668	5888	474	0.24	1281	284	948	6039	530	0.29
	Sd		350	514	1700	375	0.06		343	473	1610	282	0.06		289	495	1671	330	0.05
IND	mean	30	0	886	5401	729	0.37	5						4					
	Sd		668	629	2168	327	0.12												
MIX	mean	21918	39	946	6224	540	0.29	2561	-264	686	6182	482	0.24	2642	266	952	6316	537	0.29
	sd		348	479	1734	297	0.06		344	426	1723	261	0.05		260	454	1780	283	0.05

Table 72 resilience for different farm types in the Central Mountain on average, in 2009, and 2010

			2005 to 2013						2009						2010					
Farm type	**St**		**Res**	**Prof /Cow (€)**	**Prod /Cow**	**Feed/Cow (€)**	**p****		**Res**	**Prof /Cow (€)**	**Prod /Cow**	**Feed/ Cow (€)**	**P****		**Res**	**Prof /Cow (€)**	**Prod /Cow**	**Feed/Cow (€)**	**Price €/kg**
IND	mean	43	-62	699	4114	883	0.44	3						4					
	Sd		391	470	1563	389	0.08												
MNT	mean	7948	33	1113	5923	666	0.36	866	-292	978	5904	610	0.33	851	174	1153	6016	628	0.36
	sd		387	604	1687	446	0.09		413	521	1616	409	0.09		332	600	1685	382	0.09

Table 73 resilience for different farm types in Southern Central on average, in 2009, and 2010

Farm type	St	2005 to 2013						2009						2010					
		n	Res	Prof /Cow (€)	Prod /Cow	Feed/Cow (€)	p**	n	Res	Prof /Cow (€)	Prod /Cow	Feed/ Cow (€)	P**	n	Res	Prof /Cow (€)	Prod /Cow	Feed/Cow (€)	Price €/kg
GRS	mean	1255	1	1021	6195	1001	0.36	115	-184	778	5990	969	0.34	112	63	778	5877	940	0.34
	sd		556	818	1888	550	0.10		416	739	1778	473	0.09		356	797	1873	408	0.10
GMX	mean	1503	4	970	6379	904	0.34	155	-226	717	6159	875	0.31	137	120	737	6055	856	0.32
	sd		494	732	1764	489	0.08		598	660	1837	421	0.08		329	644	1544	399	0.08
IND	mean	704	48	1358	7054	1137	0.39	84	-16	1292	6777	966	0.37	68	83	1420	7243	1170	0.39
	sd		557	738	2007	501	0.08		628	728	2061	416	0.06		504	747	2017	485	0.08
MIX	mean	2471	36	976	6755	1004	0.34	343	-161	903	6657	950	0.32	286	211	1099	6880	1017	0.35
	sd		534	738	1892	476	0.08		570	703	1889	452	0.08		595	870	1933	470	0.10

Table 74 resilience for different farm types in Mediterranean on average, in 2009, and 2010

Farm type	St	2005 to 2013						2009						2010					
		n	Res	Prof /Cow (€)	Prod /Cow	Feed/Cow (€)	p**	n	Res	Prof /Cow (€)	Prod /Cow	Feed/ Cow (€)	P**	n	Res	Prof /Cow (€)	Prod /Cow	Feed/Cow (€)	Price €/kg
GRS	mean	487	-22	1048	5941	866	0.35	30	46	1260	6485	626	0.33	27	-286	927	6197	732	0.30
	sd		451	633	2045	456	0.08		488	556	2453	253	0.11		363	479	2077	347	0.04
GMX	mean	379	7	1098	5846	907	0.37	29	-87	1135	5897	767	0.35	21	6	1196	6713	995	0.37
	sd		513	743	2081	497	0.08		539	673	1771	434	0.06		743	757	2658	576	0.09
IND	mean	1301	-26	928	6613	1238	0.37	141	-115	972	6777	1150	0.36	136	-102	916	6603	1174	0.35
	sd		510	642	2092	636	0.08		515	728	2123	582	0.09		579	734	2157	635	0.08
MIX	mean	1086	12	904	6452	1176	0.37	152	-163	831	6481	1129	0.35	138	105	933	6353	1113	0.37
	sd		529	727	2193	617	0.08		601	806	2253	519	0.09		437	724	2167	585	0.09

