iSAGE
Innovation for Sustainable Sheep and Goat Production in Europe

CIHEAM

iSAGE TRAINING COURSE

Innovations to improve the sustainability in the sheep and goat sector

10-13 December 2019, Zaragoza (Spain)

Impact of climate change, predictive models and strategies for adaptation on sheep and goat systems

bc3
BASQUE CENTRE FOR CLIMATE CHANGE
Klima Aldaketa Ikergai

Outline:

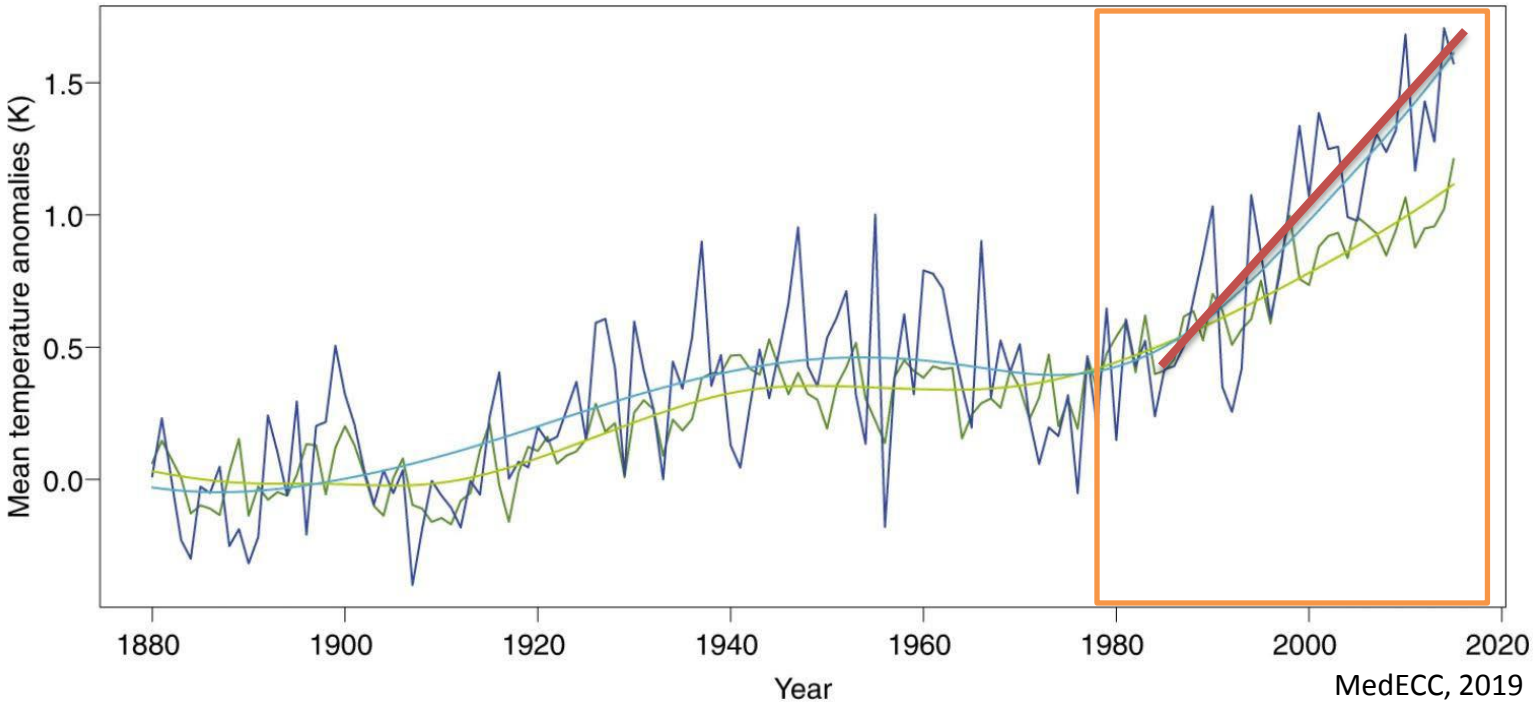
1. General overview of climate change (CC)
2. General effects of CC on sheep and goat systems
3. Regional implications and adaptation strategies
4. Development of methods/models to predict impact of climate change

Impacts of climate change in the Mediterranean region

Impacts of climate change

A. Changes in temperature: Hotter

A. In the Mediterranean region, average annual temperatures are now approximately **1.5°C higher** than during the preindustrial period (1880-1899) and well above current global warming trends (+1.1°C) (MedECC, 2019)

