agri benchmark

THÜNEN

Beef and Sheep Network

Katrin Agethen
Peter Weeks

Climate change adaptation strategies in beef and sheep production

Survey and Workshop Results of the *agri benchmark* Beef and Sheep online Conference 2020

Briefing Paper 2020/1

Climate change adaptation strategies in beef and sheep production

Prepared by

Katrin Agethen
agri benchmark Beef and Sheep Network,
Thünen Institute of Farm Economics,
Braunschweig, Germany

Peter Weeks
Weeks Consulting Services,
Sydney, New South Wales, Australia

Braunschweig, Sydney, October 2020

Related information available on the *agri benchmark* website

Briefing paper: Climate change adaptation strategies in beef and sheep production
http://www.agribenchmark.org/beef-and-sheep/publications-and-projects/briefing-papers.html

Fact Sheet: Climate change and adaptation strategies in beef and sheep production
http://www.agribenchmark.org/agri-benchmark/news-and-results.html

Content

Summary

In the public opinion, livestock production is usually accused of being a major contributor to climate change. On the other hand, the changing climate impacts livestock production in different ways and intensities. It results in direct, and very often indirect, effects. The ability of agricultural producers to cope with these effects depends on a large variety of factors – including managerial skills and knowledge, access to technologies and the availability of resources.

Following the 2019 *agri benchmark* Conference, at which members saw first-hand the severe impact of a changing climate on Namibian livestock producers, it was decided to harness the resources and broad experience of the *agri benchmark* Beef and Sheep network to conduct a top-level expert-based exploration of the issue of livestock farm adaptation to climate change.

The aims of this project were:

- to gain an overview of livestock **producer views** towards climate change, the nature and impacts of climate change on livestock production in all regions;
- to explore and share **producer adaptations** to these impacts; and
- to showcase **best practice examples** of how farmers react to changing environmental production conditions.

This report summarizes the outcomes of this study, conducted using a **qualitative survey** of *agri benchmark's* 40 beef and sheep country members and **two results workshops** as part of the 2020 *agri benchmark* Conference (online). Survey responses were received from 33 countries, including all the largest beef and sheep meat produces and with responses from all continents and regions.

The survey covered three major topics: 1) the impact of climate change on livestock production, 2) the way producers adapt to these impacts and 3) programs and instruments set in place by governmental, industrial and research institutions to support adaptation.

Given the complexity of the topic, this has been a **most interesting and rewarding survey and workshop discussion:** one that was difficult to complete, yet the results were **remarkably consistent**, internally, between neighbouring countries and between regions with similar climatic conditions. The main findings are:

(1) In 73% of countries, many or most producers believe that the climate is changing. However, in some countries, only a few producers believe, and these were countries where climate change was reported as having either no impact or only a minor impact on livestock production.

(2) Climate change is affecting livestock producers across the globe but these effects vary between regions and countries.

(3) All respondents able to answer the question reported that climate change is having an economic impact on livestock producers, with two thirds of these reporting a moderate, significant or severe negative impact.

(4) The most severe economic impacts are observed in the southern hemisphere, particularly in some African and South American countries. The least impact on livestock producers occurs in the high latitude countries of Europe and Canada.

(5) In particular, the climate is becoming hotter and drier (wetter for a few countries) and more variable, with more extreme events. Also, seasons are altering. These changes are impacting livestock production and challenging livestock producers.

(6) The changes also negatively impacting feed productivity in almost all countries and water availability in 70-80% of the countries.

(7) Livestock producers are generally adapting to climate change in 77% of respondent countries and, again, in a variety of ways. This change happens in all southern hemisphere countries, the region most affected, but less in the northern hemisphere, and least in high latitude countries. The level of adoption among producers, however, varies greatly both within and between countries, regardless of the geographic location.

(8) Adaptations can be planned or forced; simple or complex; costless or costly and high or low risk.

(9) The main adaptations were in feed – including pasture management, supplementary feeding, changing the pasture or fodder type or species, combining livestock and feed production systems, feed storage and altering the timing of sowing/harvesting of feed.

(10) Most countries reported adaptations to increase water access, storage and reticulation – particularly in the drier countries of Africa, South America, Australia and the Middle East.

(11) Almost all countries were making adaptations related directly to animal management – mainly to stocking rates; animal culling and marketing; changes in the timing of breeding or weaning, altering genetics and animal shelters.

(12) Adaptations are often interrelated and need to be applied together, as a package, to be fully successful.

(13) Most producers are not adapting consciously. Existing adaptation knowledge, technologies and innovations are being underutilised, especially in developing countries.

(14) Even in this qualitative and cursory exercise, world best practise adaptations were found, many of which would be applicable to other producers and other countries – suggesting that more concerted targeted research could unearth many more worth sharing.

(15) There are many simple, older and public adaptations that could be more widely shared and adopted to lift productivity elsewhere.

(16) There are many management tools publicly available to assist producers in adapting to climate change.

(17) In contrast to climate change mitigation, there are surprisingly few countries with country plans (programs) specifically aimed at climate change adaptation, though around half had some government or industry funding of programs or research in this field.

The success of this largely qualitative and subjective research in painting a consistent and believable picture of the impact of climate change on livestock producers around the world and in un-earthing useful and transferable adaptations suggests that a much more rigorous academic and policy development study is warranted. International institutions, governments and industry bodies and major multinational companies in more countries need to make agricultural adaptation to climate change a higher priority and enable greater sharing of successful adaptations both within and between countries. *agri benchmark* as global network with considerable expertise in production systems and economic analysis see many opportunities in linking practice to research and thus helping to promote viable production strategies in a changing environment.

1 Climate change and the livestock sector

Climate change is defined by the United Nations Convention on Climate Change (UNFCCC) as *"a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods."*[1]

The political, economic and scientific debate and work around climate change, in recent decades, has moved on from whether the climate is changing and how and how fast to whether these changes are attributed directly or indirectly to human activity and – as this is now widely accepted – what humans can do to stop or reverse it. Much less attention has been given to how to adapt to a changing climate, which is of particular importance for activities dealing directly with the weather: to agriculture and the production of our food.

In the recent past, it became obvious in many parts of the world: the climate has changed remarkably quickly and seems likely to continue to do so for the foreseeable future. On a global scale, the effects of climate change have already become reality: shrinking glaciers, earlier ice breaks, earlier flowering of trees, changing precipitation and drought patterns. Human kind will need to adjust to it – in how and where to live and in how to cloth, water and feed itself.

Livestock plays a critical role in the sustainable development of many societies (FAO-AGAL 2016), in the way we eat and cloth ourselves, and in economic performance of many rural areas. The role of livestock in the context of climate change is ambiguous: while ruminants have been identified as important contributors to global warming, their management is largely dependent on environmental conditions and under particular pressure with rising concerns on food security.

Climate change is directly or indirectly impacting agricultural producers in all countries. It can effect animals directly, the basic production factors, such as feed and water, or the production environment (Rojas-Downing et al. 2017). However, locally, the effects of climate change are likely to differ from region to region and from country to country. In the context of a changing climate and growing global demand for livestock products, it is crucial for producers to develop sustainable locally adapted strategies to cope with these changes.

The *agri benchmark* network of Beef and Sheep is formed by institutions, producer organizations, advisory groups and marketing organisations with an expertise in production systems and their economics. It covers 40 countries globally, including the most important producers and emerging markets.

Harnessing the resources and combined experience of the *agri benchmark* Beef and Sheep network to conduct a top-level exploration of the issue of farm adaptation to climate change was an idea that arose from the southern hemisphere climatic extremes that formed the backdrop of the 2019 annual *agri benchmark* conference. In June 2019, *agri benchmark* Beef and Sheep Conference took place in Windhoek, Namibia, where participants witnessed the impact of that country's worst drought in over 100 years, which pushed them close to famine and led to the loss and culling of large numbers of cattle, sheep, goats and wild animals.

In 2019, Australia's livestock producers also experienced the full force of climate change in one of the most devastating and widespread 2-year droughts ever experienced. The national cattle herd and sheep

[1] United Nations Framework Convention on Climate Change, 1992, Article 1: Definitions page 3. https://unfccc.int/resource/docs/convkp/conveng.pdf

flock both fell 11%. In the same year, Australia had a more isolated, but also devastating, flood covering over 11.4 million hectares of Queensland that killed an unprecedented 457,000 cattle, 43,000 sheep, 3,000 goats and destroyed 29,000kms of roads/farm tracks and 22,000kms of fencing as well as numerous houses, sheds, water storages and reticulation, equipment and machinery.[2]

Figure 1: The impact of 2019 weather extremes in Namibia (left) and Australia (right)

Source: agri benchmark partners, own pictures

Climate change has not only been a phenomenon for the southern hemisphere but globally, with challenging conditions in the recent past and currently. News headlines show that new records and extreme events are occurring in many parts of the world: the hottest year on record in Europe in 2019, devastating bushfires in Australia, highest recorded rainfall in 130 years in Brazil, tornadoes in the US, super-cyclone and extraordinary rainfall events in Asia. Remote sensing observatories reported rain deficits and soil moisture deficits in the months of April to June in many regions of Europe and South America. Network partners from Paraguay and Colombia witnessed the drought occurring in different locations of South America – in Paraguayan Chaco „one of the worst in the last 30 years".

Based on this information, an online survey was circulated within the *agri benchmark* Beef and Sheep network and an online results workshop conducted. This report summarizes the results and findings on climate change and livestock production adaptation derived from this expert consultation and presented during the 2020 annual *agri benchmark* Beef and Sheep Conference.

[2] See official Queensland Department of Agriculture estimates**,** as summarised in Beef Central's *Final tally reached for Northwest Qld's February 2019 flood losses*, Jon Condon 18 March 2020. https://www.beefcentral.com/news/final-tally-reached-for-northwest-qlds-february-2019-flood-losses/

2 Study background: Data collection and coverage

The *agri benchmark* Beef and Sheep network counts 40 partner countries, covering most of the relevant producing countries, the global variety of production systems and all continents. This report presents the results of an online expert survey of *agri benchmark* members and the outcomes of two associated workshop sessions conducted on June, 17th as part of the 2020 annual *agri benchmark* Beef and Sheep Conference (conducted online).

The project was undertaken using a customised online survey questionnaire sent to all the *agri benchmark's* partners in April 2020. In order to obtain a global survey coverage as wide as possible, and considering "hard facts" focussing on the livestock producers experience with climate change might only be available in a few countries, participants were asked to answer the survey using primarily their own perception, experience and knowledge. Participants were, however, also invited to support their evaluation with, and share, relevant data or other material. Responses were reviewed and specific adaptation case studies were collected in May 2020. Following the conference, final remarks and questions were exchanged with contributing partners.

The survey covered three major topics: 1) the impact of climate change on livestock production, 2) the way producers adapt to these impacts and 3) programs and instruments set in place by governmental, industrial and research institutions to support the adaptation. During the workshop presentations, additional data on specific questions were collected via polls.

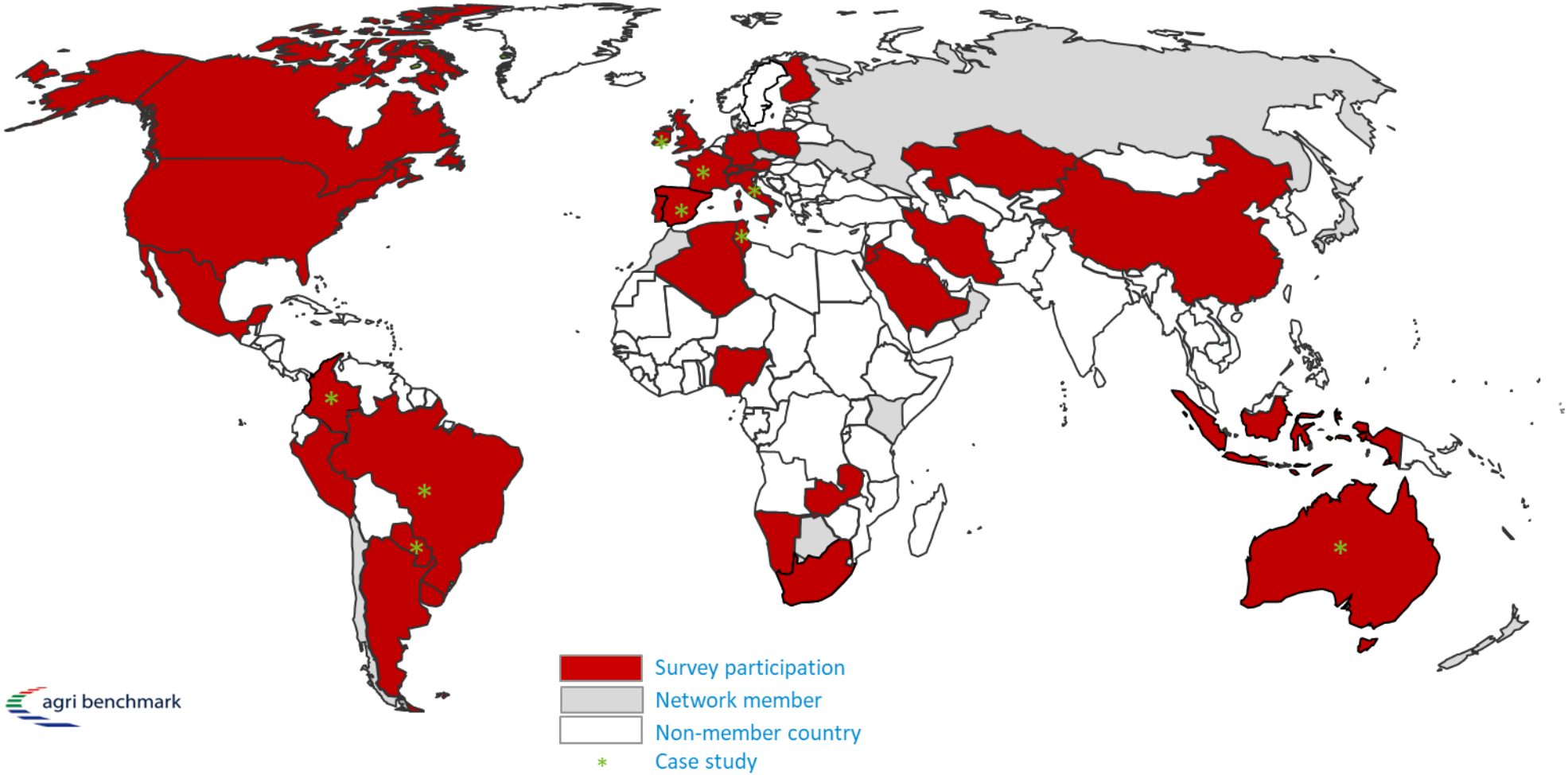
The aim of the study is to draw on the **considerable experience and expertise** of all *agri benchmark* partners:

- to gain an overview of livestock **producer views** towards climate change, the nature and impacts of climate change on livestock producers in all regions,
- to explore and share **producer adaptations** to these impacts,
- and to showcase **best practice examples** of how farmers react to changing environmental production conditions.

Completed survey responses were received from 33 member countries, including all the largest beef and sheep meat producing countries and with responses from all continents and regions (see **Figure 2**). The adaptation case studies represent a mixture of beef and sheep production stages, systems and regions, addressing different challenges related to climate change. A total of 45 experts from 23 countries participated in the workshop session.

We thank all *agri benchmark* partners who participated in the survey and workshop discussions, helped to collect country-specific information and consulted livestock experts in their countries and, in this way, contributed substantially to this study.

Figure 2: Participating countries in the pre-conference *agri benchmark* survey on "Climate change & Livestock adaptation"



Source: own graph

3 Situation and rising concerns: The impacts of climate change on livestock production

Reaction to the environmental conditions has always been an imperative for agricultural producers. In the light of changing climate and more rapid changes, the focus of attention within agriculture is often on cropping activities, as this is the basic resource for feeding a growing population. Livestock production is more often overlooked, despite its importance in the use of environmental resources, such as land and water. This chapter explores the issues of beef and sheep producers' perception of climate change and its observable impacts at the farm level.

3.1 Perception of climate change

Intuitively, one could think that the recognition and acceptance of a situation is the pre-condition to act. In the context of adapting production practices to changing environmental conditions due to global warming, this might be the belief in climate change.

We started our survey with the question "Do livestock producers in your country believe that the climate is changing?" (see **Figure 3**). Generally, there was a positive response to this survey question, with 73% of countries reporting either many or most producers believed the climate is changing. The countries reporting that most producers believe the climate is changing are primarily in Europe, but also Central America and some in Africa.