Table 75 resilience for different farm types in Mediterranean Mountain on average, in 2009, and 2010

		n	2005 to 2013					n	2009					n	2010				
Farm type	St		Res	Prof /Cow (€)	Prod /Cow	Feed/Cow (€)	p**		Res	Prof /Cow (€)	Prod /Cow	Feed/ Cow (€)	P**		Res	Prof /Cow (€)	Prod /Cow	Feed/Cow (€)	Price €/kg
IND	mean	214	2	1127	6741	1009	0.35	31	-286	1105	6948	964	0.32	35	-182	1097	6709	984	0.34
	sd		624	792	1872	526	0.10		674	919	1931	485	0.10		634	989	1752	414	0.12
MNT	mean	2054	14	997	6232	893	0.34	229	-388	866	6182	845	0.32	224	-41	877	6226	904	0.33
	sd		565	662	1891	455	0.08		659	572	1940	395	0.07		523	764	1938	454	0.09

Beef suckler

Table 76 resilience for different farm types in the Atlantic region on average from 2005 to 2014

		North Atlantic				West Atlantic				Atlantic Mountain			
Farm type	St	n	Res	Prof /BLU (€)	Feed/BLU (€)	n	Res	Prof /BLU (€)	Feed/BLU (€)	n	Res	Prof /BLU (€)	Feed/BLU (€)
GRS	mean	7556	-2	108	192	5522	9	325	206				
	sd		183	188	116		228	255	173				
GMX	mean	696	-4	145	245	3954	11	323	217				
	sd		204	188	130		202	267	153				
IND	mean	3				149	31	401	318				
	sd						213	318	235				
MIX	mean	122	-19	166	261	2188	4	314	317				
	sd		245	230	136		249	297	218				
MNT	mean									117	37	270	174
	sd										227	233	92

Table 77 resilience for different farm types in the Boreal region on average from 2005 to 2014

			Boreal		
Farm type	**St**	**n**	**Res**	**Prof /BLU (€)**	**Feed/BLU (€)**
GRS	mean	232	-26	-45	328
	sd		389	381	320
GMX	mean	179	-28	-39	311
	sd		441	365	290
MIX	mean	50	-125	-62	337
	sd		340	408	265

Table 78 resilience for different farm types in the Continental region on average from 2005 to 2014

			Central Europe				Central Mountain		
Farm type	**St**	**n**	**Res**	**Prof /BLU (€)**	**Feed/BLU (€)**	**n**	**Res**	**Prof /BLU (€)**	**Feed/BLU (€)**
GRS	mean	3805	12	202	239				
	sd		200	301	206				
GMX	mean	2010	7	213	222				
	sd		194	259	184				
IND	mean	2				6			
	sd								
MIX	mean	1098	15	278	200				
	sd		224	247	160				
MNT	mean					1887	6	260	221
	sd						195	269	167

Table 79 resilience for different farm types in the Mediterranean region on average from 2005 to 2014

			Southern Central				Mediterranean				Mediterranean Mountain		
Farm type	**St**	**n**	**Res**	**Prof /BLU (€)**	**Feed/BLU (€)**	**n**	**Res**	**Prof /BLU (€)**	**Feed/BLU (€)**	**n**	**Res**	**Prof /BLU (€)**	**Feed/BLU (€)**
GRS	mean	1122	9	263	309	1855	19	254	280				
	sd		245	299	207		248	265	190				
GMX	mean	815	8	260	322	458	12	278	323				
	sd		289	335	217		282	326	195				
IND	mean	56	8	371	360	115	34	113	320	178	3	194	345
	sd		323	409	249		201	293	259		214	253	192
MIX	mean	570	-4	380	399	711	40	275	287				
	sd		435	437	230		320	377	209				
MNT	mean									3999	5	174	338
	sd										239	255	174

Beef finisher

Table 80 resilience for different farm types in the Atlantic region on average from 2005 to 2014