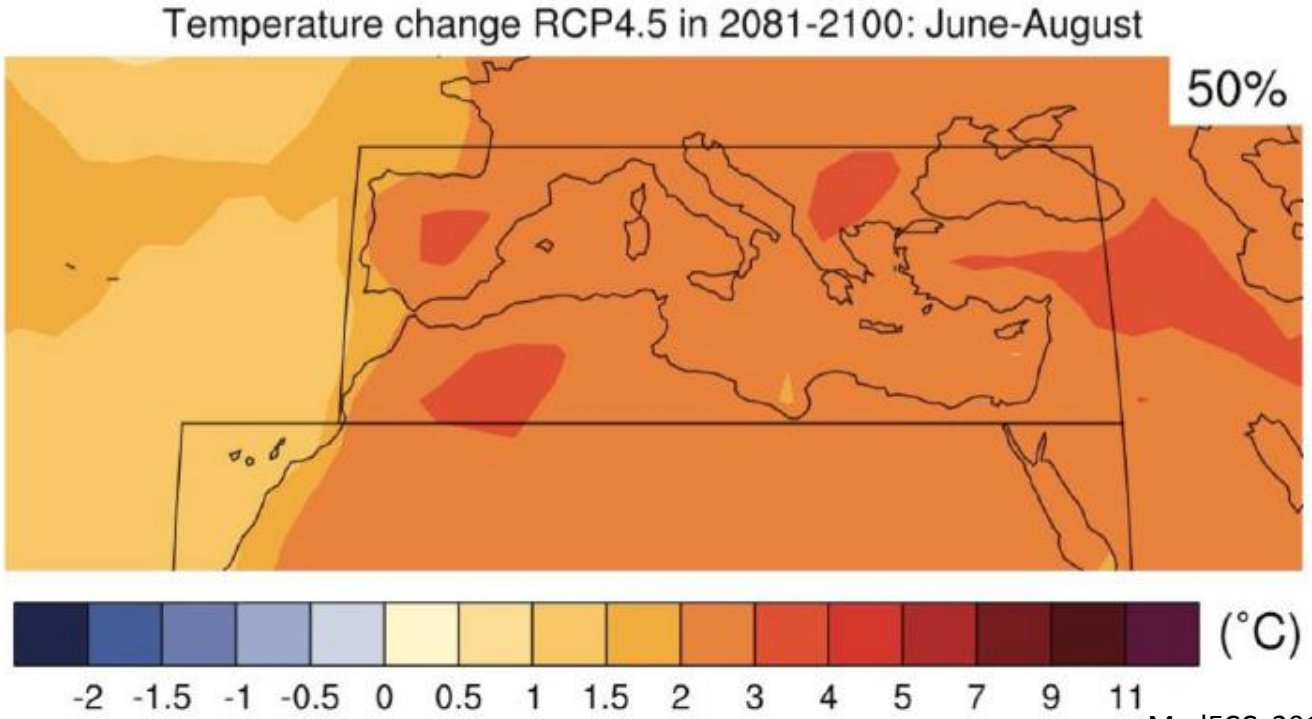


MedECC, 2019

Impacts of climate change

A. Changes in temperature: Hotter

- In the Mediterranean region, without additional mitigation regional temperature increase will be **2.2ºC in 2040** possibly exceeding 3.8ºC in some regions in 2100 (MedECC, 2019)



MedECC, 2019

Impacts of climate change

A. Changes in temperature: Heat waves

- High temperature events and heat waves (periods of excessively hot weather) are likely to become more frequent and/or extreme (MedECC, 2019)

A third of the world now faces deadly heatwaves as result of climate change

Study shows risks have climbed steadily since 1980, and the number of people in danger will grow to 48% by 2100 even if emissions are drastically reduced

▲ 'For heatwaves, our options are now between bad or terrible,' says the lead researcher behind the new study. Photograph: Gerard Julien/AFP/Getty Images

Nearly a third of the world's population is now exposed to climatic conditions that produce deadly heatwaves, as the accumulation of greenhouse gases in the atmosphere makes it "almost inevitable" that vast areas of the planet will face rising fatalities from high temperatures, new research has found.

Climate change has escalated the heatwave risk across the globe, the study states, with nearly half of the world's population set to suffer periods of deadly heat by

bladi.net Forum Marocains du monde Maroc Société Culture Economie

La vague de chaleur continue au Maroc (+43 degrés)

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20 mai 2019 - 20h30 - Maroc

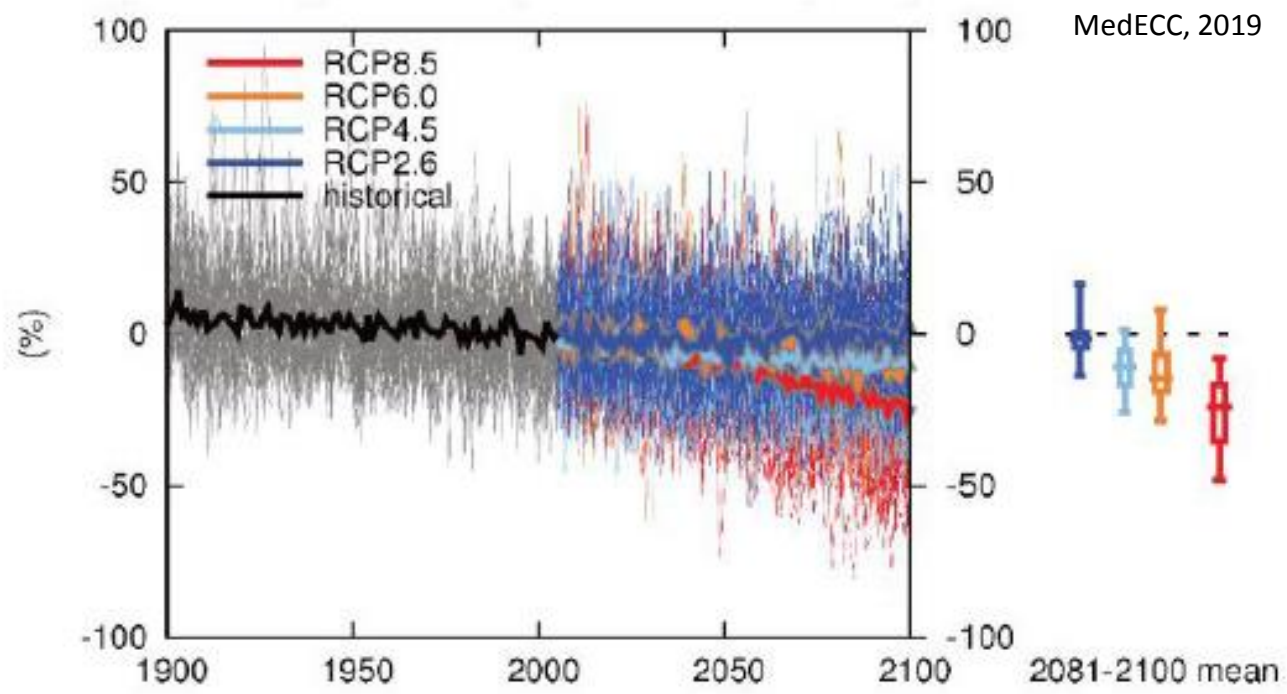
La vague de chaleur que connaît actuellement une bonne partie du Maroc va durer au moins jusqu'à dimanche, vient de prévenir la Direction de la météorologie nationale (DMN) dans un bulletin spécial.