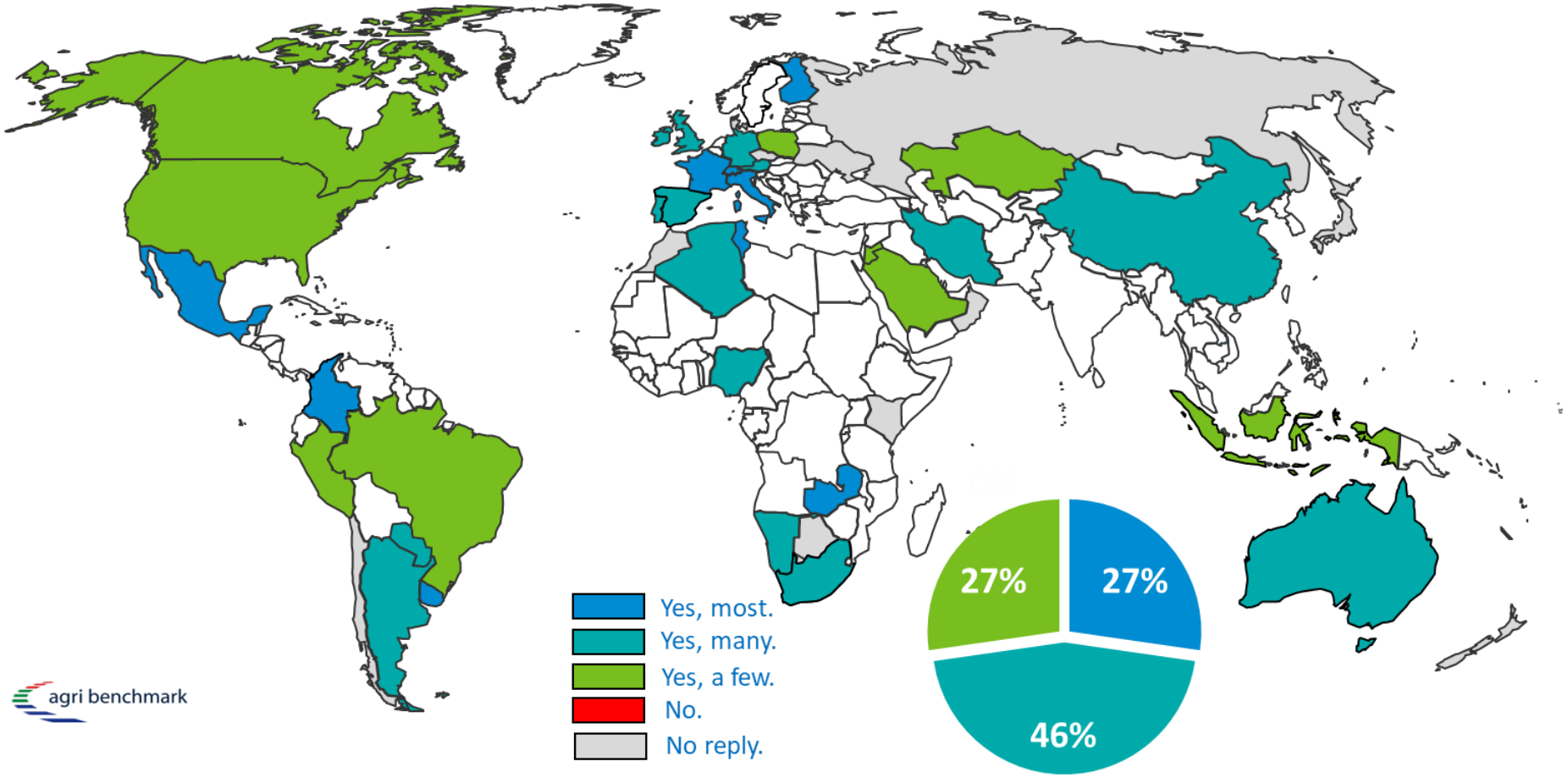
While no partner replied that producers do not believe that the climate is changing, in several countries only a few believe – including major red meat producing countries, like the US and Brazil. For most of these cases this response was logical, as these countries also reported either minor or no impact of climate change on livestock producers – notably in Brazil, Canada, Poland and Peru. However, in other countries', such as the US, belief in climate change is not as strong as expected, given the economic impact of a changing climate.

Studies show that whereas belief in climate change is crucial to mitigating greenhouse gases, the adaptation to climate change is rather linked to perceived risks (Arbuckle et al. 2015). Focussing on adaptation, belief seems less relevant in the decision process. Additionally, belief is closely linked to trust in referred institutions and actors. In this light, responses from countries like the US, Brazil, Indonesia appear to be plausible – if we put it in the context of a political leader's commitment to global warming goals.

Taking the US survey response as an example, it reports that few livestock producers believe that the climate is changing despite also reporting a moderate climate change economic impact on those producers. The answer to this question might have been made from a subjective perspective, but reflects a general civic, and especial conservative farming, attitude to climate change. For largely political and economic reasons, many people, including agricultural producers, in some countries see the climate changing but do not believe in climate change as they do not want to believe it is man-made and/or do not accept the economic cost of mitigation. Research from Canada pointed out the sensitivity of producers to the term 'climate change' (Davidson et al. 2019), and also Australian producers, despite having a comparably high share of "believers", argue about the "concept of climate change" versus "climate variability".

Without pre-empting the responses to the further questions, our results support the assumption that livestock producers' adaptation actions are rather linked with perceived risks than beliefs.

Figure 3: Producers' perception of climate change – Do livestock producers believe?



Source: own graph based on responses to pre-conference online survey, Q2: "Do livestock producers in your country believe that the climate is changing?"

3.2 Effects of climate change on livestock production systems

Following the assessment of belief in climate change among producers, experts were asked to describe the observable impacts and related economic and agronomic effects with regards to their beef and sheep production systems.

3.2.1 Weather impacts of climate change

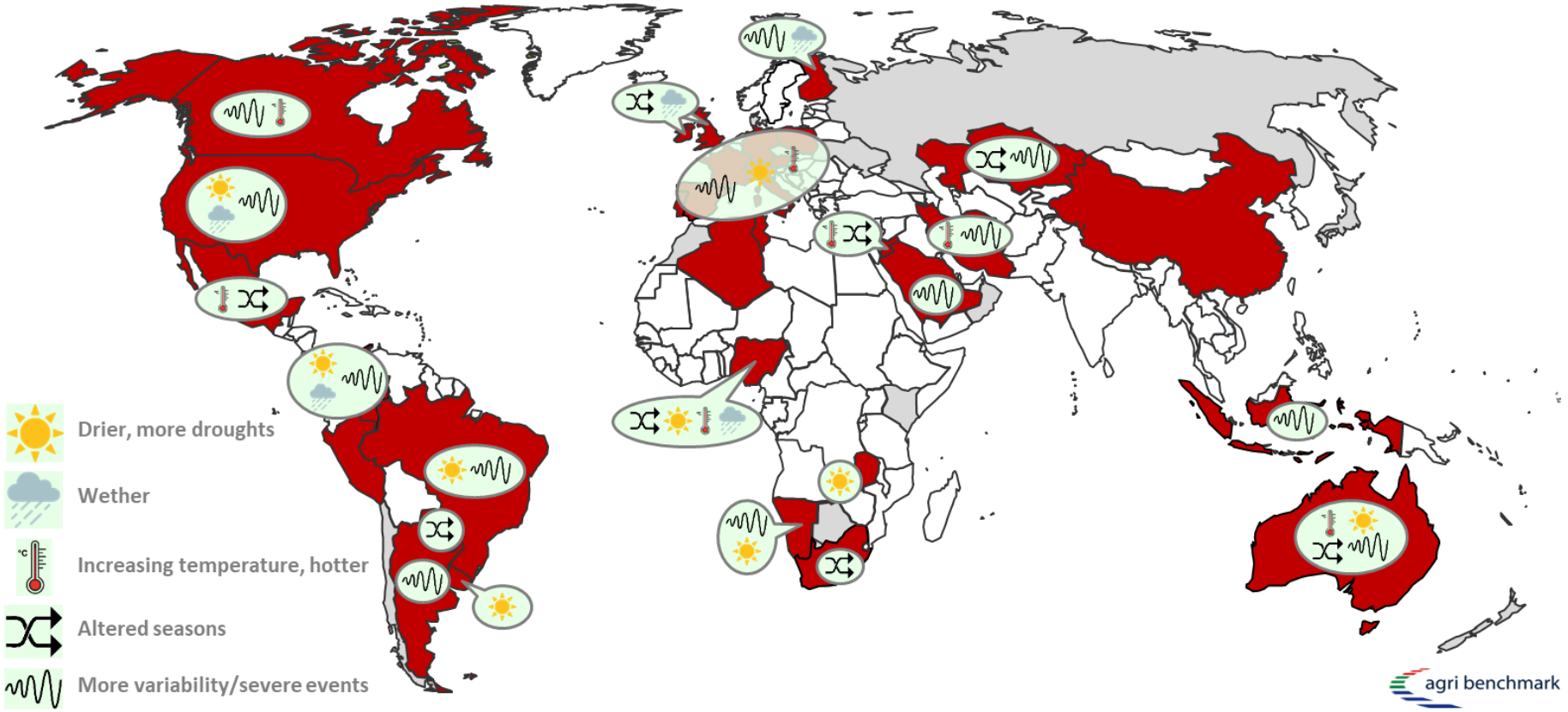
The reported effects of climate change varied greatly. The information given in open answers was clustered into five categories – drier, wetter, hotter, altered seasons and variability.

- **Drier**: various countries on all continents/regions, excluding in Asia and the Middle East, were drier or reported drought events happening more often
- **Wetter**: Six countries were wetter, with all of these already having relatively wet climates in at least parts of their country (especially Columbia and Nigeria)
- **Hotter, increasing mean temperature:** a large number of countries reported increasing temperatures and it being hotter. The tendency can be observed across continents and climatic zones – from countries with rather low annual temperatures, e.g. Canada and European countries, to arid and tropical countries like Iran, Mexico and Nigeria.
- **Altered seasons:** Eight countries reported altered seasons – ranging from later onset of winter, earlier spring breaks, shifting raining seasons and changes in the length of growing seasons
- **Increasing variability, more severe events:** Most countries across all regions and continents reported more climate variability.

In Figure 4, these changes are depicted by country. For Europe, the islands (the UK and Ireland) and the western-central-continental countries have been grouped. Most countries reported not only one impact. Nigeria, US and Columbia all reported being both wetter and drier – reflecting the diverse climatic zones within these countries and fitting with their reporting of more variability and altered seasons.

The responses indicate that a “normal” average year might become less probable. Instead, producers need to prepare for an increase in “unusual” weather variability, season timings, rainfalls, droughts and heatwaves.

Figure 4: Observed weather effects related to climate change



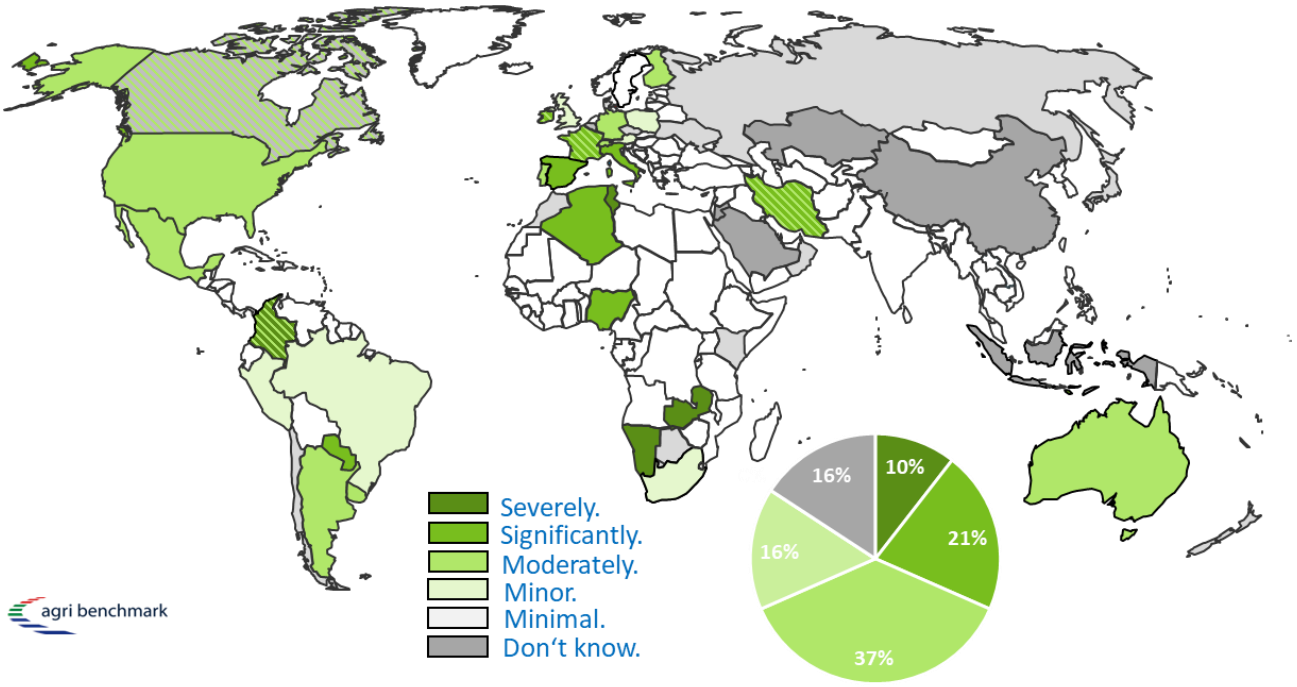
Source: own graph based on responses to pre-conference online survey; Q3: "What are the effects of climate change in your country?" (open answer)

3.2.2 Economic impacts of climate change

Even if the climate is changing in a country or region, this does not mean that it economically effects livestock production. If it does, the magnitude of its impact is likely to be varied. Being asked about the economic effect related to climate change, in our survey, all the 75% of respondents that could answer this question said livestock producers are being economically affected by climate change – the other 25% answered with "*don't know*".

Figure 5 gives a global overview of the perceived severity of climate change's economic impact. Of those that reported that climate change was affecting livestock producers, two thirds reported being moderately, significantly or severely affected.

Figure 5: Assessment of economical severity of climate change's impact



Source: own graph based on responses to pre-conference online survey; Q4a: "If yes, how seriously (in economic terms) is climate change affecting livestock producers?". Multiple diverging responses per country are reflected in hatched colouring.

Brazil and South Africa are the only major beef and sheep producing countries with only a reported minor impact from climate change. Australia, although hit by several extreme events in the recent past, observes only moderate economic impacts. Those countries where producers are being severely affected are Namibia, Zambia, Tunisia and Columbia (according to one of the two responses from Columbia).

Especially striking are those responses where neighbouring countries witness strong differences in the severity of impacts:

- South Africa's producers were being impacted in a minor way, while Namibia and Zambia have been severely affected.

- Brazil's and Peru's producers have only been impacted in a minor way while surrounding countries have been moderately to severely affected.

In Brazil, changes in rainfall patterns are being concentrated in some isolated regions. Also, the country is experiencing a moment of increasing farm productivity because producers started to assimilate more strongly the technologies in animal nutrition and reproduction and pasture management.

In South Africa, producers are in general able to adapt to the observed shift in seasons, with altering planting and calving/weaning seasons. Unlike Namibia and Zambia, it has not been reported to be drier due to climate change. Thus, their livestock performance does not suffer as bad as their neighbouring countries. Only a small proportion of the production which is located in the north, close to the Namibian border, would suffer major economic impacts of droughts.

The diversity in economic impacts suggests that there are various ways to adapt to climate change and that the level of preparedness and ability to adapt to climate variability differs markedly across locations and countries. It might also be that in countries reporting more serious economic effects, climate change impacts various production factors, making it more difficult and expensive to counteract. In the next section, we look into the detail of the production factor impacts.

3.2.3 Production factor impacts of climate change

In beef and sheep production systems, a wide variety of production factors might be susceptible to climate change impacts. As the magnitude of sensitivity might differ for specific factors and/or even show contrasting results within the main categories of feed, animal, water and land, price and infrastructure, a detailed assessment on 24 factors was requested from participants. The respondents were asked to evaluate the impact of climate change – ranking the impact as minor, moderate or major negative, stable, minor, moderate or major positive; or don't know. For analytical purposes, the range of impacts of climate change on livestock producers have been grouped into feed, animal and other impacts

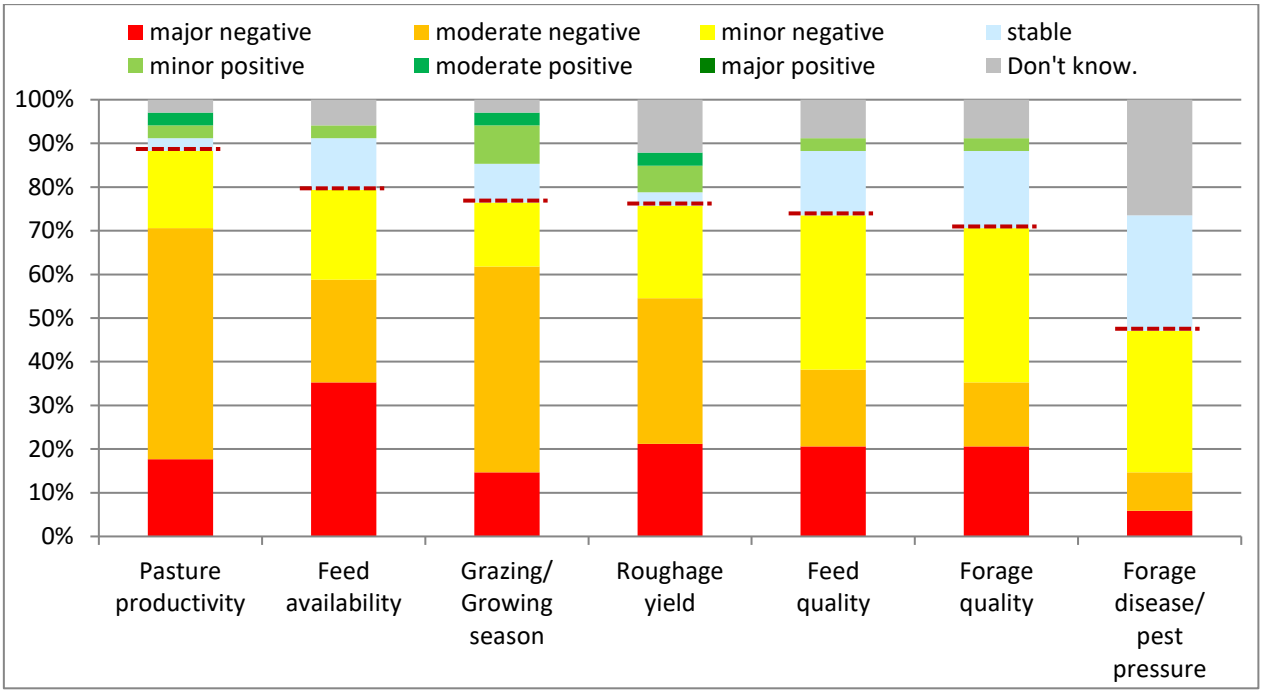
Feed categories

A good fodder basis depends on different quantity and quality aspects of the ration's components. For beef and sheep production, this may be pasture, roughage silage or other fodder components, depending on the feeding scheme and production system. To reflect the diversity of climate change's effects observed across countries, the feed category included the factors "Pasture productivity", "Feed availability", "Grazing/growing season", "Roughage yield", "Feed quality", "Forage quality" and "Forage disease/pest pressure".

Figure 6 shows the feed impacts, with the red horizontal line marking the magnitude of total negative impacts.

Compared to the other categories, the most commonly reported impact was on feed – with almost all countries reporting a negative impact on pasture productivity overall, and over 70% of respondents reported negative impacts on almost all feed characteristics. A moderate or major impact on pasture productivity, feed availability, grazing/growing season and roughage yield was reported by the majority of respondents. The lowest impact was on forage disease/pest pressure, where a majority reported stable or minor effects.

Figure 6: Evaluation of the impact of climate change on feed production (in percent of survey respondents)



Source: own graph based on responses to pre-conference online survey; Q4b: "If yes, in what way is it impacting livestock producers?". N=33, excluding "no reply".