			North Atlantic				West Atlantic		
Farm type	**St**	**n**	**Res**	**Prof /BLU (€)**	**Feed/BLU (€)**	**n**	**Res**	**Prof /BLU (€)**	**Feed /BLU (€)**
GRS	mean	1170	16	141	238	222	-9	247	243
	sd		209	207	158		245	297	170
GMX	mean	258	40	150	298	393	9	201	302
	sd		232	200	183		198	212	182
IND	mean	1				106	-4	345	509
	sd		.	.	.		233	500	280
MIX	mean	102	110	514	5	1473	22	296	462
	408		251	376	408		250	301	261

Table 81 resilience for different farm types in the Boreal region on average from 2005 to 2014

			Boreal		
Farm type	St	n	Res	Prof /BLU (€)	Feed /BLU (€)
GRS	mean	82	-33	-117	672
	sd		450	440	394
GMX	mean	171	-10	44	600
	sd		325	331	300
MIX	mean	124	-19	-38	632
	sd		403	416	386

Table 82 resilience for different farm types in the Continental region on average from 2005 to 2013

			Central Europe				Central Mountain		
Farm type	St	n	Res	Prof /BLU (€)	Feed/BLU (€)	n	Res	Prof /BLU (€)	Feed/BLU (€)
GRS	mean	153	-9	90	383				
	sd		220	332	234				
GMX	m	431	18	282	340				
	sd		271	323	201				
IND	m	7				5			
	sd								
MIX	m	2066	22	400	366				
	sd		283	293	200				
MNT	m					194	29	432	425
	sd						483	602	348

Table 83 resilience for different farm types in the Mediterranean region on average from 2005 to 2014

			Southern Central				Mediterranean				Mediterranean Mountain		
Farm type	**St**	**n**	**Res**	**Prof /BLU (€)**	**Feed/BLU (€)**	**n**	**Res**	**Prof /BLU (€)**	**Feed/BLU (€)**	**n**	**Res**	**Prof /BLU (€)**	**Feed/BLU (€)**
GRS	mean	69	62	530	614	44	-116	589	662				
	sd		471	758	307		718	573	518				
GMX	mean	128	-13	286	625	30	206	915	687				
	sd		498	659	348		359	1216	479				
IND	mean	194	-25	508	623	38	86	443	662	8			
	sd		676	619	298		661	730	516				
MIX	mean	542	0	460	652	84		21	767				
	sd		554	577	321			723	785				
MNT	mean									123	-56	780	889
	sd										1112	838	627

8.3. Best worse survey method

Object case best-worst scaling (BWS), or maximum difference scaling is a stated preference method (Louviere et al., 2015). With BWS, respondents repeatedly choose the best and worst item from subsets of items (choice sets). The number of – and composition of- choice sets follows an experimental design; in this case, a balanced incomplete block design (BIBD). The frequency with which an item is chosen as either best or worst in each choice set is indicative of the relative importance that a respondent assigns to that item. In this case, we were interested to elicit the relative importance of genetic traits in dairy and beef cattle. Following the objectives of GenTORE, we were interested to understand this preference for cattle traits in the context of both *resilient* animals and *efficient* animals. As such, respondents selected the traits that would promote a resilient animal and an efficient animal, separately. An example choice set is shown in Figure 47.

Respondents completed choices based on traits of dairy or beef animals. Traits were selected based on earlier GenTORE stakeholder and partner engagements, both through the online stakeholder e-platform (accessible through the GenTORE website) in 2017, and a survey of partners in 2018. It was also important that genetic parameters were available for selected traits, so that a response to selection could be calculated (see Figure 47). In total, 8 traits were selected for each dairy and beef choice blocks.