Il est ainsi question de températures dépassant les 40 degrés de jeudi à dimanche. Ce sera le cas par exemple à Assa-Zag, Smara, Tata, Zagora, Béni Mellal, Chichaoua, Marrakech, Settat, Kelaat-Sraghna, Fquih Ben Salah, Youssoufia, Khouribga, Larache, Ouezzane, Sidi Kacem, Sidi Slimane ou encore Taroudant.

Impacts of climate change

B. Changes in rainfall patterns: Precipitation

- Climate models indicate a trend towards reduced rainfall in coming decades in the region of southern Europe/Mediterranean. For each degree of global warming, mean rainfall will likely decrease about 4% in much of the region (MedECC, 2019)



MedECC, 2019

Impacts of climate change

B. Changes in rainfall patterns: Droughts

- Frequency and intensity of droughts have already increased significantly in the Mediterranean since 1950 (MedECC, 2019)

'Day zero' water crises: Spain, Morocco, India and Iraq at risk as reservoirs shrink

A new early warning satellite system reveals countries where shrinking reservoirs could lead to the taps completely drying up

Al Massira reservoir, Morocco | Source: NASA/Landsat

The Guardian, 2017

Impacts of climate change

B. Changes in rainfall patterns: Droughts

- Frequency and intensity of droughts have already increased significantly in the Mediterranean since 1950 (MedECC, 2019)

Balada de auxilio de unas ovejas por la sequía

Un rebaño trashumante que no encuentra pastos en Extremadura pide asilo en Mad

ESTHER SÁNCHEZ

Comunidad de Madrid

El pastor Julio de la Losa, en la finca del municipio de Majadahonda donde el rebaño trashumante espera ser rescatado. CARLOS ROSILLO

La intensa sequía que padece España ha obligado al rebaño de 1.300 ovejas que

El País, 2017

DE CUENCA

La sequía complica la trashumancia en su viaje a las dehesas de invierno

- Los hermanos Cardo atraviesan estos días las cañadas reales camino del Valle de Alcudia
- La incertidumbre de no saber si las 1.600 ovejas que conducen podrán beber al menos una vez al día es su mayor preocupación

C.I.P. / Las Noticias de Cuenca

15/11/2017 - 11.56h

Google ha cerrado el anuncio

La Tribuna de Cuenca, 2017

Impacts of climate change

B. Changes in rainfall patterns: Heavy rainfall events

- Heavy rainfall events are likely to intensify by 10-20% in all seasons except for summer (MedECC, 2019)

Floods in Calabria, Italy

21 NOVEMBER, 2013 BY RICHARD DAVIES IN EUROPE

As mentioned in our update report on the floods in Sardinia, other area of Italy have also been experiencing sever weather. One of the worst hit areas has been Calabria, in particularly around Catanzaro, Crotone and Vibo Valentia.

Floods in the streets of Calabria, Italy. Photo: twitter.com/Ladymistakes1

Floodlist.com, 2019

Inondation au sud du Maroc : au moins 7 morts

Mercredi 28 Août 2019 modifié le Jeudi 29 Août 2019 - 09:59

La crue subite d'une rivière a fait au moins sept morts mercredi dans le village de Tizert, dans la région de Taroudant (sud du Maroc), a-t-on appris auprès des autorités locales.

Like Tweet

Inondation au sud du Maroc : au moins 7 morts (Photo d'illustration)

Atlasinfo.fr, 2019

Impacts of climate change

Other consequences:

- **Increased risk of fires** due to drought and heat waves but also to changes in land management (MedECC, 2019)

Europe's extreme June heat clearly linked to climate change, research shows

Heatwaves that saw deadly forest fires in Portugal and soaring temperatures in England were made up to 10 times more likely by global warming, say scientists

▲ Firefighters try to extinguish a forest wildfire in Colmeal in central Portugal on 21 June. Photograph: Francisco Leong/AFP/Getty Images