Just to remind us that it is not all negative, climate change is having a moderate positive impact on pasture productivity, grazing/growing season and roughage yield and thus feed availability in Finland (see **Table 1** for the details). Minor positive impacts were also reported in other cold climate countries, such as the UK, Poland and Switzerland but, surprisingly, not in Canada or Ireland.

It would also be interesting to know if Russia, China and Mongolia are having positive impacts on feed – no detailed evaluations were received from *agri benchmark* partners in Russia or China and Mongolia is not currently a member of the *agri benchmark* network, despite the importance of its nomadic production of grazing sheep and goats, cattle and yaks and camels.

However, the observed negative effects on pasture productivity and feed availability, as the key indicators for the forage basis, have not only been reported from arid regions. African and Middle East countries predominantly witness major impacts, but also the Mediterranean countries Portugal and Spain. In South America, Brazil sticks out, reporting only minor effects – probably reflecting the currently ongoing farm productivity increase and grassland improvement strategies. Livestock production in the neighbouring countries Colombia, Paraguay and Argentina is more severely affected via forage availability.

Table 1: Detailed evaluation of feed categories under climate change (colour scheme as per **Figure 6**)

Countries	Pasture productivity	Feed availability	Grazing/ Growing season	Roughage yield	Feed quality	Forage quality	Forage disease/pest pressure
PY							
AR							
CO							
PE							
BR							
MX							
UY							
US							
CA							
FI							
AT							
ES							
PT							
CH							
PL							
IT							
UK							
FR							
DE							
IE							
TN							
DZ							
NG							
ZM							
ZA							
NA							
JO							
IR							
KZ							
AU							

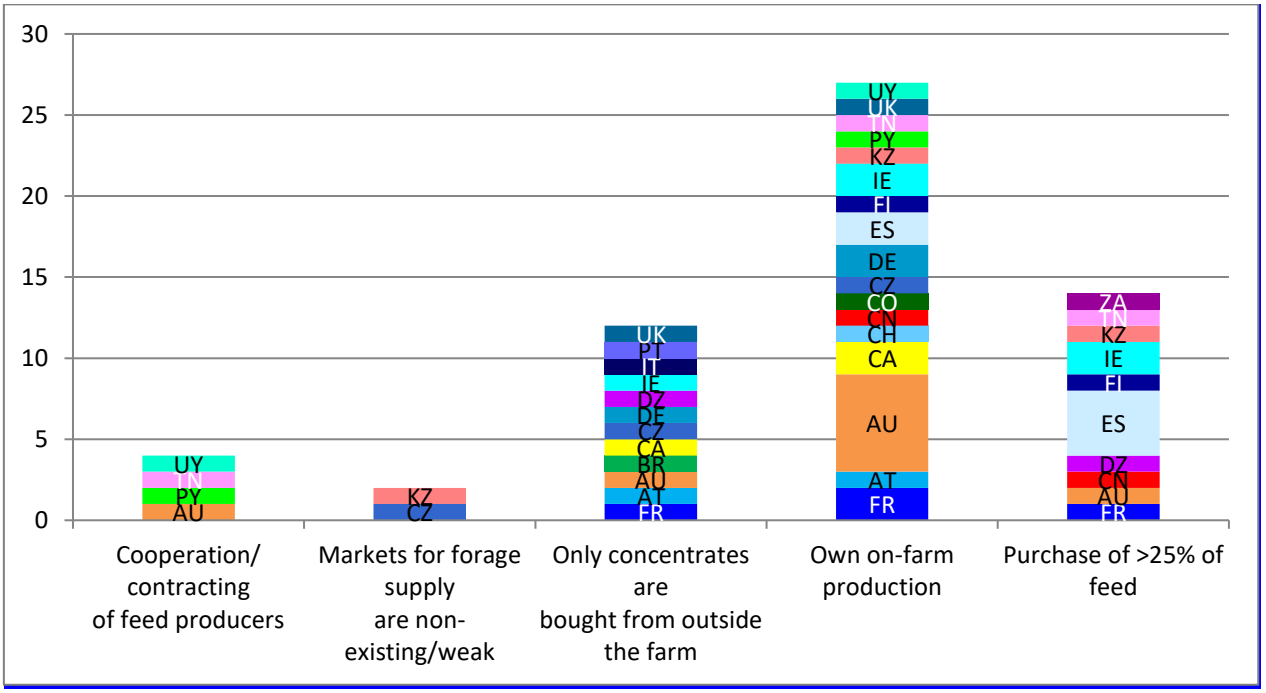
Source: own graph based on responses to pre-conference online survey; Q4b: "If yes, in what way is it impacting livestock producers?". Colombia, Canada, Ireland and Iran with double answers. Countries ordered by regional aspects.

With the observed impacts on the feed basis, it is important to consider whether producers can make use of it (in case of positive effects) or react and prepare for shortages (in case of negative effects). Feed planning, sourcing and supply chains play a critical role in this. Farmland infrastructure can help to overcome

adverse weather and soil conditions, and improve the use efficiency of available forage (see case studies for examples).

During the workshop presentations, participants were asked to describe typical feed sourcing practices of their producers (see **Figure 6a**). The multiple answer poll indicates that the majority grow a substantial part of their feed on their own lands (principally pasture). Additional feed resources from outside the farm, however, play a crucial role, too. Their share in the feed ratio differs across countries: twelve countries reported to source only concentrates for supplementation, whereas a similar number of countries reported to source more than 25% of the feed ratio from outside. Only two countries (Czechia and Kazakhstan) described their local forage markets as non-existent or weak – uncovering a challenge for producers in case of unpredicted feed shortages. In Uruguay, Tunisia, Paraguay and Australia, livestock producers cooperate with or contract feed producers to secure sufficient feed supply.

Figure 6a: Feed sourcing practices by countries (in number of workshop respondents)



Source: own graph based on instant query during the workshop sessions held at the *agri benchmark* BSC 2020, Poll 2: "How do most producers obtain feed supply in your country?". Multiple answers.

Animal categories

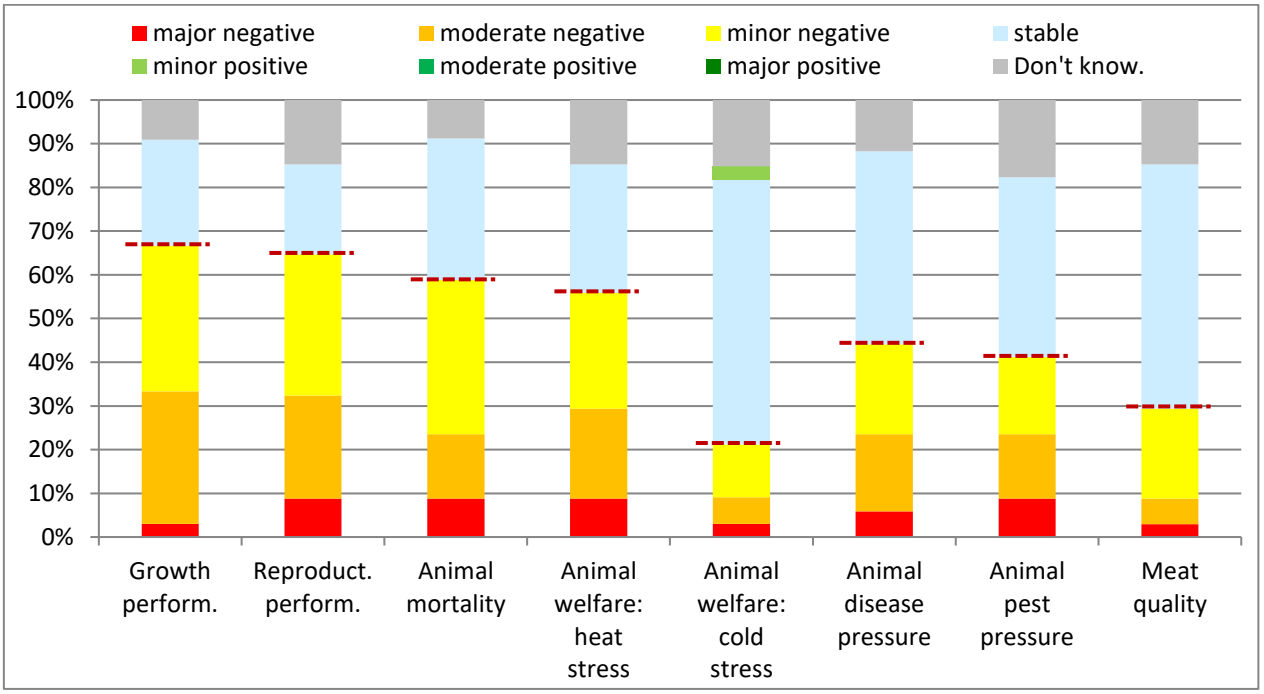
Via the forage availability, but also through direct weather and environmental effects, animals experience climate change. To get an overview of the impacts of climate change on animal productivity and livestock directly, participants were asked to give their assessment on eight factors related to animal well-being and performance: "growth performance", "reproduction performance", "animal mortality", "animal welfare: heat stress", "animal welfare: cold stress", "animal disease pressures", "animal pest pressure" and "meat quality".

The reported impacts of climate change were high on overall animal productivity, with two thirds of countries having negative impacts on overall animal growth performance and reproductive performance (**Figure 7**) – the latter might indicate decreasing appropriateness of breeds to environmental conditions. Over

50% of respondents reported negative impacts on animal mortalities and heat stress – unsurprisingly not cold stress.

However, the impacts on animals were less severe than on the feed categories. While in most countries animals are somewhat affected directly, many more reporting a stable impact of climate change and the magnitude of negative effects on animals is less compared to the feed in general, with most being minor. Also, there is only one mention of positive impacts of climate change, unlike in the feed.

Figure 7: Evaluation of the impact of climate change on animal production (in percent of survey respondents)



Source: own graph based on responses to pre-conference online survey; Q4b: "If yes, in what way is it impacting livestock producers?". N=33, excluding "no reply".

A minority of countries reported negative impacts on animal disease, pests and meat quality. The much smaller numbers reporting a negative meat quality impact (relative to growth, reproduction and heat stress) is probably explained by the high prices of beef and sheep meat, as it is worth keeping animals on longer and/or buying feed to obtain acceptable meat quality rather than turning off unfinished cattle or sheep for slaughter.

At the country level (see **Table 2** for the details), the majorly negative impacts of climate change on livestock are restricted to a handful of countries only: Nigeria, Zambia, Namibia, Jordan and Iran. However, some more report moderate negative effects on the key factors of animal mortality, growth and /or reproduction performance. For producers in Colombia, Algeria, Uruguay, Portugal, Paraguay, Spain and Tunisia, it might be important to find appropriate solutions to these challenges – whether it is about production system changes, breeds or technical solutions improving animal wellbeing.

Only France, the UK and Austria report no negative impacts across all animal categories. Finland reports even a positive effect: Global warming leads to less harsh winters, alleviating cold stress for animals in Finland.

Table 2: Detailed evaluation of animal categories under climate change (colour scheme as per **Figure 7**)

Countries	Growth performance	Reproduction performance	Animal mortality	Animal welfare: heat stress	Animal welfare: cold stress	Animal disease pressure	Animal pest pressure	Meat quality
PY								
AR								
CO								
PE								
BR								
MX								
UY								
US								
CA								
FI								
AT								
ES								
PT								
CH								
PL								
IT								
UK								
FR								
DE								
IE								
TN								
DZ								
NG								
ZM								
ZA								
NA								
JO								
IR								
KZ								
AU								

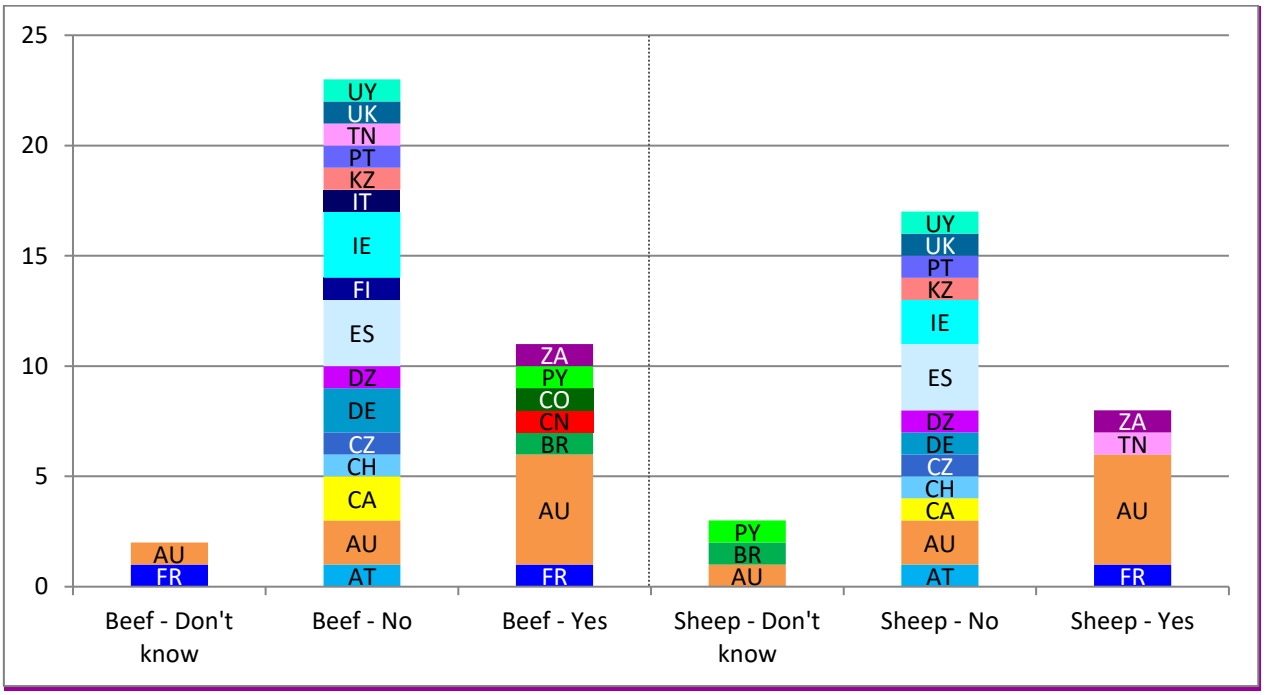
Source: own graph based on responses to pre-conference online survey; Q4b: "If yes, in what way is it impacting livestock producers?". Colombia, Canada, Ireland and Iran with double answers. Countries ordered by regional aspects.

In combination with the feed categories' analysis, the picture of climate change impacts so far is very diverse. Wherever the feed basis is substantially challenged, animal productivity does not seem to suffer

equally. This led us to integrate another poll in the workshop sessions, asking participants to assess the observable ultimate effect of climate change on beef and sheep production. Separated into two different polls, participants responded to the question "Can you observe in your country a reduction in beef/sheep production due to changing environmental production conditions?" according to their field of expertise and knowledge (**Figure 7a**).

Only a few countries reported a decrease in beef and sheep production due to climate change effects. However, among those are major global producers, such as Brazil (beef), China (beef), South Africa (beef and sheep) and Australia (beef and sheep). Looking at it from a regional perspective, there is an accumulation observed in South American countries (except for Uruguay). Responses from Asian and African countries were inconclusive. European countries mostly denied a decrease in production due to climate change, with France being the exception with a decrease in both beef and sheep production due to deteriorating environmental production conditions.

Figure 7a: Observed decrease in beef and sheep production due to climate change (in number of workshop respondents)



Source: own graph based on instant query during the workshop sessions held at the *agri benchmark* BSC 2020, Poll 3: "Can you observe in your country a reduction in BEEF/SHEEP meat production due to changing environmental production conditions?". Single answer.

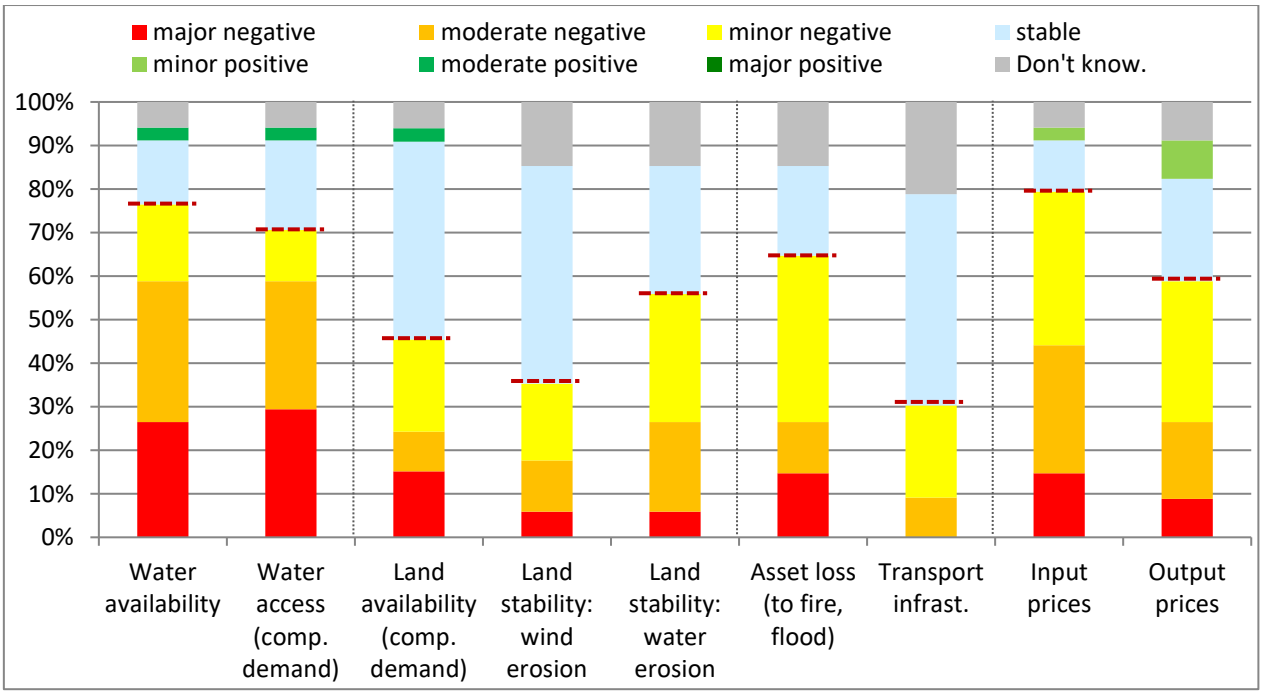
The varied responses given by the eight Australian workshop participants probably reflect the regionalism of these observations (differing climatic zones) and the fact that falling stock numbers have been more-than-offset in some regions by rising production per animal. While a reduction in animal numbers might be a logical answer to droughts and severe floods, restocking and increase in animal efficiency are common strategies after these severe events. With an increased frequency of severe events, producers are challenged to find sustainable balances in stocking rates and feed purchases, but on the other hand, might also drop out of the insecure and highly variable business.