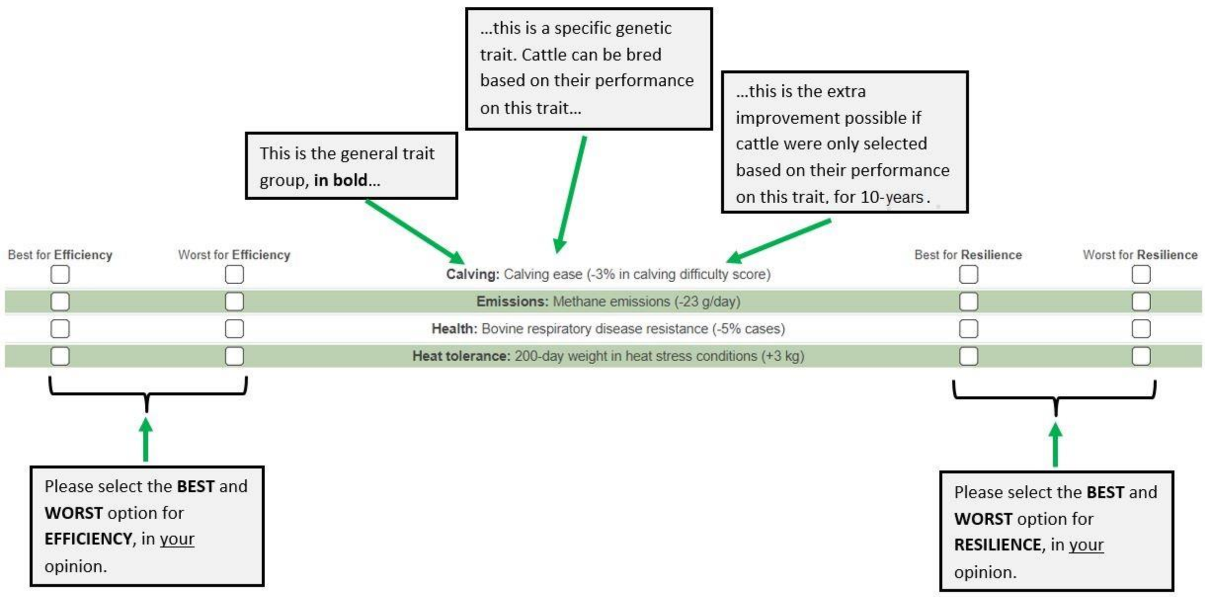

Figure 47 Figure 8.3.48 An example choice set from the beef choice block. Respondents selected the best and worst item, relative to all items presented. Respondents have three pieces of information for each item, which ranges from general to specific: the traits group, the trait, the phenotypic improvement if animals were selected on this trait alone for 10-years.

For the analysis, there are two approaches to analysing responses to object case BWS questions: the counting approach and the modelling approach (Aizaki *et al*., 2015). The current work uses the counting approach at a regional scale. Standardised scores are calculated based on the aggregated number of times each trait is selected as the best or worst, in the separate contexts of resilience and efficiency, by all respondents across all choice sets in each choice block. This approach indicates the overall perceived importance of traits for beef and dairy production in the separate contexts of resilience and efficiency.

$$BW_i = B_i - W_i$$

$$Standardised\ score = \frac{BW_i}{Nr}$$

Where BW_i is the aggregated best-worst score, a product of the number of times trait i is selected as best (B_i) and worst (W_i) across all questions. The standardised score adjusts BW_i according to the frequency with which trait i appears across all questions (r), for all respondents (N). The standardised score is between -1 and +1; a negative score indicates the trait was chosen as worst more often than best, a positive score indicates the trait was chosen as best more often than worst.

8.3.1. Estimating response to selection

For both choice blocks, dairy and beef, response to selection for all traits other than heat tolerance were calculated as the improvement that could be achieved if all selection emphasis was placed on a single trait.

$$Response = \frac{i \times h^2 \times \sigma_p}{L}$$

Where, i is the selection intensity, a product of the selected proportion, h^2 is the heritability, the ratio of additive to non-additive genetic variance, σ_p is the phenotypic standard deviation for each trait in a given population, and L is the generation interval. Selected proportions for beef and dairy followed Cottle & van der Werf (2017) and Nguyen *et al*. (2016), respectively. Genetic parameters were taken from several sources for beef traits (average daily gain: , calving interval: , calving ease: , carcass weight: , residual feed intake (RFI): , methane emissions: , bovine respiratory disease:) and dairy traits (protein yield: , calving interval: , calving ease: , RFI: , longevity: , methane emissions: , mastitis resistance:). The generation interval was calculated as follows, (i) for beef, average generation length of males and females followed Cottle & van der Werf (2017), (ii) for dairy, for males, we assumed genomic selection and, for females, age-class tables based on UK Holstein data were used. For heat tolerance, due to this field being under-researched, the possible improvement for the dairy trait *milk yield* (litres) was taken from Nguyen *et al*. (2016), and the same magnitude of improvement was applied to the beef production trait *200-day weaned weight*.