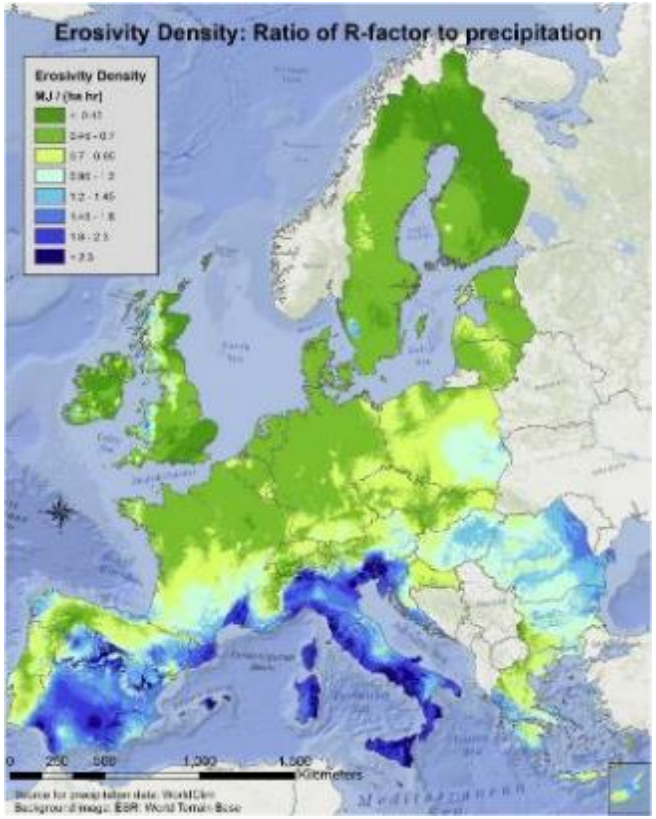
Human-caused climate change dramatically increased the likelihood of the

The guardian, 2018

Impacts of climate change

Other consequences:

- **Increased risk of fires** due to drought and heat waves but also to changes in land management (MedECC, 2019)
- Increased **risk of erosion** due to couple effect of heavy rainfall events and fires

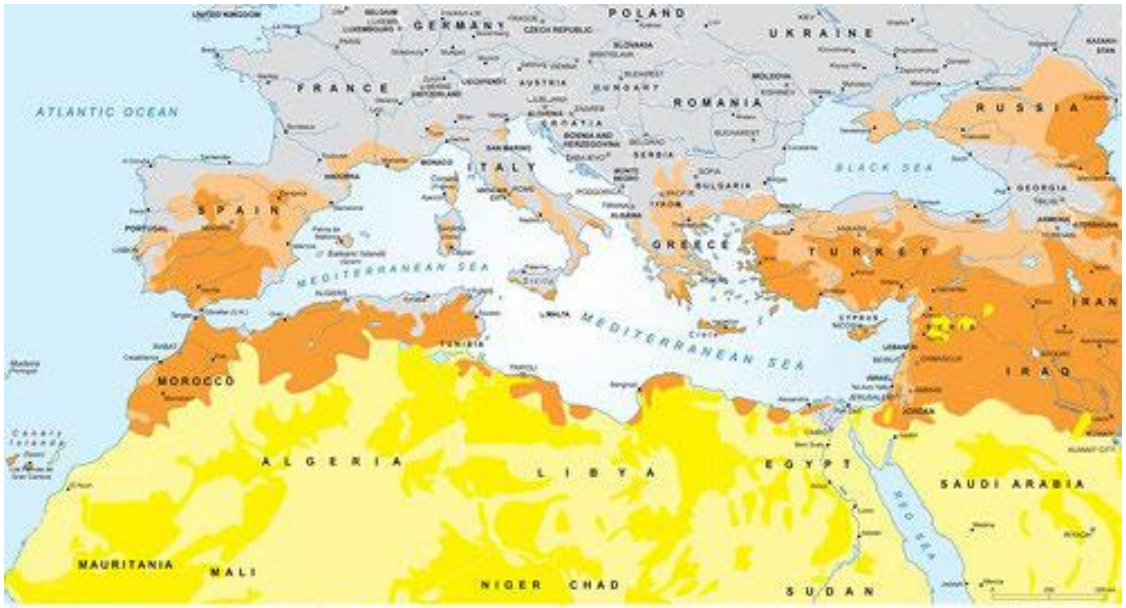


Panagos et al., 2015

Impacts of climate change

Other consequences:

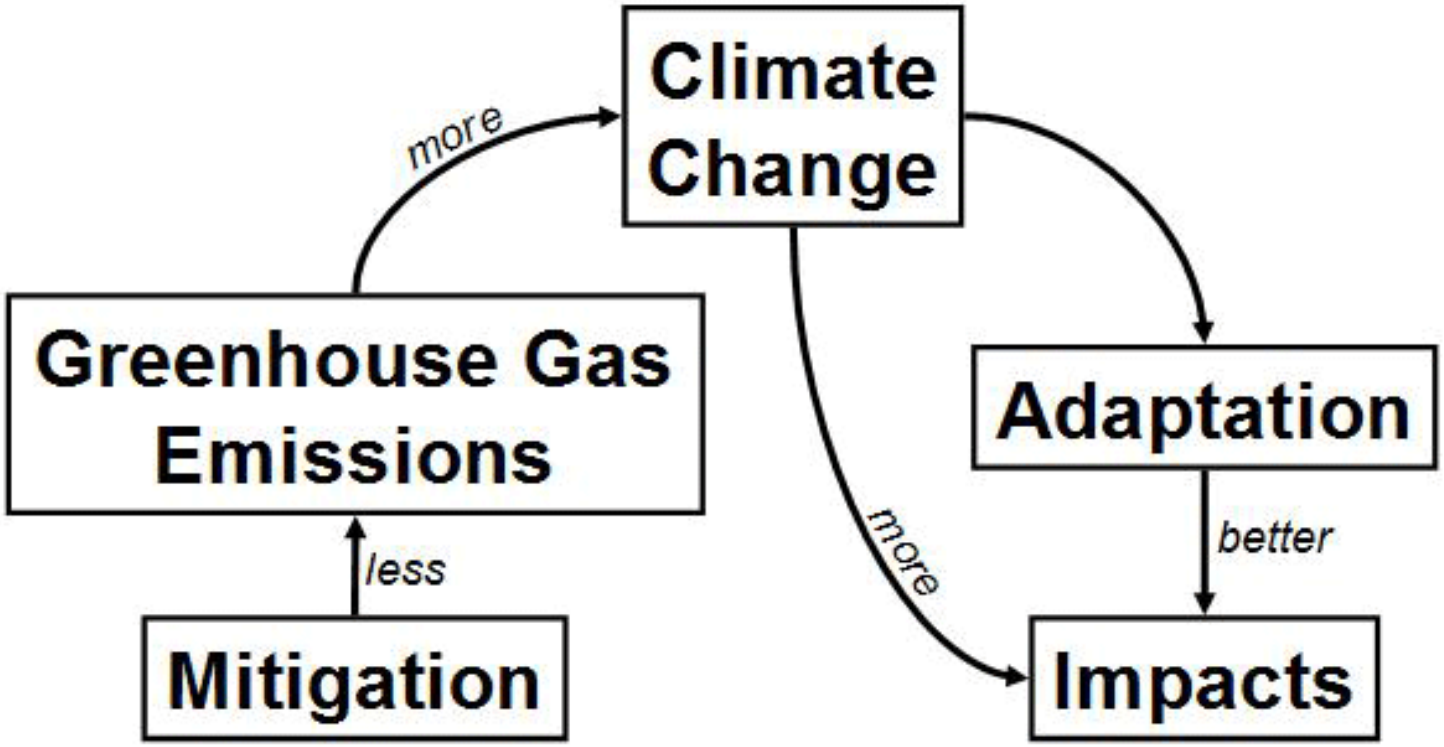
- **Increased risk of fires** due to drought and heat waves but also to changes in land management (MedECC, 2019)
- **Increased risk of erosion** due to couple effect of heavy rainfall events and fires
- **Desertification**: warming and drought is expected to increase aridity and subsequent desertification of many Mediterranean land ecosystems



MedECC, 2019

Solutions to face climate change:

Climate change mitigation and adaptation

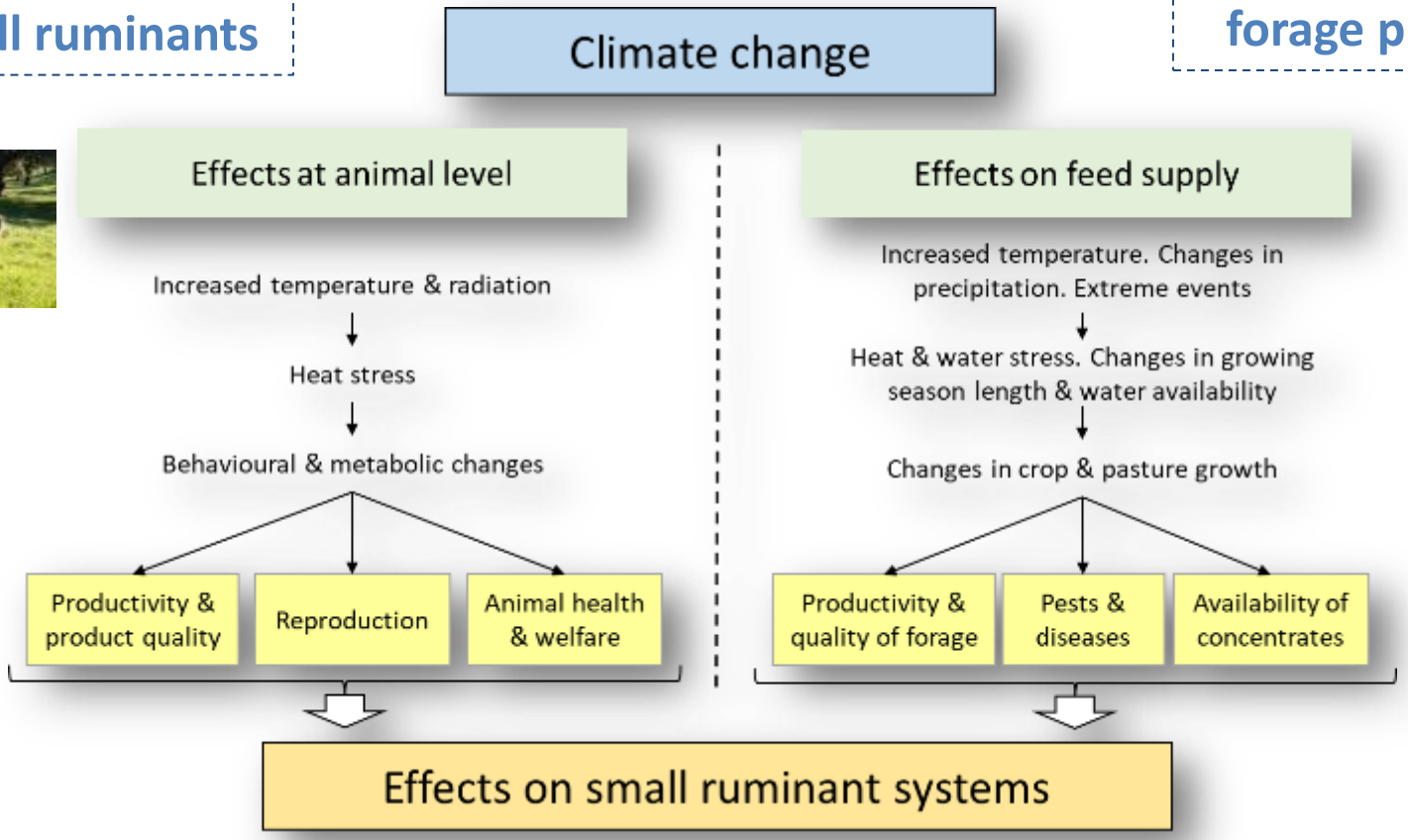


General effects of climate change on sheep and goat systems

Impacts of CC on sheep and goat systems

Effects of CC on small ruminants

Effects of CC on forage production



Regional implications for small ruminant production systems and adaptation measures

Effects of climate change on forage production

Effects of CC on forage production

- Increase in CO_2 may promote greater production in grasslands (**10-20%**).

Increase in CO_2

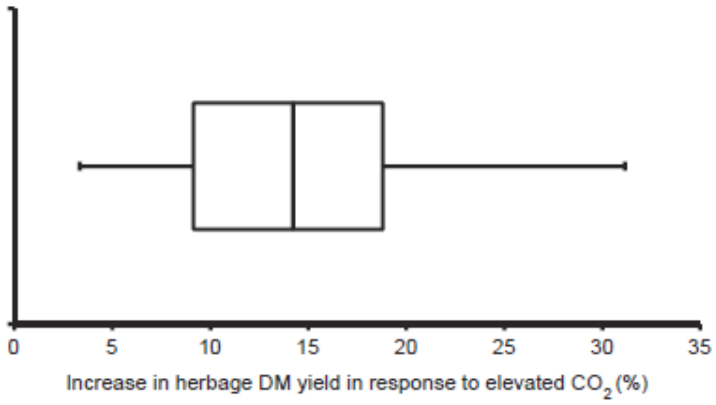


Figure 1 Variability in the annual herbage dry matter (DM) yield response of temperate pastures to elevated CO_2 (600–700 ppm) under optimal nutrient supply, displayed as ranges (whiskers), 25th percentile to the 75th percentile (boxes) and the median line. Created using 44 annual means from control and elevated CO_2 treatments from Newton *et al.* (1994), Casella *et al.* (1996), Soussana *et al.* (1996), Hebeisen *et al.* (1997) and Schneider *et al.* (2004).

Lee et al., 2013

Increase in CO_2

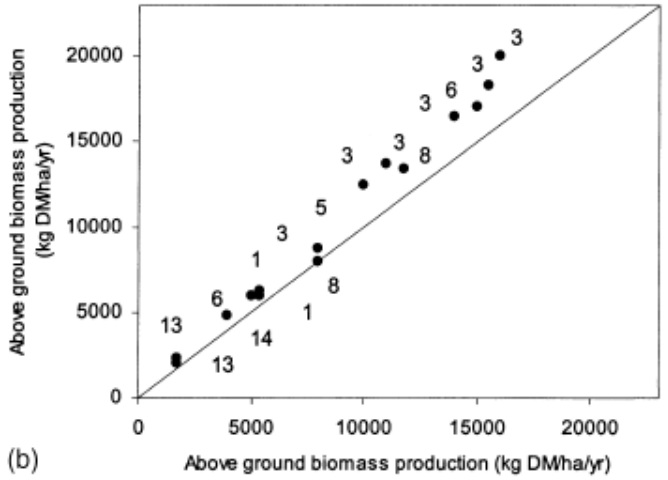
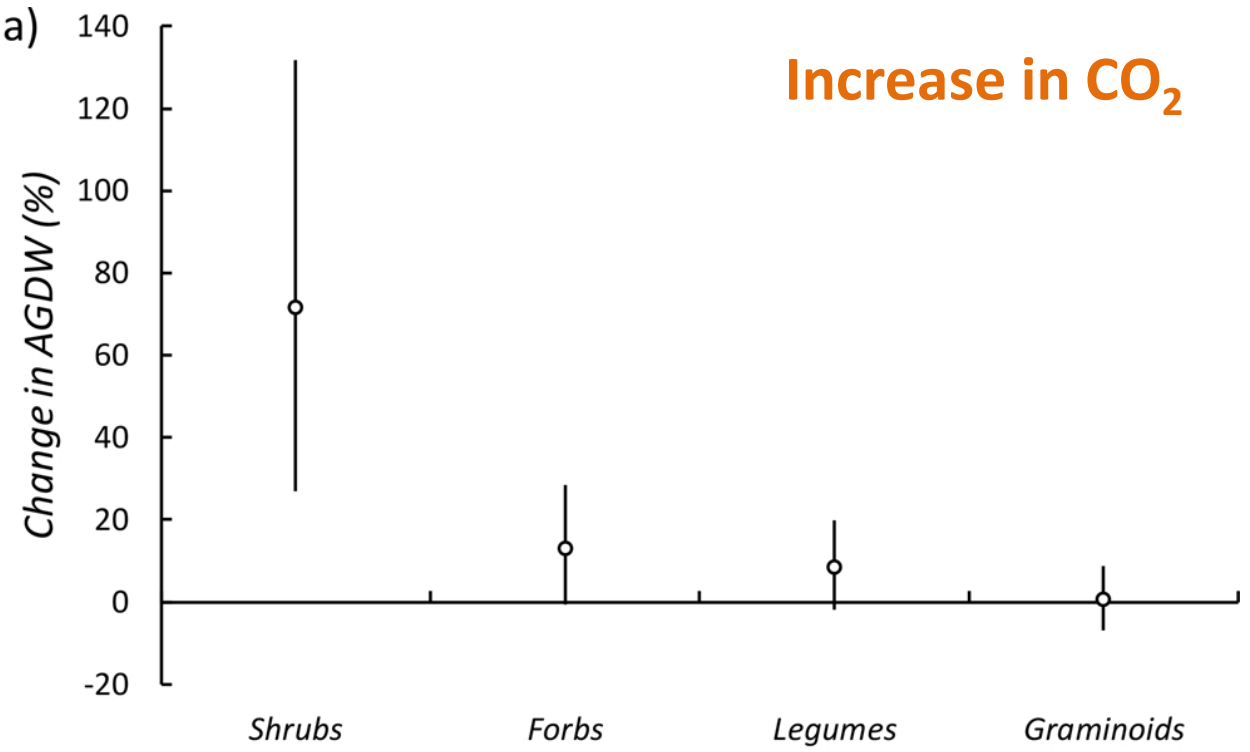