Other factors: Water, land, infrastructure, prices

Besides feed and animal-related impacts, the more basic production factors of water and land, as well as on- and off-farm infrastructure and market factors might also be subject to impacts of changing climate. They might underlie an increased competition with a global warming induced scarcity or a risk of serious damage in case of extreme events. Further evaluation was thus requested on "water availability", "water access", "land availability", "land stability – wind erosion", "land stability – water erosion", "asset loss (to fire, flood), "transport infrastructure", and "input prices" and "output prices".

The responses are summarised in **Figure 8** and displayed per country in **Table 3**. In the following, the analysis focusses on the thematic groups of water, land and infrastructure and prices.

Figure 8: Evaluation of the impact of climate change on water, land, infrastructure and prices (in percent of survey respondents)



Source: own graph based on responses to pre-conference online survey; Q4b: "If yes, in what way is it impacting livestock producers?". N=33, excluding "no reply".

Table 3: Detailed evaluation of water, land, infrastructure and prices under climate change (colour scheme as per **Figure 8**)

Countries	Water availability	Water access (competing demand)	Land availability (competing demand)	Land stability: wind erosion	Land stability: water erosion	Asset loss (to fire, flood)	Transport infrastructure	Input prices	Output prices
PY									
AR									
CO									
PE									
BR									
MX									
UY									
US									
CA									
FI									
AT									
ES									
PT									
CH									
PL									
IT									
UK									
FR									
DE									
IE									
TN									
DZ									
NG									
ZM									
ZA									
NA									
JO									
IR									
KZ									
AU									

Source: own graph based on responses to pre-conference online survey; Q4b: "If yes, in what way is it impacting livestock producers?". Colombia, Canada, Ireland and Iran with double answers. Countries ordered by regional aspects.

Water

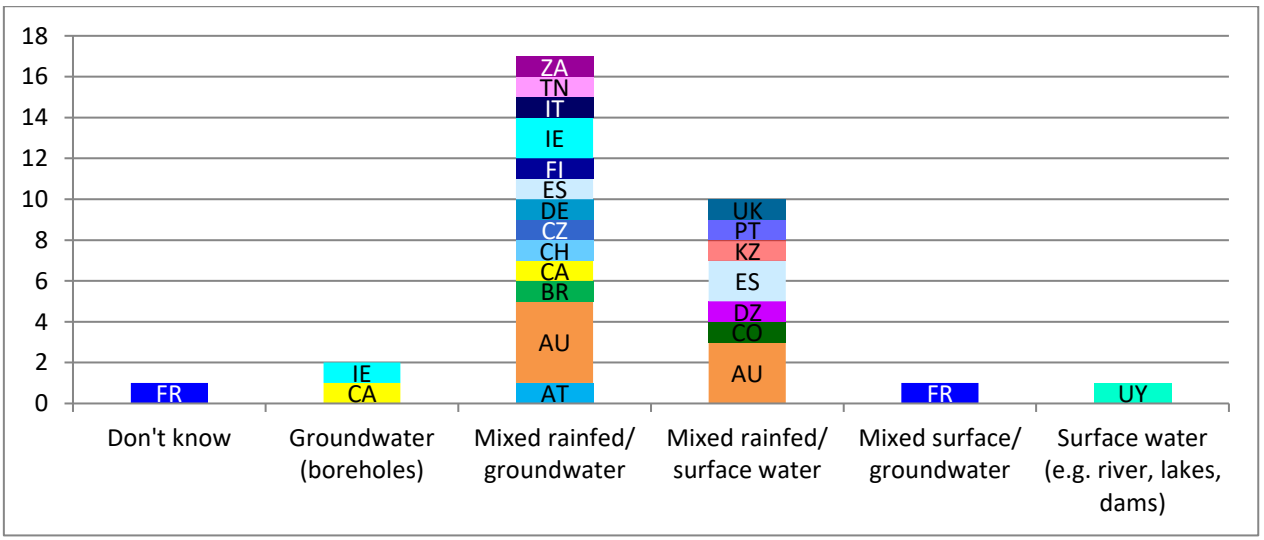
In 70-80% of countries, climate change negatively impacts water availability and access, reflecting the predominance of hotter, drier conditions in most countries (**Figure 8**). This puts water availability and access among the most severely impacted of all categories with approximately 30% reporting a major negative impact and a further 30% a moderate negative. This poses a crucial challenge, especially in countries already struggling to source sufficient water supply for their livestock.

Awareness on water availability and usage, however, does not only (need to) lift in arid regions. Production areas being water fed by melting glaciers, such as for example Switzerland, northern Italy, south western China already observe an increase in competing demand and need to come up with water use efficient solutions.

The exceptions to this are Germany, Austria, Ireland, UK, Canada and Paraguay, which reported no effect on water either way. With Finland, reporting a moderate positive impact on water consistent with the observed wetter weather, these make up the majority of higher latitude countries (Paraguay being the odd one out).

Taking up one prominent discussion when it comes to water use and livestock, our next instant poll during the workshop sessions expanded the scope to water sources used and exploited to raise livestock (and their feed). Although this might be very diverse even within a country and thus difficult to assess, participants were asked to select the water sources predominantly used for beef and sheep production, including for forage production in their respective countries.

Figure 8a: Water sources used for beef and sheep production by countries (in number of workshop respondents)



Source: own graph based on instant query during the workshop sessions held at the *agri benchmark* BSC 2020, Poll 4: "Which water sources are predominantly used for beef and sheep production – including forage – in your country?". Single answer.

Responses show (**Figure 8a**), that livestock production relies on a variety of water sources in most of the production regions. A mixture of rainfed and groundwater or rainfed and surface water predominate. Considering the renewal time of different water sources, regional water flows and expected changes to rainfall patterns, this could be a good starting point for further investigation.

Land and infrastructure

Consistent with a more variable climate and more severe weather events, several countries also reported impacts on land stability via water and/or wind erosion and asset loss to fire, flood, etc. (**Figure 8**). Compared to the frequency of severe events and increased variability mentioned in the observed climate change impact, however, the direct effects on land and farm assets seem manageable. Major negative impacts are the exception. On-farm prevention measures or insurances are supposed to help to manage the risk. In case of high frequency, extreme events or severe local accumulation of exposures (see Zambia, Tunisia, Iran) producers might need additional support in order to cope with the default risk.

Transport infrastructure, including road damages and accessibility of markets, was only impacted in a few countries and predominantly minor. Decreasing land availability considering competing demand from other land uses is observed in 45% of the countries, with major impacts in some African and Middle East countries.

Output and input prices

80% of countries reported a negative impact on input prices –reflecting the increased cost of feed, water and/or young livestock following droughts. The only countries reporting no input price effects are Argentina, Canada (partly), Austria and the UK, probably indicating sufficient supply and storage capacities and appropriate market mechanisms. Poland is the only country reporting positive effects on input prices. This can be seen in line with positive yield impacts and mostly stable animal indicators.

Considering output prices are partly dependent on animal productivity, carcass quality and meat supply, the mostly negative impact on output prices probably reflect poorer animal condition at sale and slaughter and an oversupply in drought situations. 60% of respondents reported a negative impact on output prices, but mostly minor – covering all Africa and the Middle East, but only partly Europe or the Americas (**Figure 8** and **Table 3**).

There was a minor positive effect on output prices in Australia, Finland and Poland. In the Australian case, it reflects the impact of prolonged drought in reducing the supply of cattle, sheep and lambs, but particularly lambs and a supply shortage induced output price increase.

Further impacts

Several respondents went further in looking at the consequences of climate change on beef and sheep production, some even beyond the production systems.

- **Farm infrastructure** costs: water supply and animal welfare (heat/flies) (Switzerland)
- Risk of losing harvest by **contamination** with mycotoxins (Italy)
- **Transport losses** (live weight and mortality) due to heat stress (Italy)
- **Off-farm income** or diversification/mixed enterprises maintain viability (Canada)
- Negative impact on **succession planning** and property prices (Australia)
- Reduction in **number of livestock farmers and employment** in the livestock sector (Iran)
- Negative social impact on individual's **mental health** and rural **communities' welfare** (Australia)

4 Action and perspectives: Livestock producers' strategies of adaptation

Results presented so far point to the climate changing, in particular, it is becoming hotter and drier (wetter for a few countries) and more variable with more extreme events. Also, seasons are being altered. All this is impacting livestock production in diverse ways via impacts on feed, animals, water, farm assets, markets and beyond.

The most critical part of this project is to find out if and how producers are adapting to these changes and to share successful climate change adaptation measures. This component was the hardest part of the questionnaire, but it yielded rich and consistent results.

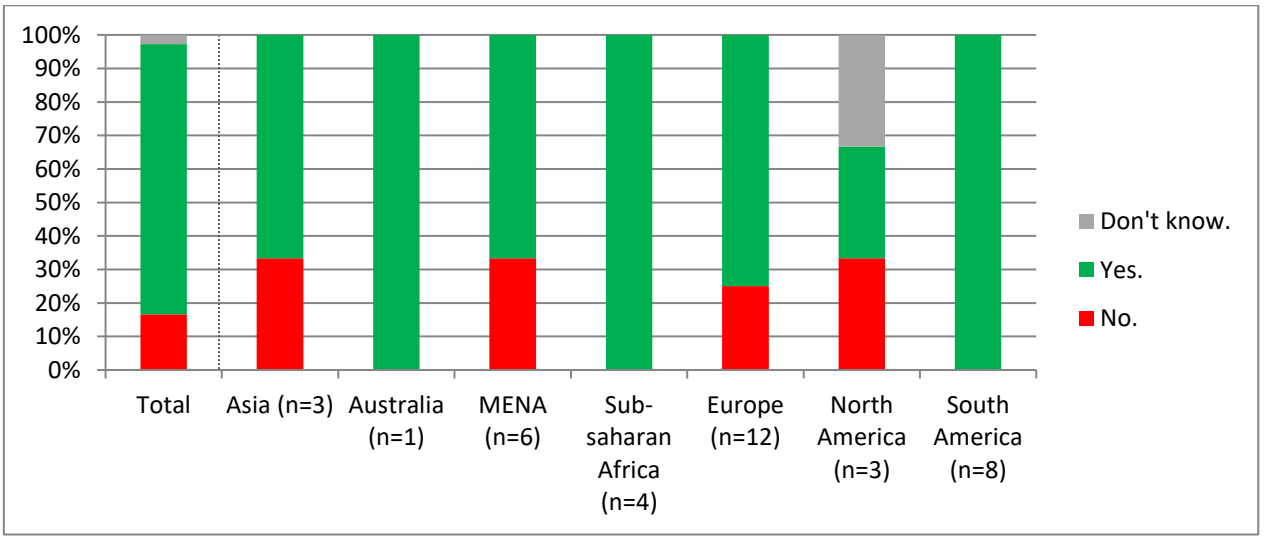
4.1 Global overview on adaptation action

We have seen so far, that all countries reported climate changes impacting livestock producers in their countries; however, the level and direction of these impacts are very diverse. Before taking action, altering the production and adapting to climate change, one would expect a certain damage threshold to be met. The level of threat or damage might be individual to producers, sectors or locations.

In our survey, 77% of countries reported that their livestock producers are altering farm management or infrastructure to adapt to the changes in climate. This included all the responding countries in the southern hemisphere – in South America, Sub-Saharan Africa and Australia – the regions most affected by climate change.

Countries, where producers are not adapting, include all the colder, higher latitude countries of Canada, Germany, Austria, Poland and Finland. The responses from Asian and Middle Eastern countries were ambiguous, probably reflecting highly diverse structures, limited capabilities to alter production systems and little access to information and resources.

Figure 9: Do producers act to cope with climate change? (in percentage of survey respondents)

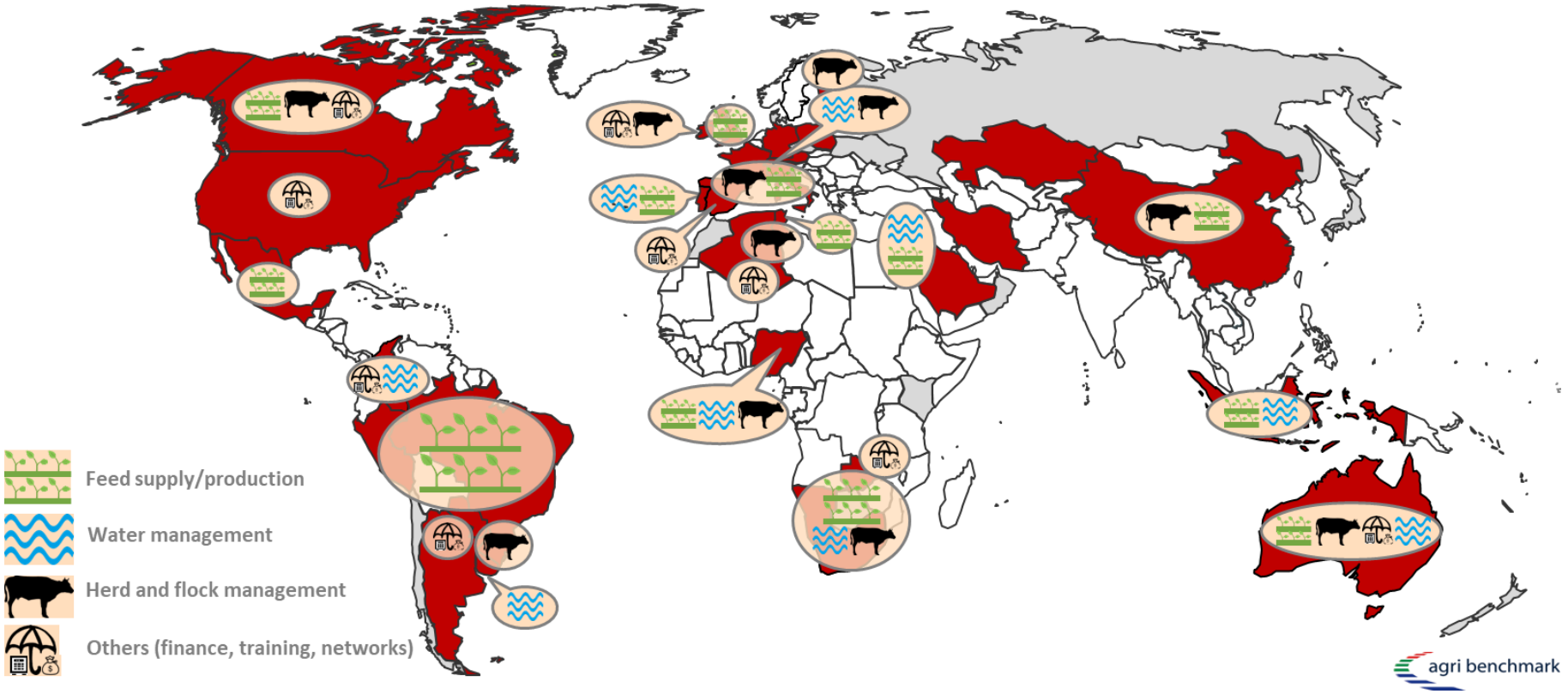


Source: own graph based on responses to pre-conference online survey; Q5: "Are livestock producers altering or starting to alter farm management or infrastructure, to adapt to the changes in climate?". Single answer.

Livestock producers are adapting in a wide variety of ways. Before embarking on some of these and applied case studies, it is worth reflecting on a number of features of adaptation that this exercise illustrated:

- Often adaptations are not planned but forced – like reducing stocking rate
- Some are simple and relatively costless – like turning animals off earlier
- Some are simple but costly – like buying in extra feed or water
- Some are complex and costly – like enterprise changes
- Some are low risk and others high risk
- Many involve a set of interrelated changes – such as stock containment paddocks, which also require changes in fencing, feed, stock management, water and/or shelter
- It was often difficult to distinguish which innovations were adapting to changes in the climate and which were simply productivity improvements
- Many farms that are adapting are doing a lot of unrelated adaptations, reflecting an openness to doing things differently
- Many farms are not consciously adapting and many profitable innovations are slow to be adopted – such as new grass varieties

Figure 10: Adaptation priorities of beef and sheep producers



Source: own graph based on responses to pre-conference online survey; Q5a: "If yes, in what way are they adapting? Referring to your typical farm, a farm you know or farms generally, please give details on how climate change adaptation is integrated into the beef production system. This might be in the area of feed, water, genetics, land or herd/flock management or a combination of those. Please describe these "typical" adaptation strategies". Open answer.

These adaptation strategies again have been clustered into four sections reflecting their focus: **feed production and supply**, **water access and use**, **herd and flock management** and **other changes** related to farm or production management. A detailed list of adaptation strategies mentioned in the survey can be found in **Annex I**.

Feed

The main adaptations were in feed and these were applicable across all continents (**Figure 10**).

The main feed changes were in pasture management, supplementary feeding, changing the pasture or fodder type or species, combining livestock and feed production systems, feed storage and altering the timing of sowing and/or harvesting of feed.

Common examples in pasture management were managing the feed gap and rotational grazing and spelling pastures (sometimes using containment paddocks or sheds). Supplementary feeding often involved grains and forage and/or hay but sometimes also agricultural waste products. In some countries, livestock farms were increasingly growing their own feed crops or fodder trees. In a number of countries, producers were changing pasture or fodder species, including Australia.

Water

Given that water availability was a major negative impact of climate change, it is not surprising to find that most countries reported adaptations to increase water access, storage and reticulation, as well as to water efficiency and quality (**Figure 10**).

Increasing water access and storage was a common adaptation in most of the drier countries of Africa, Australia, South America and the Middle East – often new dams, bores or wells, aqueducts, tanks and reticulation. In some countries of Europe (including, surprisingly, Switzerland) and Canada, it was irrigation, water quality and water use efficiency.

Herd and flock management

Almost all countries were making adaptations related directly to animals (**Figure 10**) – especially to cattle herd or sheep flock management. Surprisingly, this included many European countries which are already highly intensive and efficient.

The main animal changes were to management, to stocking rates, animal culling and marketing, changes in the timing of breeding or weaning, altering genetics and animal shelters.

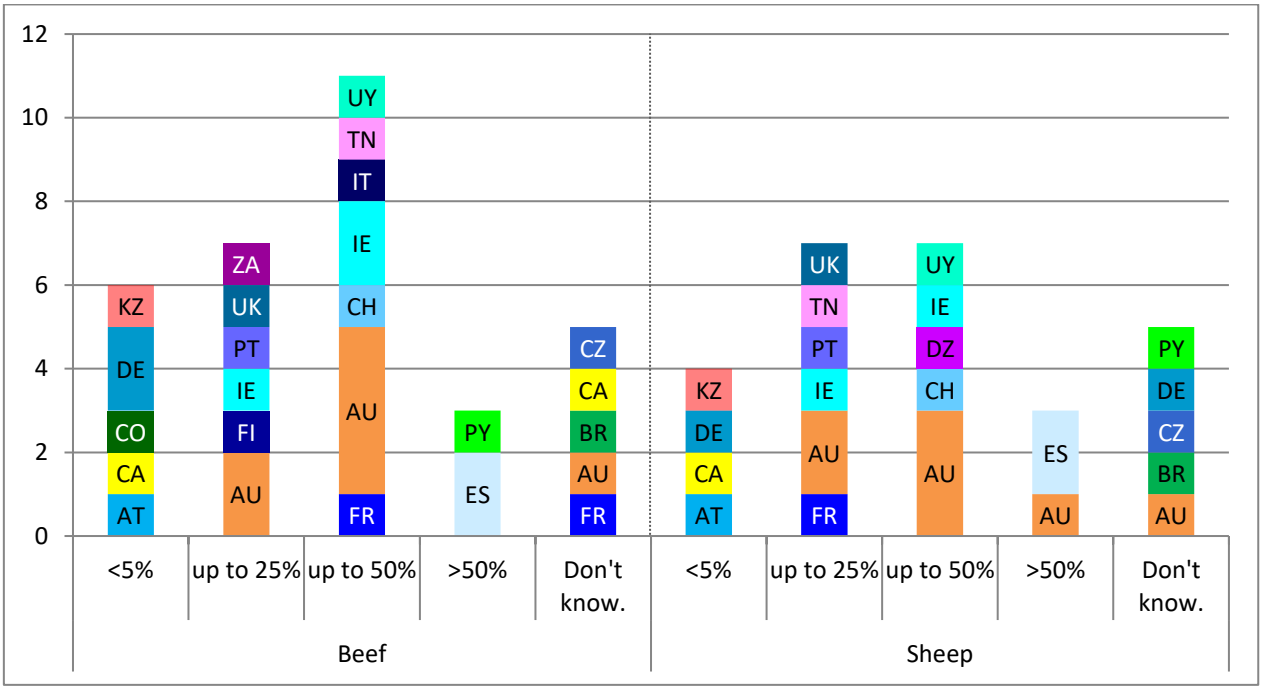
Other adaptation measures

There were other adaptations to climate change scattered across all continents that did not fit into these three previous categories. Many were changes that you would not necessarily think of and included some important ones:

- Financial management/farm planning
- Insurance
- Advice/Training/Research
- Networks
- Land-use changes (trees, crops, dairy)

Talking about adaptation implores us to consider the level of adoption. Our final poll in the workshop sessions thus requested the participants to estimate what proportion of their producers (polls separated by livestock type) have already altered their production with any kind of adaptation strategy.

Figure 11: Adoption rate among beef and sheep producers per country (in number of workshop respondents)



Source: own graph based on instant query during the workshop sessions held at the *agri benchmark* BSC 2020, Poll 5: "Which percentage of BEEF/SHEEP producers alter their production system with any kind of adaptation strategy?". Single answer.

These results are hard to interpret as the adoption rates are not necessarily matching the economic severity of climate change impacts – the expectation is that the more severe the impact, the more the adaptation. In almost all countries (even those severely impacted), less than 50% of beef and sheep producers are altering their production system with any kind of climate change adaptation strategy.

This result probably reflects the complexity of the issue – it is probably too difficult for any observer to judge what percentage of producers are innovating, let alone knowing which innovations are a reaction to the impact of climate change. The Australian result lends weight to this argument, as responses from the seven Australian workshop participants range from '5% to 25%' to 'over 50%' with one 'don't know' response as well.

On the other hand, this comparison might mask the actual causalities:

- The assessed severity of economic impacts is reduced due to a high number of adopters.
- The severity of economic impacts would push producers towards the adoption of adaptation strategies, but other barriers are preventing a higher adoption share.

With the next chapter, we intend to showcase a diverse range of best practice adaptation examples, to help overcome information gaps.

4.2 Case studies of local adaptation strategies

With a selection of specific case studies based on *agri benchmark* partners' contributions, we intend to demonstrate the wide range of technologies, tools and management strategies available and applied on beef and sheep farms. In the following, the case studies are summarised with their core features. More details are available in **Annex II**.

Cattle case studies

- Ireland: Working with the weather

Pasture land infrastructure and well-advised pasture growth and herd management increase pasture production potential and input use efficiency, improving the return from the suckler cow herd and finishers and generating financial benefits.

- Spain: Pasture improvement with rotational grazing and organic fertilization

High rotation of suckler cows benefits the pasture land condition and pasture productivity while at the same time saving feed costs through higher pasture use efficiency.

- France: Improved permanent pasture use via strip grazing and cow herd performance

The adapted feeding strategy allows to reduce crop area in favour of more climate-resilient permanent pasture: with a close observation of pasture growth and animal productivity, input use efficiency is improved and production costs, as well as greenhouse gas emissions, can be reduced.

- Italy: Heat stress reduction via ventilation

Reduced heat stress of beef finishers kept in typical northern Italian barns through the use of innovative ventilation systems benefits animal productivity, production costs, animal welfare and GHG emission intensity per kg live weight produced.

- Brazil: Integrated crop-livestock production systems

Lifted beef output by 50% and revenue by more, through the allocation of 10% of pastureland to a rotation of soybeans, tropical forage and maize (both for cash and silage).

- Paraguay: Rotational grazing and holistic pasture management

Improved breeding performance and stocking rate, especially in drought years, by selling weaners rather than steer finishing; sub-dividing paddocks to rest pastures; holistic grazing planning and protein salt supplementation.

- Australia: Matching cattle to feed

Lifted rate of return to assets from 2% to 5% on a large extensive cow-calf operation and beef output per cow by 64% via reducing the cow herd by 30%; measuring pasture; proactively managing stocking rates; rotational grazing and using only proven (EBV) bulls.

- Tunisia: Adapted feed rations and animal productivity improvement

With adapted feed rations focussing on improved ingestion and digestion, and the continuous selection for performing animals, animal productivity is enhanced and feed costs are saved.

Sheep case studies

- Spain: Transhumant sheep production on grassland

Increase in farm profitability by moving sheep between summer and winter grazing lands – profits up by 23-30% by making use of available low-cost feed resources and decoupled payments while simultaneously contributing to the maintenance of high-quality grazing lands.

- France: Lamb finishing in sheepfold and lucerne hay supplementation for ewe winter feeding

Maintaining stocking rate and finishing off lambs earlier despite shortages of pasture growth and grass production through a change in ewe winter feeding and lamb production system: feed purchase costs reduce by 20% with nutritious lucerne hay winter feeding and more efficient lamb finishing.

- Australia: Sheep containment areas

Took all ewes into a large containment area in the off season and during droughts, resting pastures, plus associated considerable investment in growing and storing silage on farm and in dams, water tanks, reticulation and water troughs. This contributed (along with a lift in seasons and prices) to an impressive jump in ewe numbers and lamb output.

5 Institutional support

Especially in a changing production environment, research, information generation and knowledge transfer play an important role for change and adoption of new technologies. Besides direct interaction with peer producers and colleagues, “close” institutions are an important source of information and support to farmers. In the survey, we, therefore, asked participants to screen and share knowledge about local programs and initiatives tackling the issues related to climate change adaptation in their countries.

5.1 Governmental and sectoral support programs

A supportive environment can be created in various ways, e.g. via advisory activities, information and knowledge transfer campaigns, cohesive infrastructure planning and implementation, investment support programs and emergency aids. Targeting livestock producers, the actors in this field range from ministerial bodies of agriculture and environment and associated institutions to producer and marketing associations.

While respondents from 25 countries (76%) answered this question with a “Yes”, on closer examination this came down to about half of all countries (18 of 33) after removing those mentioning mitigation (not adaptation) programs only or where programs were only in the formation or planning stage. Of the 18 countries with adaptation programs, 15 were Government programs and three private industry programs. A detailed list of responses can be found in **Annex III**.

Climate change adaptation is often mixed up with mitigation – three country respondents to the survey answered this question in the affirmative but were referring to greenhouse gas mitigation programs. There are surprisingly few countries with programs specifically aimed at climate change adaptation – only Colombia, Uruguay, Finland, Spain, Ireland and Nigeria have country adaptation plans – though the vast majority have climate change mitigation programs.

Climate change adaptation programs are strongest in countries where prevailing short-term economic and political interests support the existence and impact of climate change. In fact, where prevailing economic and/or political interests are opposed to climate change mitigation efforts, such as in Australia, the US and Canada, climate change adaptation efforts also appear to have suffered: Government climate change adaptation programs and research in both Australia and Canada have recently been abolished or curtailed under conservative governments (which deny the causal link between man-made greenhouse gas emissions and recent climate trends).

Much of the on-farm adaptation occurs naturally as producers respond to the impacts of a changing climate (drought, heat, floods, etc), or are assisted to do so by governmental and/or industry programs or agribusiness initiatives. Adaptation strategies can often be ad hoc and reactionary in nature and this approach can be promoted by governmental disaster relief programs, which were prevalent in responses from five countries with adaptation programs and were probably also important in other countries.

Alternatively, adaptation can be strategic and planned in advance, as in Colombia, Uruguay, Finland and Spain, all of which have country adaptation plans. Australia is an interesting illustration, as it does not have country adaptation programs and recently drought relief has largely reverted to a range of federal and state government ad hoc support payments (disaster relief). However, following this experience, Australian federal government drought policy has been replaced in 2020 with a policy based on promoting drought-preparedness.

5.2 Research on livestock adaptation

(Applied) research can also play a critical role in developing capabilities to cope with climate change or in adapting production systems to changing production environments. Similar to adaptation programs, research programs are also to be found in around half of all countries (17 of 33 countries or 52%), after those mentioning greenhouse gas mitigation only (not adaptation) and those without funding are excluded.

Of the 17 with research programs, several were found to have multiple institutions researching on the topic, with various institutional backgrounds: 15 had public institutions involved (be it university or national research institutes), seven had governmental bodies being active and in six countries private organisations worked in research. Four countries with research gave no details to allow the nature of the research to be determined.

The lines of research in many cases had been defined by national adaptation plans, building on a vulnerability assessment of agricultural production sectors. Besides, (non-governmental) public institutions and private organisations also focussed on observable producer's needs, and bottom-up research requests, whether from producers or the industry as a whole.

In Europe, international multi-stakeholder projects funded by the EU bring together research institutions and private organisations across different countries to jointly tackle common challenges. This helps to bring together various stakeholders in designing solutions and to disseminate findings across countries in different languages – probably a common barrier for knowledge and tool transfer across countries. Three such projects have been mentioned in the survey: Life+ project "Beef Carbon", Life+ project "Forage4Climate" and H2020 project "iSAGE". Additionally, the agricultural European Innovation Partnership (EIP-AGRI) has been mentioned.

Adaptation-relevant research is likely to be understated in this survey, as much of the adaptation research is normal research to improve productivity or to address the impacts of climate change without being identified as climate change research – e.g. to combat drought, heat, flood, changing seasons, pests or weeds, etc. Adaptation research projects are likely to have interlinkages with mitigation research.

Nevertheless, many programs and frameworks addressing climate change adaptation call for a sound research and data basis. Transdisciplinary and participatory approaches, integrating various stakeholders of livestock production – from producers to processors and consumers – seem to be reasonable to holistically address the disruptive potential of climate change. Still, this remains an exception among the research programs mentioned in our survey.

Anyhow, one of the biggest challenges for research remains the transfer of knowledge into the farming and producing community. This cursory research on programs offered by institutions or research might leave some projects uncovered, however, it also unveils a disparity between countries and regions in their ability to adapt. Livestock producers in highly developed countries seem to be advantageous in their access to knowledge, support programs and the ability to adapt compared to their colleagues in other countries and regions, particularly in the least developed economies, subject to economic and political instability. Often the latter are also in much more challenging situations through climate change, but having the most to gain by adaptation and innovations in production practices and systems through closing the efficiency gap.

6 Conclusions and recommendations

(1) Climate change adaptation aligns with closer observation and management of available resources (improving productivity) but is generally multifaceted

Data infrastructure on a local level increases the basis for proper decision substantially. Whether with local weather stations, reports and forecasts, individual or public precipitation records, pasture growth databases and benchmarks, or feed analysis – to manage production well in changing times, producers need to keep track of their critical production factors. Intelligent solutions have the potential to support farmers in their decision process, on when to move herds onto a new paddock, how to adjust herd size to available resources, where to irrigate or fertilize forage lands to secure yields, etc. But even analogue decision making gets more sound if the necessary data are available. Publicly available data bases and easy access of farmers to information can greatly support their capability to cope with a changing environment.

(2) Good management skills, tools and sensitivity to critical farm inputs are critical and can enable producers to sustain output in difficult situations

Professional advisory, training and farming educational programs are required to form and strengthen producer's knowledge and capabilities, especially with regard to individual farm planning and management. Many tools are available globally. A transfer of findings, knowledge and supporting tools across countries and regions is a cost-effective and fast option to spread knowledge and improve management capabilities. Best management practices and case studies can help in building confidence in new ways of production and contribute to learning processes.

(3) Improved technologies (e.g. genetics) need continuous research

Livestock production and productivity is especially challenged in marginal production sites. Well-established strategies and techniques might not be sufficient in managing the change in the production environment to maintain livestock production. New technologies are required to sustainably make use of lands with limited availability of resources. Research on grass and animal genetics though is costly and requires strong research organisations. International cooperation can help to overcome research gaps. South-south-cooperation is one way to develop adapted technologies.

(4) Several adaptation strategies seem to have a GHG mitigation effect

In the light of the dual challenge livestock, and especially ruminant, production has to meet, co-benefitting strategies addressing global warming and adaptation goals need to be supported in tandem. Furthermore, lifting the efficiency of converting feed to meat can assist producers to adapt to climate change and survive, while at the same time being an effective mean of reducing livestock greenhouse gas emissions. Taking into consideration the importance of belief in climate change for appropriate mitigation action, well-formulated adaptation strategies can also be the first step towards a responsible development even in climate-change-sceptic producer communities.

(5) Competition for the limited land and water resources increases

In semi-arid ecoclimatic and biogeographic zones of transition, such as the Sahel zone, the potential for conflict increases with ongoing climate change. Fuelled by degrading grasslands and a population-growth-motivated expansion of cropping areas, clashes among nomadic livestock producers and cropping farmers are becoming more frequent. With only a limited amount of water and land being available, this type of conflict has the potential to spread in many more regions of the world, where especially access to water is not yet regulated. Without proper planning and management of the production resources, including fair

participation of livestock and crop producers, the increased competition could lead to severe losses on both sides.

(6) Climate change specifically threatens livestock production

Various critical input factors needed for livestock and especially ruminant production underlie substantial variations due to climate change. To produce one kilogram of meat, more land, more water and more time is needed, compared to cropping activities. With an increasing variability in weather and severe events happening more often, maintaining or expanding animal production is a real challenge. In the long-term, this has the potential to reduce the attractiveness of livestock farming. Beef and sheep production, already being mainly located in marginal areas, seems to be specifically hit by continuous climate change.

(7) Livestock production is being pushed to the marginal lands.

With an extension of rural infrastructure and given the increased competition for lands, cropping activities are likely to conquer productive areas. In turn, livestock production is being pushed to more marginal areas, becoming less productive and viable. Besides worsening its situation in the light of global warming, this development also threatens the social status of many rural families globally who are relying on livestock production, and the nutritional level of rural communities. Cohesive land and resource planning and zoning might be able to mediate between diverging interests. However, forward looking production strategies should include disinvestment options in case it is more advantageous to abandon certain types of livestock production than maintaining or improving a status quo. This includes the development of income alternatives to ensure social sustainability.

(8) Is crop integration a long-term risk to livestock production or a benefit to both?

Despite the potential of growing conflicts described above, cropping and livestock activities potentially benefit each other, with livestock digesting unpalatable residues and biomass and returning fertilizer, in some regions also draught power, to cropping activities. Greater integration of both activities on a farm or cooperation between livestock and crop producers could be beneficial in terms of income risk spread, land productivity and environmental aspects (soil, biodiversity). Silvopastoral systems or forest-crop-grassland integration have proven to be a multiple-win answer to land degradation and agricultural area expansion into native vegetations. However, crop integration into a livestock production region often is the first step to pushing out livestock, e.g. see the expansion of cropping areas in Brazil, the US and Canada. Technologies such as mineral fertilizer, residue burning and advances in crop breeding contribute to the loss of importance of animals to a farming system. Considering the global challenges of human nutrition, environmental and biodiversity protection and climate mitigation, and integrating the producers' perspective on adapting to a changing climate, a well-founded balance between the different agricultural activities needs to be discussed and implemented regionally.

(9) Adaptation potential remains underutilised and restricted to advantaged efficient producers

Despite the finding that climate change is having a significant negative impact on livestock producers globally, adaptation has been only limited. Existing adaptation knowledge, technologies and recent innovations are not yet utilised by the majority of livestock producers. Adoption of climate-smart practices and innovations remains largely confined to the more efficient producers in developed countries.

(10) International institutions and multinational actors could enable a greater sharing of successful adaptations

Just as beef production systems resemble each other globally, so do adaptation strategies. In a globalized information society, it seems easier than ever to disseminate techniques, tools and knowledge across boundaries and to fit them to local needs. Hence, there is hope if international institutions, governments and industry bodies and major multinational companies in more countries make agricultural adaptation to climate change a high priority and enable much greater sharing of successful adaptations both within and between countries.