Fig. 2. Effect of doubled ambient CO_2 on above-ground biomass production plotted against above-ground biomass production at the current CO_2 concentration for different pasture and rangeland systems: (a) percentage effect; (b) absolute effect. Numbers refer to studies listed in Table 1: (1) M. Jones, unpublished; (3) Hebeisen et al. (1997); (5) Tuba et al. (1998); (6) Casella et al. (1996); (8) Newton et al. (1994), Clark et al. (1997); (13) J. Morgan, unpublished; (14) Owensby et al. (1999).

Campbell et al., 2010

Effects of CC on forage production

- Increase in CO_2 may promote greater production in grasslands (**10-20%**). Differences among **plant functional groups**.



Dellar et al, 2018

Effects of CC on forage production

- Higher temperature (warming) tend to enhance plant growth. Beyond the optimum temperature, starts to decrease.
- Wheat (south), Ryegrass(north), Mountain regions implications

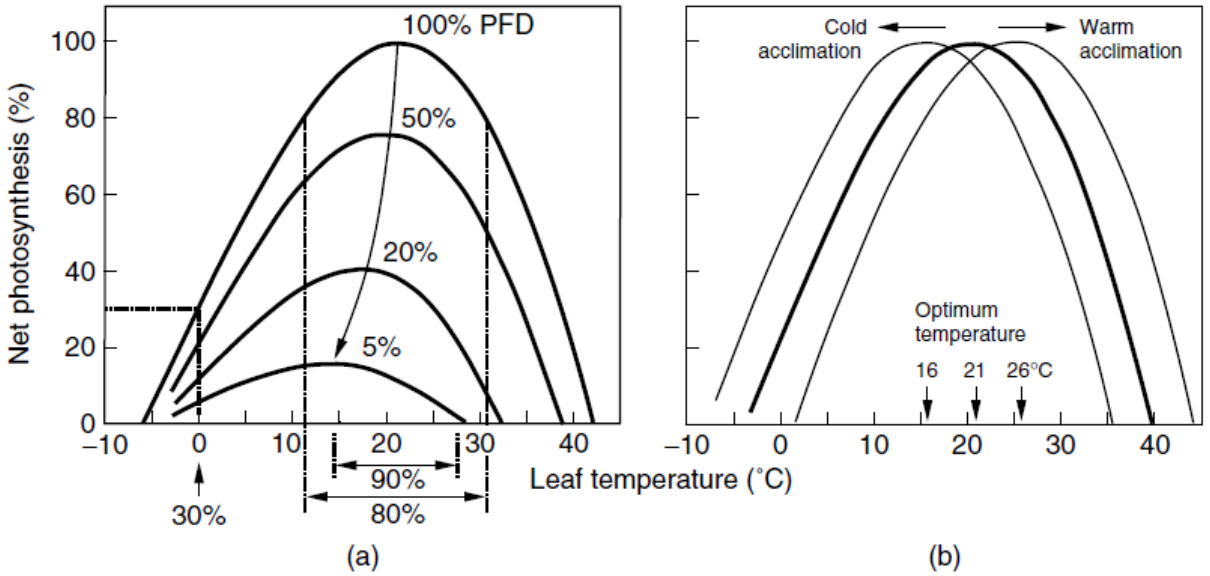
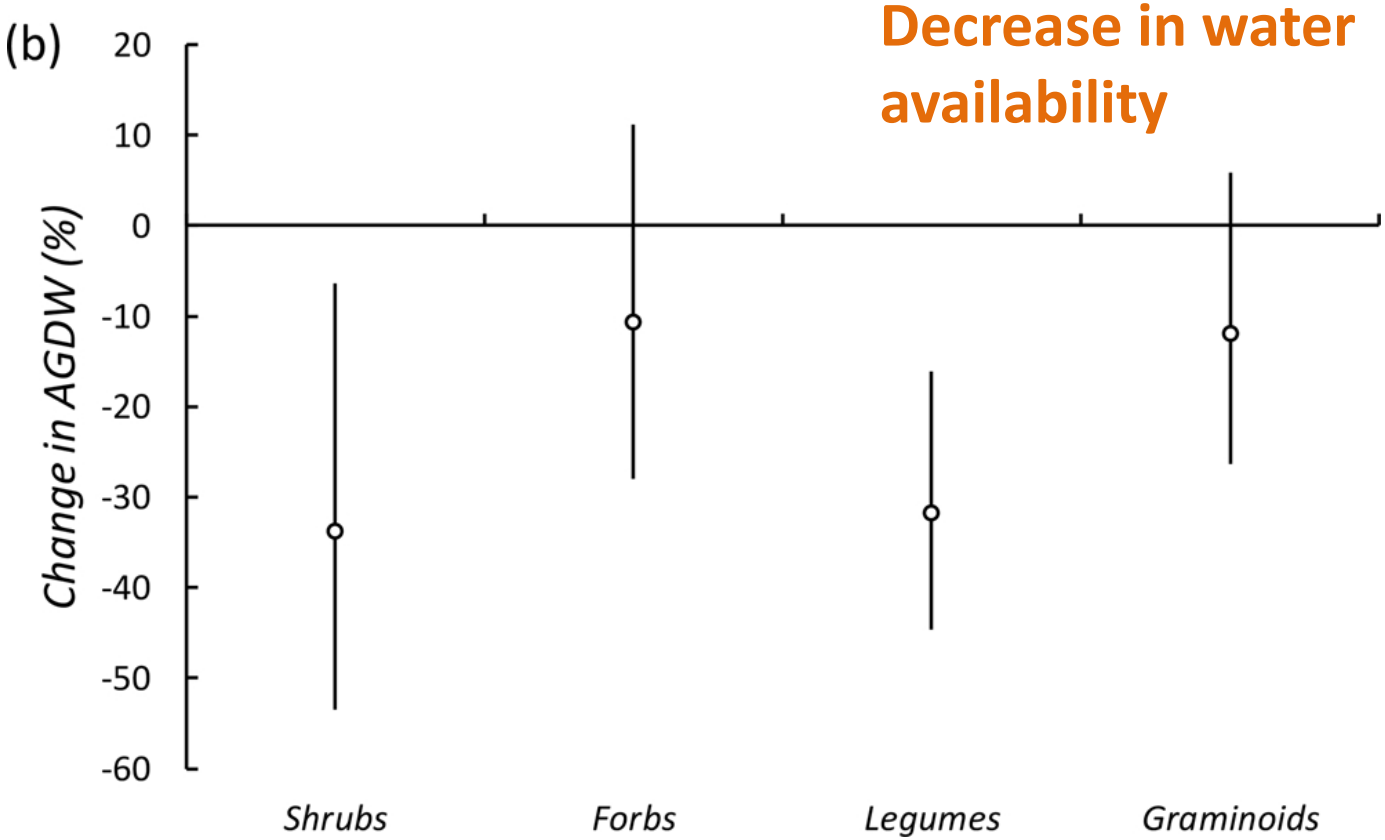