Annex I: Adaptation strategies

Table A I-1: Adaptation strategies mentioned by survey respondents have been grouped in the categories: “Feed”, “Water”, “Herd & Flock management”, “Other adaptation measures”

Adaptation category	Subcategory	Strategy	Country
Feed	Pasture/fodder type or species	Improved pastures and pasture management – rotational grazing, pasture spelling, ponded pastures, fodder trees	Australia
		Except for permanent grassland, fodder crops are diversifying: alfalfa, catch crops, less maize area	France
		Bush to feed (harvesting bushes), better adapted grasses, feeds and licks	Namibia
		Changing pasture species to match changing cycles/production needs	Australia
		Beef cattle farmers growing maize are interested to use new varieties that prevent the growth of mycotoxins. Research is directed to this purpose	Italy
		Looking for new pastures	Jordan
		Shift to feed concentrate	Indonesia
		Asking for help in designing low cost rations	Jordan
		Research in plants using less water	Namibia
		Invest in research on forage varieties with better flood/drought tolerance	Canada
	Combined livestock/ feed systems	Silvopastoral systems	Colombia
		Integrated crop-livestock systems	Brazil
		Commercial farms are currently feeding their cows with hay and silage based on the intensive management system. The system allows the farmer to manage the faecal wastes of cows which is a high emitter of methane. They typically process the faeces into manure which is applied to the feed and fodder plot. This system is gradually being introduced to smallholder farmers within close proximity to some commercial farms. A key strategy is a symbiotic relationship between crop farmers and cattle rearers. Specifically, they allow the cows to graze on harvest residues for a token while fertilizing the land in preparation for the next planting season	Nigeria
	Managing the feed gap	Producers are aware that they will need to estimate the forage production gap that they will have during the dry/not-growing season.	Paraguay
		Fodder balance (supply and demand)	Uruguay
		Forages production to overcome feed needs	Portugal
		Evaluation of local feed resources and improvement of the nutritional status of the low feed quality	Tunisia

	Feed storage	More focus on establishing a feed bank as the stored feed/forage requirement after winter is larger since the rain season starts later.	South Africa
		Feed management – utilising own grass for silage/hay	Ireland
		Fodder/grain reserves on farm/feed bins in paddocks	Australia
	Other	Better pasture and grazing management and promotion of transhumance	Spain
		The size of the herd remains the same but the utilized farm area increases, in particular, the grassland areas. The stocking rate does not change.	France
		Evaluation of local feed resources and improvement of the nutritional status of the low feed quality	Tunisia
Water	Water storage	Water reserves and water management	Uruguay
		Water collection and conservation, livestock aqueducts	Colombia
		Construction of reservoirs – as well in alpine regions!	Switzerland
		Water dams	Jordan
		Increased water storage capacity/more dams and bores/tanks/troughs and reticulation	Australia
		Water still remains a challenge for smallholder farmers as cows require a lot of water per day. We have seen coping strategies such as communal ownership of wells (which sometimes dries up in the dry season) and reliance on streams.	Nigeria
		They have used other alternative sources of water e.g. well, boreholes – other than water bodies as was the case in the past	Zambia
		Increase access to water – common for dairy but also increasingly important to pig and beef cattle	Indonesia
	Reticulation	Irrigation	Switzerland
		Irrigation infrastructures	Portugal
		Construction of drought lots and water infrastructure	Australia
	Water efficiency	Efficient use of water and energy (efficient machinery with less fuel consumption and renewable energy)	Spain
		Research in plants using less water and in cattle using less water per kg produced	Namibia
	Other	Water testing for high sulphates that reduce reproductive performance and total dissolved solids (TDS) that reduce palatability	Canada
		Much more focus on preserving groundwater sources as the lower rainfall caused the levels of the groundwater to drop.	South Africa
Herd & Flock management	Genetics	Use of native breeds and crosses better adapted to climate change	Spain
		Breeding strategies – utilising more focused strategies regarding appropriate breeds	Ireland

		Hardy animals, medium frame animals with less impact on land	Namibia
		Genetic improvement: selection of the most productive breed and maintain the most productive ones	Tunisia
		Have earlier calving: 24 or 30 months than 36 months	France
		Farmers keep high disease-resistant breeds such as local breeds (indigenous) e.g. Tonga breed, Ngoni and Barotse (Lozi)	Zambia
		Research in cattle using less water per kg produced	Namibia
		Drought tolerant breeds such as the Droughtmaster	Australia
	Stocking rate/culling/ marketing	Finishing cattle at a younger age	Ireland
		Adapted livestock sales strategies	Algeria
		Reduce the animal number and improve single animal productivity	China
		Pro-active destocking	Australia
		Reducing livestock intensity on dry stock cattle farms	Ireland
		Reducing flock size	Jordan
	Change timing	Adaptation to better production periods (e.g. insemination, weaning, etc)	Paraguay
		Change in calving or lambing periods	France
		Re-considering calving and weaning seasons/dates	South Africa
		Changing calving/lambing dates to match changing season breaks	Australia
	Herd management	Herd management	Uruguay
		Smallholder farmers usually split their herds in the dry season to allow access to distant places that still have fodder. They typically work with local cropping calendar and rain pattern-indigenous knowledge to implement this plan. In extreme cases, smallholder farmers sell a few of their cows to buy concentrates to feed the remaining herd.	Nigeria
	Shelter	Improvements in animal welfare (shading devices, ventilation improvements)	Spain
		Old stables for beef cattle, that were often closed buildings, have been opened by eliminating external walls	Italy
		In the last two decades, beef cattle farmers invested a lot in artificial ventilation systems (called "helicopters") to fight heat stress and to improve animal welfare	Italy
		Bringing animals to the stables during peak hours of heat (alpine regions)	Switzerland
	Other	Invest in research to monitor ticks entering regions previously not seen	Canada
Other adaptation measures	Financial management	Better management - finances, procuring inputs, marketing cattle early	USA

	Farm planning and financial management - more forward-focused	Ireland
	Increased reserves (feed storage capacity or cash/equity)	Australia
	Increased cash reserves including Farm Management Deposits	Australia
	Specific drought insurances	Spain
Land use changes	Changes in land use including trees in paddocks	Colombia
	Farmers prioritising their enterprise's activities between dairy and beef production to survive	Zambia
	Changing business market niche/focus or product (for example producers moving from grain into cattle)	Australia
Productivity/Costs	Invest in research for general productivity improvements	Canada
	Production efficiency by minimizing the inputs (feed, fossil fuels) and undesirable outputs (greenhouse gases, negative impacts on water quality)	Argentina
Other	Fire prevention strategies are being applied	Paraguay
	Use of forecast meteorological risk systems	Spain
	New knowledge	Colombia
	Technical training of farmers	Spain
	Increase relationship networks to access resources (land, pasture and water)	Algeria

Source: Table based on responses to pre-conference online survey; Q5a “If yes, in what way are they adapting? Referring to your typical farm, a farm you know or farms generally, please give details on how climate change adaptation is integrated into the beef production system. This might be in the area of feed, water, genetics, land or herd/flock management or a combination of those. Please describe these “typical” adaptation strategies”.

Annex II: Case studies

Case study Ireland: Working with the weather

Outdoor pasture-based cow-calf system, pasture-based beef finishing

Ger McSweeney's Cattle Farm, 38.57 ha in North County Cork, with 33 suckler cows, replacement breeding and finishing of heifers at 22-24 months, bulls <16 months

Description of the climate change impact

- *Climate change*: Unpredictable and variable weather patterns, rainfall average of 1685 mm with high variability, drought in 2018 and in parts of the country in 2020, increase in average annual air temperature
- *Impacts*: Changing weather patterns, extreme weather events, more rain in a short period, increased winter feed requirements, challenging grazing conditions in spring and autumn

Description of the adaptation

30% of annual rainfall occurs in the first 3 months of the year, with high variability. Drainage systems enable extending the grazing season. Pasture development is closely observed to improve growing, grazing and utilising more grass**.** Improved soil and pasture increase forage quality**.** Ger joined various networks to improve management of his farm.

Associated farm changes

- Weekly grass measurement, early pasture closure in autumn, early silage cutting (mid-May)
- Subdivision of paddocks and improvement of gates for safe stock movement across roads
- Controlled breeding (AI), reduction of cow size, implementation of herd health plan, incl. vaccination planning
- Reclaimed land and invested in drainage system
- Soil improvement based on soil sample analysis, clover integration, in-time manure application and use of protected urea

Benefits

- Increase pasture production and quality, better paddock accessibility, reduced feed costs, reduction of finishing age, improved breeding performance, health and daily weight gains
- More efficient use of inputs: feed supplements, organic and synthetic manure, Ger's time

Costs & Financial benefit

*Expense**	*Cost (€)*	*Financial benefit*
Improving management practices	€0	
Slaughtering heifers 1.5 weeks earlier & carcass weight 18kg heavier		Worth €89.31/head/year
Slaughtering bulls 4 weeks earlier & carcass weight 80kg heavier		Worth €377.60/head/year

Improving infrastructure	€500 (once-off capital cost)	Worth €202/year (indirect cost for time and labour)
Building soil fertility	€2000/year	Worth €1318/year & €3500/year = €4818/year
Reseeding	€670/ha	Worth €284/ha/year x 10 years = €2840/ha
Following herd health plan	€20/animal	Saving €23.49/animal in vet fees
Reclamation and drainage	€21,424	Worth €2500/year x 15 years = €37,500
		** NOTE – All of these expenses generate a return on investment in 1 to 10 years*

Source: G. McSweeney, A. Molloy Teagasc

Resource material/web links (selection)

- Overview of Ger's farm: https://www.youtube.com/watch?v=GTlUn02U2cA
- PastureBase Ireland: https://pasturebase.teagasc.ie/V2/
- Teagasc Beef: https://www.teagasc.ie/animals/beef/
- Grass 10 Program: https://www.teagasc.ie/crops/grassland/grass10/
- Heavy Soils Program Weather Data: https://www.teagasc.ie/crops/grassland/heavy-soils/weather-data/
- Met Éireann: https://www.met.ie/

Source: Ger McSweeney

Case study Spain: Pasture improvement with rotational grazing and organic fertilization

Outdoor pasture-based cow-calf system with feed supplementation, grain-fed beef finishing

Typical cattle farm in the region of Salamanca, Castilla y Leon, Spain, with 180 suckler cows on 350 ha of pasture and a 500 head grain-finishing feedlot.

Description of the climate change impact

- *Climate change*: hotter, less rainfall and more frequent and severe droughts
- *Impacts*: periodic shortages in pasture feed and water, poor quality pasture, land erosion, pasture degradation and livestock heat stress

Description of the adaptation

Cows are frequently rotated among different fenced pastures. These rotations along the year allow the fenced areas without livestock to regenerate by not having a continuous trampling of the animals. The longer the rest time per plot, the greater vegetative growth they will have.

The size for each plot and the number of animals depends mainly on the availability of good quality pasture. Plots with a large amount of food will have a greater number of animals and a greater number of days as well. Typical for the region, plot changes are usually made approximately every two weeks.

Manure available from their own feedlot is spread on the pasture to increase the organic matter contents of soils.

Associated farm changes

- Greater amount of wire fencing in order to fragment grasslands in smaller enclosures
- Increased amount of labour due to having to move animals between plots
- Purchase of a manure spreader. In some other farms, the manure spreading on the fields is externally contracted

Benefits

- Increased pasture productivity and less soil erosion. Greater retention of water in the soil through better pasture condition and higher organic matter content
- Lower costs in food purchased by having to perform less supplementation of concentrated and non-concentrated feed

Costs

- Fence cost: 6 €/m
- Manure spreader with a capacity of 6 m^3: 10.000 €
- Diesel cost: 0,6 €/m^3 of manure

Resource material/web links (selection)

Grupo Tragsa, *agri benchmark* typical farm ES 150 CYL

Pictures



Source: Grupo Tragsa

Case study France: Improved permanent pasture use via strip grazing and cow herd performance

Cow-calf and finishing production in mixed pasture and silage system

A 138 Charolaise cow-farm, finishing 78 young bulls and 16 heifers on 141 ha in western France, with 22 ha permanent grassland, 65 ha temporary grassland, 30 ha silage maize and 24 ha cash crop cereals. Two calving periods with 50% weaners born from January to March, just before the grazing season starts, and 50% born from July to September.

Description of the climate change impact

- *Climate change*: Summer drought
- *Impacts*: necessity to feed animal during pasture season (lack of fodder)

Description of the adaptation

Adapt feed supplements to animal needs: reduce concentrates from 712 kg/LU to 633 kg/LU. Allows reducing crop area for maize cultivation on the total farm. Increase permanent grassland acreage from 22 ha to 33 ha. More efficient use of pasture through strip grazing.

Cow herd management to reduce unproductive animal days. Reduction of calving interval from 394 days to 370 days.

Associated farm changes

- Introduce strip grazing to increase pasture growth use
- Implement pasture and animal observation processes

Costs

- Realize forage analyse of own produced feed: Working time spend to calculate new fed ration with less concentrates that is adapted to forage quality
- Working time spend to organize strip grazing before grazing and during grazing period

Benefits

- Reduction of beef carbon footprint: 14 CO_2 eq./kg live weight from 14.7 CO_2 eq./kg live weight via improved animal productivity and increased carbon storage: -0.4 CO_2 eq./kg live weight through reduced calving interval and -0.2 CO_2 eq./kg live weight through permanent grassland increase
- While the increase of permanent grassland area does not affect the profit, an increase in animal productivity and reduction in feed supplements make the business more profitable

Resource material/web links

Beef Carbon project (European project with Spain, Italy and Ireland; in French): http://idele.fr/reseaux-et-partenariats/life-beef-carbon.html

Pictures

POSITIVE CONTRIBUTION

My beef production stores	My beef production maintains	My beef production feeds
-3t carbon	36 éq ha biodiversity	1005 people

ACTION PLAN

	Gross Emissions	Storage	Net Emissions
Result of intial diagnosis	14,1	0,2	14
Result after action plan	13,1	0,4	12,7
Previsional variation (%)	8%	50%	10%

Source: Institute de l'élevage (Idéle), Life Beef Carbon project

Case study Italy: Heat stress reduction via ventilation

Silage-based beef finishing, partly grain-finishing feedlot

Indoor housing on straw or slatted floor in barns with 200-5,000 heads of French backgrounders (Charolais, Limousin, Salers, Aubrac) in the plain of the river Po, Northern Italy. 12-15 heads per box with central or lateral feed course, start weight 400 kg live weight to end weight 600-700 kg live weight.

Description of the climate change impact

- *Climate change*: Hotter summers and less rainfall, more frequent and hotter severe droughts, average maximum temperature in summer is 31 °C, but periods of 10 days of 40°C occur more frequently, average temperature rose by 1,5°C from 1980-1999 to 2000-2018
- *Impacts*: general decline of animal welfare and higher aggressiveness of animals, reduction of daily weight gain, higher mortality

Description of the adaptation

In order to reduce heat stress, artificial ventilation systems ("helicopters") have been introduced in the barns in many beef cattle finisher farms. Indoor temperature reduces significantly via a joint implementation of a covered open ridge in the roof.

In straw bedding systems it has an advantageous effect of producing drier bedding for the cattle: reduce lameness problems of animals. On slatted floors, the drying effect may create some problems for manure removal.

Associated farm changes

- Changes to the barn: opening of walls or covered open ridge in the roof to allow more air ventilation
- Ventilation system A: Vertigo system creates a longitudinal air stream through the entire barn. Helicopters of 2.5m in diameter
- Ventilation system B: Alternative system creates an "air-fall". Helicopter of 3 m in diameter

Costs

- System A: 110€/head for purchase of ventilation system and electrical energy consumption
- System B: 160€/head for purchase of ventilation system and electrical energy consumption

Benefits

- Average daily gain remains increases and the feed conversion rates improve
- Lower mortality rates and losses because of improved animal welfare with animals being less aggressive
- Net production of kg live weight increases, feed costs increase per day, but decrease per kg live weight
- Costs per kg live weight produced decreases (reduction in feed, medical services, bedding material, labour and other costs) despite an increase in energy costs and depreciation costs
- Carbon footprint of kg live weight produced decreases through the productivity gains offering triple win solution for farmers: fewer costs, less greenhouse gas emissions and more animal welfare

Resource material/web links

- Montanari, Claudio; De Roest, Kees (2019): Mitigation of GHG emissions and beef costs in innovative beef farms: some case studies. Presentation held for the LIFE BEEF CARBON 2nd international annual meeting in Racconigi (Piedmont), in October 2019
- Ventilation technology: https://www.cmp-impianti.com/

Pictures

Source: CRPA

Case study Brazil: Integrated crop-livestock production systems

Outdoor cow-calf system, pasture backgrounding, finishing on feedlot

Santana do Araguaia's typical farm, 4004 hectares (with 3000 ha farmable area) in South of Pará, Brazil. 1,600 Nelore cows, finishing of average own-produced 620 Nelore & Nelore/Angus crossbred bulls slaughtered, plus 300 purchased Nelore bulls slaughtered.

Description of the climate change impact

- *Climate change*: Reduced rainfall in recent years
- *Impacts*: Reduced forage availability during the dry season affects the number of culled cows

Description of the adaptation

Livestock producer allocates 1/3 of the property's farmable area to soybean production. Post-harvest, an average of 70% of the harvested area is used to sow a tropical forage (Brachiaria ruziziensis), accessible to the herd during the dry season, while the remainder is destined to corn production. That area is shared to produce maize silage (50%) and commercial grain maize (50%). 10% of the pastureland area is annually rotated to cash-crop areas, thus recovering and improving its fertility.

Any associated farm changes

- Contracting additional workers on crop areas (tractor drivers)
- Implementation of fixed-time artificial insemination protocols
- Building of a feedlot
- Additional storehouses and worker housing
- Acquisition of machinery

Costs

- ~R$85,782 (~US$16,000) in additional wages
- ~R$67.50 (~US$12.60) per cow in reproduction expenses including medications, semen and veterinarian wages
- ~R$445,000 (~US$83,000) in additional buildings
- ~R$3.2 million (~US$600,000) in additional machinery

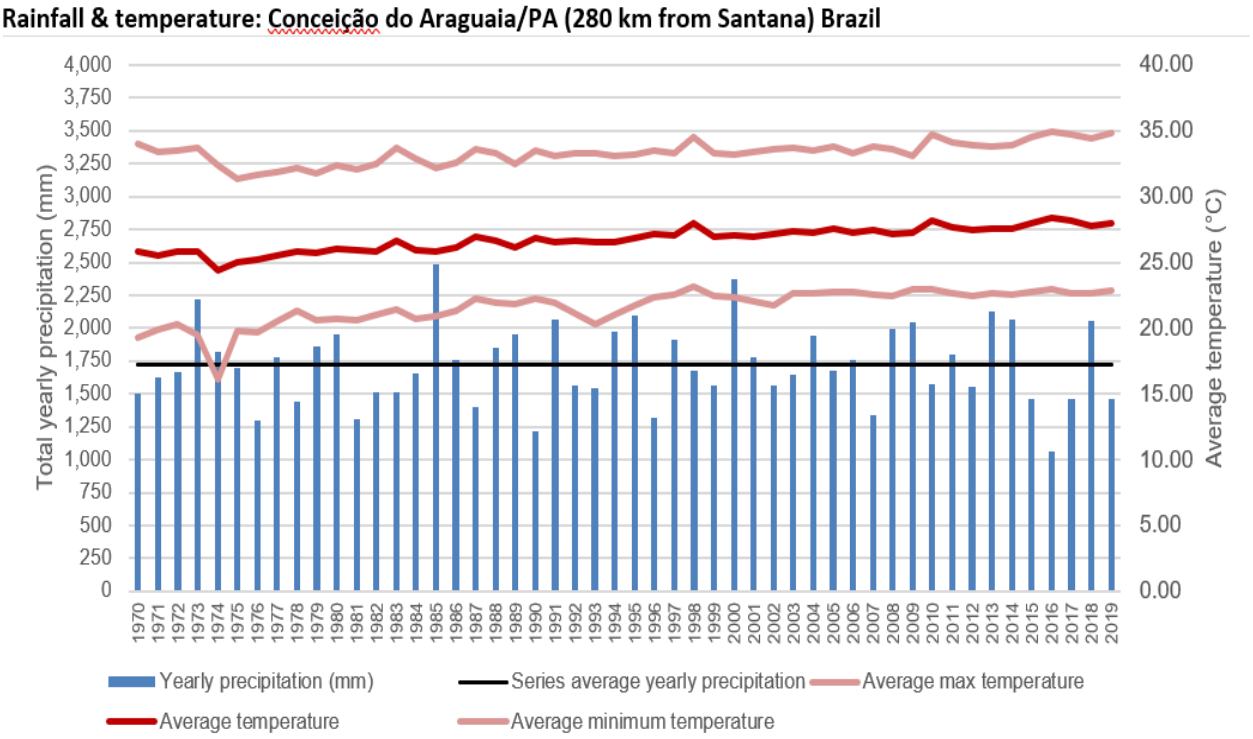
Benefits

- Improved weight gains in the backgrounding phase, due to better forage quality associated with supplementation, resulting in higher yearly weight gains: from 450 grams per day to 900 g/day
- Increased stocking rates, from 1,06 AU/ha to 1,56 AU/ha (one AU=450 kg of live weight)
- Increased birth rates (from 68% yearly to 80%) and reduced calf death rates (from 5% yearly to 2%)
- Increased meat output from 204 kg/ha to 305 kg/ha
- Diversification of produced goods reduces product price variation effects in farm income

Resource material/web links

CEPEA typical farms, Caio Monteiro

Pictures



Source: Inmet (http://www.inmet.gov.br/portal/index.php?r=bdmep/bdmep)

Case study Paraguay: Rotational grazing and holistic pasture management

Outdoor cow-calf system

1,480 cows in 2,555 hectares of improved pastures, mostly Bos Taurus x Bos Indicus (Brangus and Braford) breeds.

Description of the climate change impact

- *Climate change*: hotter, a severe drought this year, and less reliable rains
- *Impacts*: pasture degradation due to warm temperatures after rain, not enough rainfall to achieve good forage growth, lower reproductive performance

Description of the adaptation

The property is covered by *Panicum maximum* cv. Gatton Panic and the forage supply has a notorious gap during the dry season (April to September). The farm changed its enterprises from cow-calf and beef finishing production to only cow-calf, as the quality and quantity of forage was insufficient to ensure weight gain of the steers. Sub-divided grazing paddocks allow achieving the optimal rest period for grass during the growing season (November to February). Former 70 ha paddocks are now 35 ha each.

A supplementation strategy with protein salt is put in place to improve the digestibility of the dry matter. A grazing planification based on a previous forage balance has been implemented to organize the decision-making process according to the production objectives. Holistic management grazing planification method and pasture map tool are being used for this.

Associated farm changes

- Capacity building for field workers to motivate them to understand the importance of their work and ensure that activities are in accordance with the objectives. Frequent meetings to review plans and make new decisions
- Pasture subdivision and regular movement of animals between the paddocks
- Improvement in the systematization of animal production data collection during work in the corral

Costs

- Mainly additional costs in pasture improvement: electrical fences and reseeding
- Supplementation ~US$5/cow/year

Benefits

- Maintenance of the stocking rate during severe drought, above-average pregnancy rate
- Improved cash flow through better organization of trading transactions
- Reduction of production costs through better-informed decisions

Resource material/web links

- Teague, W.R.; Dowhower, S.L.; Baker, S.A.; Haile, N.; DeLaune, P.B.; Conover, D.M. (2011): Grazing management impacts on vegetation, soil biota and soil chemical, physical and hydrological properties in tall grass prairie. Agriculture, Ecosystems and Environment, 141, 310-322

Pictures





Source: M. Mongelos, WWF Paraguay

Case study Australia: Matching cattle to feed

Outdoor pasture-based cow-calf system

Large 214,000 ha cattle breeding property in far north Queensland with carrying capacity of 30,000 cattle. Herd has been strategically reduced from 25,500 to currently running 17,500 cattle. Turn off weaners at 180-200 kg live weight. Pasture consists of Mitchell grass, spear grass and blue grass. Pastures peak at 2,500-3,000 dry matter/ha after monsoon rains.

Description of the climate change impact

- *Climate change*: shorter and less reliable monsoon wet season, more severe rain events, hotter
- *Impacts*: high mortalities, sub-optimal reproduction, slow growth rate, poor cattle welfare, forced de-stocking, high cost for supplementary feed, poor financial return

Description of the adaptation

Key is handling grass inventory by regularly adjusting stocking rate and selling cattle early. Measure pasture at least three critical times per year (setting a pasture budget), adjust stocking rate a number of times a year to match pasture availability. Reduce numbers when necessary by moving cattle to finishing properties or selling cattle and turning them off, always when still in good condition.

Buying only Brahman bulls with complete & good fertility records (EBVs - Estimated Breeding Values).

Associated farm changes

Introduced rotational grazing and altered water points (bores) to 6km apart. Phased breeding in groups of 600-800 cows.

Costs

- Water distribution work A$250,000
- Fencing
- Bulls A$2,000/head extra (average A$4,500 instead of A$2,500/bull)

Benefits

- Producing 2.1 million kg beef, up from 1.9 million kg previously – 123 kg/Animal Equivalent (AE) up from 75 kg/AE
- Lowered cost of production from 152 A¢/kg live weight to 108 A¢/kg live weight, mainly in lower use of feed and supplements
- Spacing of water points 6 km apart provides a natural feed ‘buffer’ as cattle only generally graze in a 2 km radius when feed availability is good
- Mortality 3 %, down from more than 5 %
- Rate-of-return to assets of 5.1 %, up from 1.8 %
- People benefit, as staff no longer stressed trying to keep starving animals alive until the rains arrive and pastures respond

Resource material/web links

- Adult Equivalent Methodology by Bush Agribusiness: https://www.bushagri.com.au/2014/02/adult-equivalent-methodology/
- Estimated Breeding Values by Breedplan: http://agriculture.vic.gov.au/agriculture/livestock/beef/breeding/simple-performance-records-for-beef-cattle
- Phosphorus management of beef cattle in northern Australia by MLA: http://www.gascoynecatchments.com.au/assets/4-phosphorus-management.pdf

Pictures

Source: Paraway Pastoral Co., https://www.paraway.com.au/our-stations/northern-australia/armraynald/

Case study Tunisia: Adapted feed ration and animal productivity improvement

Indoor cow-calf system and feedlot finishing

Herd consists of 7 suckler cows, additionally finishing 47 young bulls (mainly purchased and own weaners). The total area of the farm is 3 hectares of improved pastures. 2 calving periods with 50% weaners born from January to March, and 50% born from July to September.

Description of the climate change impact

- *Climate change*: increasing temperature and severe drought period
- *Impacts*: loss of rough grazing areas and decrease in livestock population nationally, decrease of the land area used for cereal crops and arboriculture

Description of the adaptation

Selection of the more performing and reproductive animals with focus on health and longevity. Animal productivity is enhanced and improved partly by the feeding system.

Associated farm changes

- Improve animal diet through good hay quality and local on-farm concentrate production
- Management of animal waste and reuse as fertilizer for forage production

Costs

- Mainly additional costs in diet improvement: Supplementation ~US$8/cow/year
- Collection, storage and spreading of animal waste on pasture area

Benefits

With the enhancement of the feeding system by using local concentrate and natural extracts, improved ingestion and digestion of the ration is enabled. The reduced use of commercial concentrate decreases the production cost, which in common production systems represents almost 70% of the total cost.

- Maintenance of the stocking rate during severe drought
- Slaughter weight reached in short time
- Increase of animal production and decrease production costs

Resource material/web links

Tunisian *agri benchmark* partner, Ecole Supérieur d'Agriculture de Mograne, H. Ammar

Republic of Tunisia (2015): Intended Nationally Determined Contribution, published by the Ministry of Environment and Sustainable Development under the United Nations Framework Convention on Climate Change

Further research and information infrastructure are under development, but not applied at farm level yet: e.g. climate monitoring and early warning system, an insurance mechanism against climatic hazards, feed additive in animal husbandry.

Pictures

Source: H. Ammar

Case study Spain: Transhumant sheep production on grassland

Meat sheep grazing system with transhumance

Sheep farm located in Jaén, Andalucía, Spain with 800 ewes on 973 ha rented land: 98% with pastures and 2% for non-irrigated cereal production grown for summer supplementary feeding.

Description of the climate change impact

- *Climate change*: inefficient distribution of rainfall throughout the year for the production of pasture (no rain when needed most), more frequent and severe droughts and heavy rains
- *Impacts*: shortages in pasture feed and water, poor quality pasture, land erosion, livestock heat stress, lower reproductive performance

Description of the adaptation

Transfer the sheep from Santiago-Pontones village (mountain climate area) to the Sierra de Andújar Natural Park (highland area) in December each year for winter-spring grazing (6 months). Transfer the sheep from Sierra de Andújar Natural Park back to Santiago-Pontones in May each year for summer-autumn grazing (6 months). Farmer takes advantage of the food resources available in these areas. Without this strategy, the farmer would have to buy most of the feed.

Associated farm changes

- Changes associated with transport logistics: Additional labour, fences to contain sheep during transport, and rent of additional transport to carry the additional labour and the required handling means such as fences
- Changes related to the change of residence of the producer

Costs

- 27,300€ for land renting costs
- 5,300 € for transport and carrying of fences and additional labour force (2 weeks)

Benefits

From adopting transhumance as a strategy, the farm increases its profits by 23-30%. Major factors contributing to this are a higher amount of decoupled payments (up by 27%), and a reduction in feed costs (by 31%) which outweigh the increase in land cease costs.

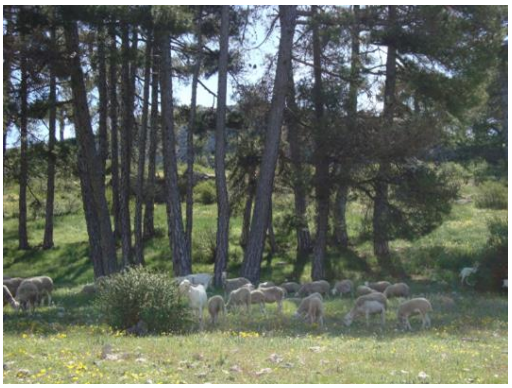
- Sheep have access to better quality pasture
- Quality and quantity of pastures are improved via seed dispersal, nitrogen (manure deposit) and carbon fixing species such as leguminous plants
- Sheep rotation in alternate plots of land improves land and soil condition
- Maintenance of green corridors through which sheep are moved from one area to another
- Fire control

Resource material/web links (selection)

Grupo Tragsa, *agri benchmark* typical farm 900-AND

Pictures




Source: Grupo Tragsa

Case study France: Lamb finishing in sheepfold and Lucerne hay supplementation for ewe winter feeding

Sheep grazing system

Sheep farm in Creuse district, central France, breeding 700 ewes on 95 ha, with 55 ha permanent grassland and 32 ha temporary (sown) grassland and 8 ha cereals for flock feeding (triticale and barley). The farm has two lambing periods: 50 % ewes are mated in June (using melatonin) for December lambing and Easter sales (indoor lambs), 50 % mated in October for March lambing, with lambs raised on grass. Only 80 % of replacement ewe lambs are mated the first year for April lambing.

Description of the climate change impact

- *Climate change*: hotter, drier, with more frequent droughts, less reliable rains, changed seasons
- *Impacts*: shortage in grass production, slower lamb finishing, lower autumn prolificacy rate

Description of the adaptation

Lucerne hay is bought for winter feeding of lactating ewes to reduce concentrate supplementation. Stocking rate can be maintained although grass productivity decreases in spring. March lambs are brought back into the sheepfold at weaning and finished on concentrate and hay. No more attempt to finish them on grass, as grass growth in spring has reduced and is insufficient for good weight gains.

Associated farm changes

Purchase of Lucerne hay (15 tons).

Costs

- Concentrate consumption: + 35 kg/ewe (almost the same quantity for spring lambs and autumn lambs: 65 kg/lamb)
- Lucerne hay purchase: 2550 €

Benefits

- Feed purchase costs reduce by 20% mainly through less concentrate consumption by ewes and lambs, which more than outweigh the superior costs for lucerne hay compared to grass hay fed previously.
- Spring lambs are sold earlier, with less sanitary risks (parasites)
- Winter feeding with Lucerne hay is more nutritious than grass hay, and cost saving compared to alternative feeding with hay and concentrates

Resource material/web links

- Adaptation project website (fr): https://www.sidam-massifcentral.fr/developpement/ap3c/
- Adaptation workshop presentation (fr): https://www.sidam-massifcentral.fr/wp-content/uploads/2019/12/AP3C-Diaporama-Atelier-colloque-OV.pdf

Pictures

Source: Danielle Sennepin, Chamber of Agriculture Creuse

Case study Australia: Sheep containment areas

Sheep breeding and lamb finishing on grass

Self-replacing Coopworth composite 9,000 ewe flock on a 1,500 ha property in western Victoria, Australia. Weaners are finished to 50 kg live weight and sold on the domestic market.

Description of the climate change impact

- *Climate change*: Becoming progressively drier and hotter, with more frequent and severe droughts
- *Impacts*: Seasonal feed and water shortages, causing extra cost in purchasing supplementary feeds and providing water, and the forced culling of sheep and lambs

Description of the adaptation

Since 2015, the producer has moved to feed all ewes in containment areas in the offseason. Ewes in containment are fed silage three days a week, grain for two days and straw to supplement.

Associated farm changes

Water supply: 20 megalitre (ML) and 10 ML dams, electric pressure pump, two 100,000 litre tanks, gravity fed to all troughs. Associated 8 km of 50 mm poly pipe, 30-40 water troughs and large capacity solar pump. Split property into smaller (15 ha) paddocks around small dams and troughs.

Storage and use of 1,500 tonnes of silage. Feed budgets using a spreadsheet and the 'Lifetime Ewe Management' tables. Planted 150 ha of summer crops to finish lambs and provide green feed for joining ewe lambs.

Costs

- A$70,000 in tanks, pipes, feed troughs and pumps. Extra fencing and one additional fulltime farmhand (as flock larger and more intensive management)

Benefits

It is impossible to estimate what proportion of the impressive improvement in productivity and profitability on this farm has been due to climate change-related innovations alone, as they have coincided with a considerable lift in seasonal conditions and lamb prices since 2015. The producer estimates that 70% of the gain is probably from the better prices and seasons and 30% due to the innovations. However, without the innovations, he would not have been able to capitalise on the better season and prices.

The outcomes have been:

- Minimised drought damage to land and pasture and helped maintain all stock in good condition
- Helps to grow between 1,000 and 2,000 tonnes of dry matter pasture in surrounding paddocks at the break of the season – before ewes are let out of containment
- Paddocks are never out of water, as no longer reliant on small dams
- Better joining – lambs per ewe (scanned) up from 150 % in 2016 (before the changes) to 175 % in 2019
- Built up sheep numbers from 4,000 in 2015 to 9,000 in 2020

- Lamb numbers increased from 6,500 in 2016/17 to 8,500 in 2019/20
- Lamb income increased 67% from A$840,000 in 2016/17 to A$1.4 million in 2019/20
- Able to buy ewes and lambs when other producers cannot (due to drought) and prices are down and have stock to sell when the drought ends, and prices are high

Resource material/web links

- http://agriculture.vic.gov.au/agriculture/farm-management/drought/managing-resources-in-drought
- http://agriculture.vic.gov.au/agriculture/farm-management/soil-and-water/water/case-studies/water-and-feed-plans-pay-dividends
- https://www.mla.com.au/extension-training-and-tools/tools-calculators/

Pictures

Source: Agriculture Victoria case study (2017) updated by personal communication with producer.

Annex III: Programs to support adaptation to climate change

Table A II-1: Governmental and sectoral support programs and frameworks

Country	**Program in place?**	**Specification of programs** (e.g. in terms of financial volume, and/or reach) and web links if available
Paraguay	No.	
Argentina	Yes.	The Argentine Beef Promotion Institute (IPCVA) is a public non-governmental institution following the passage of the National Statute Nº25.507 by agreement of all the beef chain representatives. Committed to increase beef chain competitiveness by providing sectorial expertise and information for decision-making process, contributing to the creation of improved business environments in domestic and foreign markets.
Colombia	Yes.	Sectorial Action Plan for Adaptation https://www.minambiente.gov.co/images/cambioclimatico/pdf/planes_sectoriales_de_mitigaci%C3%B3n/PAS_Agropecuario_-_Final.pdf Ministry of Environment with restoration programs for areas in Colombia Ministry of Agriculture with policies towards sustainable livestock Credit via FINAGRO with adequate fees and credit lines for sustainable livestock production
Peru	No.	
Brazil	Yes.	National Plan for Low Carbon Emission in Agriculture (ABC Plan) http://redd.mma.gov.br/en/legal-and-public-policy-framework/national-plan-for-low-carbon-emission-in-agriculture-abc-plan
Mexico	Yes.	Natural resources management, Erosion control, Cross breed https://www.gob.mx/inifap http://fz.uach.mx/investigacion/2011/12/06/lineas_de_investigacion/
Uruguay	Yes.	National Plan for Adaptation to Variability and Climate Change for the Agricultural Sector (PNA-Agro) https://www.uy.undp.org/content/uruguay/es/home/library/environment_energy/PNA-Agro_Uruguay.html Livestock and Climate Program https://www.gub.uy/ministerio-ganaderia-agricultura-pesca/comunicacion/publicaciones/folleto-informativoproyecto-ganaderia-clima
USA	Yes.	Resources are available when natural disaster strikes as a result of fire, drought, flood. Typically not advertised as climate change programs.
Canada	unclear	Adaption work and support is in hold across the agri-environmental stewardship portfolio.
Finland	Yes.	National Climate Change Adaptation Plan 2022 and Adaptation and Climate Change Act Ministry of Agriculture and Forestry: https://mmm.fi/en/nature-and-climate/climate-change-adaptation Joint website of Finland's environmental administration: https://www.ymparisto.fi/en-US/Climate_and_air Some new climate action programs are under construction (land use, carbon emission reduction, etc.)
Austria	No.	

Spain	Yes.	Several actions carried out by the Spanish National Government, coordinated through the Spanish Office for Climate Change (OECC), to achieve adaptation and implement mitigation measures to cope with climate change: Spanish National Climate Change Adaptation Plan (PNACC): reference framework to achieve integration of climate change adaptation based on the best available knowledge into all sectoral and natural resource management policies. Includes regional climate scenarios, develop and apply methods & tools to evaluate impacts, vulnerability and adaptation for all relevant socioeconomic sectors and ecological systems, incorporate in Spanish R&D&I system the most relevant needs for climate change impact assessment, continuous information and communication about the projects, participation of all stakeholders to mainstream adaptation to sector policies, prepare periodic follow-up and specific reports on the results of the evaluations and projects. https://www.miteco.gob.es/es/cambio-climatico/temas/impactos-vulnerabilidad-y-adaptacion/ Strategic Framework for Energy and Climate, incl. the National integrated Energy and Climate Plan (PNIEC) 2021-2030 which, together with the Draft Law on Climate Change and Energy Transition and the Just Transition Strategy, are the three pillars for responding to the Paris Agreement of 2015 and the United Nations Agenda 2030 for Sustainable Development.
Portugal	Yes.	Portuguese Investment Program 2014-2020 with some specific lines targeted to the adaptation to climate change.
Switzerland	Don't know.	
Poland	No.	
Italy	Yes.	Regional Rural Development Programs (EU CAP, 2nd pillar): special dedicated measures in the period 2014-2020 for subsidies on farmers' investments on adaptation and mitigation. Most of the funds directed to investments able to mitigate climate change and less to support adaptation strategies. Funds in the same programs are dedicated to financial support of investments in water-saving irrigation equipment.
United Kingdom	Yes.	ELMS (Environmental Land Management Scheme) in England: government policy to pay public good delivered by farmers (including planting trees, outcome measured environmental benefits, flooding management) Environmental policies from retailers: carbon audits of dedicated supply chain producers – led to on-farm changes, usually improving efficiency and a positive financial impact
France	Yes.	2nd pillar of the CAP: subsidies from some French regions to build forage storage sheds and plant hedges
Germany	Yes.	One-time relief paid during drought summer 2018 for those farms who declared (and later proved) existential need for support (national program), additional subsidy program for forage purchase in Bavaria. We cannot conclude that it will happen again in the future. Hilfsprogramm Existenzgefährdung Dürre 2018 (Federal state program), Bayerisches Hilfsprogramm Grundfutterzukauf Dürre 2018 (Bavarian relief program): https://www.stmelf.bayern.de/agrarpolitik/foerderung/200252/index.php
Ireland	Yes.	Financial support packages – flood relief for farmers in affected areas, sourcing appropriate feed elsewhere (e.g. France) during periods of excess demand (poor silage quality/prolonged winter periods)

		Beef Data Genomics Program (BDGP) - to improve genetic merits improve quality and efficiency of the national beef herd, and lower GHG intensity, costs approximately €45 million per year with almost 23,000 producers enrolled https://assets.gov.ie/25649/4092b0f1c806495485644360f489c63c.pdf
Tunisia	No.	
Algeria	Yes.	Only during times of crisis. For example livestock feed supply, access to pastoral plantations
Nigeria	Yes.	National Adaptation Strategy and Plan of Action on Climate Change for Nigeria (NASPA-CNN) and National Adaptation Plan (NAP): http://napglobalnetwork.org/wp-content/uploads/2020/06/napgn-en-2020-Nigeria-National-Adaptation-Plan-Framework.pdf supported by https://www.adaptation-undp.org/explore/western-africa/nigeria and https://climate-change.canada.ca/finance/country-pays.aspx?id=22
Zambia	Yes.	Extension services providing farmers with information on production and disease prevention and control, encouraging diversity in the farming activities on farms, promoting use of new technologies to mitigate climate change e.g. improved housing for livestock
South Africa	Yes.	Mostly private producer organisation and some government drought support
Namibia	Yes.	Schemes to offtake animals in drought years to protect land and to restock if rains are sufficient; focus on food security
Jordan	No.	
Saudi Arabia	Don't know.	
Iran	Yes.	Provide guidelines for the optimal use of waste Support the development of drought-resistant rangeland plants and introduction of new sources of low water forage Promoting the introduction of optimal animal breeding patterns
Kazakhstan	Yes.	Sustainable Livestock Development Program (World Bank, Government Livestock Strategy): measures and activities for sustainable development of the livestock sector, including training on good agriculture practices, change of government support policy for adoption of environmentally friendly technologies and practices, establishment of monitoring, reporting and validation system of GHG emission from livestock sector. Program is in preparation stage and planned to start in 2021. https://projects.worldbank.org/en/projects-operations/project-detail/P170365
China	Don't know.	
Indonesia	No.	
Australia	Yes.	Australian Government's Future Drought Fund: From 1 July 2020, A$100 million/year to help farmers and communities prepare for, and become more resilient to, the effects of inevitable future drought https://www.agriculture.gov.au/ag-farm-food/drought/future-drought-fund Queensland Climate Adaptation Strategy (Q-CAS): initiative of the Queensland Department of Agriculture and Fisheries that via the Drought and Climate Adaptation Program (DCAP) improves the capacity of farmers and regional communities to become more resilient to the impacts of climate variability and drought. A$175 million in funding committed by Queensland Government for the program to 2021 to improve capacities to manage variability and extremes and to adapt to changing climate. https://www.qld.gov.au/__data/assets/pdf_file/0017/67301/qld-climate-adaptation-strategy.pdf Understanding options for offsetting carbon (methane) emissions such as vegetative

	solutions and importantly the poorly understood and difficult to measure soil carbon. Considering options to mitigate methane emissions via food additives, life cycle management, etc., e.g. Australian Beef Sustainability Framework (RMAC, MLA): Managing climate change risk, while reducing GHG emissions are the key focus in climate change, it also addresses adaptation under climate change and economic resilience goals https://www.sustainableaustralianbeef.com.au/managing-climate-change-risk

Source: Table based on responses to pre-conference online survey; Q6 "Is your government or industry organisations undertaking or altering programs to help livestock producers adapt to climate change?"

Table A II-2: Research programs

Country	Research programs in place?	Specification of programs (e.g. in terms of financial volume, and/or reach) and web links if available
Paraguay	Yes (no details)	
Argentina	Don't know.	
Colombia	Yes (Public / governmental adaptation research plan).	Programs of the Ministry of Environment
Peru	No.	
Brazil	Don't know.	
Mexico	Yes (Public research institutions).	University of Autonoma De Chihuahua http://fz.uach.mx/investigacion/2011/12/06/lineas_de_investigacion/ National Institute of Forest, Agriculture and Livestock Research https://www.gob.mx/inifap
Uruguay	Yes (Public / governmental adaptation research plan).	National Plan for Adaptation to Variability and Climate Change for the Agricultural Sector (PNA-Agro); medium and long term strategies, 2025 and 2050 started 2019; focussing on adoption of sustainable agricultural production systems less vulnerable to variability and climate change https://www.gub.uy/ministerio-ganaderia-agricultura-pesca/politicas-y-gestion/lineas-accion-unidad-sostenibilidad-cambio-climatico Mitigation: Livestock and Climate Program (4 years program started in 2019) https://www.gub.uy/ministerio-ganaderia-agricultura-pesca/comunicacion/publicaciones/folleto-informativoproyecto-ganaderia-clima
USA	Yes (no details).	
Canada	Yes (Private (Industry) funded & led, Government withdrawn).	Beef cattle research, linked to production and environmental research topics: beefresearch.ca, crsb.ca Tough governmental fiscal policy led to grant applications and research programs having been struck down. A lot of ministerial staff, research positions, and extension staff, especially in the agri-environmental area, are the process of being laid off.
Finland	Yes (Public / governmental / private programs).	LUKE - Natural resources institute Finland : https://www.luke.fi/en/research/projects/ (search: "climate"), e.g. https://www.luke.fi/en/natural-resources/climate-change/ https://www.luke.fi/en/natural-resources/agriculture/grass-production/ https://www.luke.fi/en/natural-resources/agriculture/beef-production/

		https://www.luke.fi/en/projektit/juurihiili/ Finnish meteorological institute: https://en.ilmatieteenlaitos.fi/climate-system-research Industry research: Atria: CARBO - carbon-neutral beef production: https://www.atriatuottajat.fi/hankkeet/carbo-hiilineutraali-nautaketju/ Valio: CARBO - carbon-neutral milk production: https://www.valio.fi/vastuullisuus/kestava-maidontuotanto/ Many Finnish universities have their own research programs, e.g.: https://www.helsinki.fi/en/research/researchers-and-research-groups?field_field_of_science_tid=13021 https://www.uef.fi/en/node/3454#paragraph-1321 https://www.oulu.fi/university/research
Austria	Don't know.	
Spain	Yes (Public / governmental / private through Europe Innovation Partnership)	The European Innovation Partnership for "Agricultural Productivity and Sustainability" (EIP-Agri) aims to boost productive and sustainable agriculture through innovation, improved sharing and knowledge transfer to the agricultural sector. Its implementation is realized in the creation of task forces formed by agents (farmers, breeders, researchers, technology centres, universities, NGOs, etc...) interested in addressing a specific problem and developing practical solutions from the design and implementation of an innovative project. The Ministry of Agriculture, Fisheries and Food allocates €57 million via the National Rural Development Program to the establishment of task forces and implementation of innovative projects. Set up of more than 100 operational groups, able to carry out projects on various topics: including reduction of greenhouse gas emissions, directing livestock practices under extensive conditions of native breeds towards the protection and recovery of agroforestry systems (e.g. in the Dehesa), or proper management of pastures and carbon sequestration. InfoAdapta-Agri: One example is the InfoAdapta-Agri project, which includes practical measures for adapting to climate change in various sectors. Agricultural organizations, supported by the Ministry of Agriculture, Fisheries and Food, work to create support programs for farmers and livestock breeders to address the farm's adaptation process of climate-smart agricultural and livestock practices. https://www.upa.es/camposeguro/servicios-camposeguro/cambio-climatico/
Portugal	Yes (Public).	Research at Universities' Research Centers and National Institutes
Switzerland	Yes (Public / governmental research).	Research to account for climate effects and changes, reduce agricultural emissions and to adapt to changing climate, e.g. with climate risk modeling, projects on alpine production systems, pest and diseases and forage production https://www.agroscope.admin.ch/agroscope/de/home/aktuell/dossiers/dossier-klima.html
Poland	Don't know.	
Italy	Yes (Public / private, focus on mitigation).	e.g. EU Life+ project "Forage4Climate" (http://forage4climate.crpa.it/nqcontent.cfm?a_id=14261), coordinated by CRSA: project focused on strategies to improve the capacities of carbon sequestration in forage crops to foster mitigation strategies of farmers.

		The Life+ project "Beef Carbon" (http://idele.fr/reseaux-et-partenariats/life-beef-carbon.html), directed to beef cattle farmers in six EU countries: objective to disseminate strategies reducing GHG emissions of beef cattle farms. Coordinated by Institut d'Elevage (FR), CRPA as a subcontractor is carrying out the economic feasibility assessment of beef cattle farmers investments
United Kingdom	Yes (Public / private research).	"iSAGE - Innovation for Sustainable Sheep and Goat production in Europe" (https://www.isage.eu/) - research project under the EU H2020 program. 33 research and industry organisations from 7 countries looking at what makes the sheep and goat sectors more sustainable, competitive and resilient face-to-face to future challenges, such as climate change. The working areas are sustainability assessment, socioeconomic and consumer trends, climate change assessment and adaptation, redesign of production systems and integration of innovative strategies, managing sheep and goat (genetic resources) and multi-actor communication. The project is currently in its last period, and it is programming a series of training courses and workshops in several regions of Europe and the Mediterranean to disseminate and transfer the results obtained to the different stakeholders of the sector.
France	Yes (Public / governmental research)	Program for the Massif Central region "Adaptation of Cultural Practices to Climate Change: AP3C" (https://www.sidam-massifcentral.fr/developpement/ap3c/): to analyse the impacts on the region and possible production system adaptations in order to raise awareness of actors and stakeholders. Beef results: https://www.sidam-massifcentral.fr/wp-content/uploads/2019/12/AP3C-Diaporama-Atelier-colloque_BV.pdf. Sheep results: https://www.sidam-massifcentral.fr/wp-content/uploads/2019/12/AP3C-Diaporama-Atelier-colloque-OV.pdf EU Life+ project "Beef Carbon" (http://idele.fr/reseaux-et-partenariats/life-beef-carbon.html:), presentation video available with English translation
Germany	Don't know.	
Ireland	Yes (Public, focus on mitigation).	e.g. "AGRI-SOC: Evaluating Land-Use and Land Management Impacts on Soil organic Carbon in Irish Agricultural Systems" (https://www.agriculture.gov.ie/research/fundedprojects/agriculture/sustainablemanagementofnaturalresources/agri-socevaluatingland-useandlandmanagementimpactsonsoilorganiccarboninirishagriculturalsystems/), lead by Teagasc, investigating carbon sequestration within managed grasslands. Supported with €598,052 (co-funded by DAFM and EPA)
Tunisia	Yes (lack of funding).	Programs are planned but actually there is no finance.
Algeria	Yes (not for livestock)	Adaptation to climate change in different areas, but no program specifically for livestock. University research programs.
Nigeria	Yes (Public, university research).	University research assessing the impacts of climate change on livestock production and determinants of adoption: e.g. "Effect of climate change on health and livestock production in Nigeria" (https://www.researchgate.net/publication/316724702_EFFECT_OF_CLIMATE_CHANGE_ON_HEALTH_AND_LIVESTOCK_PRODUCTION_IN_NIGERIA_A_CALL_TO_ACTION), "Climate change adaptation among poultry farmers: evidence from Nigeria" (https://link.springer.com/article/10.1007/s10584-019-02574-8), and "Climate change impacts on cat-

		tle production: analysis of cattle herders' climate variability/change adaptation strategies in Nigeria" (https://www.degruyter.com/view/journals/cass/5/1/article-p12.xml)
Zambia	Don't know.	
South Africa	Yes (no details)	
Namibia	Don't know.	
Jordan	No.	
Saudi Arabia	Yes (Public / governmental)	Governmental programs in the Ministry of Agriculture, as well as in research and projects at universities, to achieve benefits for livestock producers
Iran	Yes (Public / governmental)	Main national strategies for climate change research for knowledge-based approach to agriculture and natural resources
Kazakhstan	Don't know.	
China	Don't know.	
Indonesia	Don't know.	
Australia	Yes (Public / Private (Industry) based, previous Government plan shelved).	MLA invests up to A$5.7 million a year in environment and sustainability R&D, to help producers improve the short and long-term environmental credentials of their business while boosting productivity; also assists producers in ensuring community expectations of responsible land stewardship and management. One of its project areas is "managing climate variability" (https://www.mla.com.au/research-and-development/Environment-sustainability/ & https://www.mla.com.au/research-and-development/Environment-sustainability/climate-change-and-variability/): this includes support tools for monitoring, triggers for action and strategy toolbox and decision making support. Federal Government's National Climate Change Adaptation Plan 2013 (https://www.nccarf.edu.au/content/narp-primary-industries): concerned with climate adaptation research priorities for agricultural, forestry and freshwater aquaculture producers and industries, associated industries and organisations, rural communities, and governments. Mitigation: Carbon Farming Futures 2012-2017 (https://www.agriculture.gov.au/ag-farm-food/climatechange/carbonfarmingfutures)

Source: Table based on responses to pre-conference online survey; Q7: “Has there been, or is there currently, research programs targeting adaptation to climate change?”

Annex IV: Contributing partners

Table A III-1: Contributing partner countries, country codes and network memberships

Country codes	Country	Beef network	Sheep network
PY	Paraguay	X	
AR	Argentina	X	
CO	Colombia	X	
PE	Peru	X	
BR	Brazil	X	X
MX	Mexico	X	
UY	Uruguay	X	X
US	United States	X	
CA	Canada	X	
FI	Finland	X	
AT	Austria	X	
ES	Spain	X	X
PT	Portugal	X	X
CH	Switzerland	X	
PL	Poland	X	
IT	Italy	X	
UK	United Kingdom	X	X
FR	France	X	X
DE	Germany	X	X
IE	Ireland	X	X
TN	Tunisia	X	X
DZ	Algeria		X
NG	Nigeria	X	
ZM	Zambia	X	
ZA	South Africa	X	X
NA	Namibia	X	
JO	Jordan		X
IR	Iran		X
KZ	Kazakhstan	X	
CN	China	X	X
ID	Indonesia	X	
AU	Australia	X	X

References

Arbuckle JG, Morton LW, Hobbs J (2015) Understanding Farmer Perspectives on Climate Change Adaptation and Mitigation: The Roles of Trust in Sources of Climate Information, Climate Change Beliefs, and Perceived Risk. Environ Behav 47(2):205–234. doi: 10.1177/0013916513503832

Davidson DJ, Rollins C, Lefsrud L, Anders S, Hamann A (2019) Just don't call it climate change: climate-skeptic farmer adoption of climate-mitigative practices. Environ. Res. Lett. 14(3). doi: 10.1088/1748-9326/aafa30

FAO-AGAL (2016) Synthesis - Livestock and the Sustainable Development Goals: Global Agenda for Sustainable Livestock

Rojas-Downing MM, Nejadhashemi AP, Harrigan T, Woznicki SA (2017) Climate change and livestock: Impacts, adaptation, and mitigation. Climate Risk Management 16:145–163. doi: 10.1016/j.crm.2017.02.001