Figure 3.1 The 'classical' responses of net photosynthesis of leaves (A) to temperature (cf. Larcher, 1969, 2003). (a) Typical response curves for a temperate plant species measured at different light

Körner et al., 2006

Effects of CC on forage production

- Reduced water availability decrease production

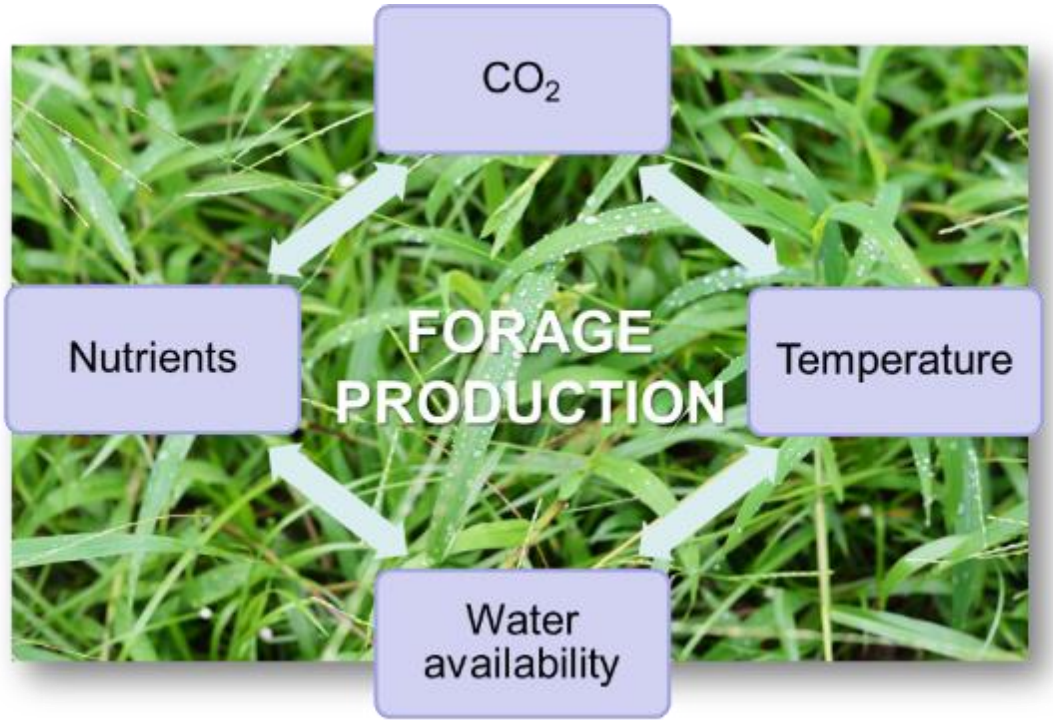


Decrease in water availability

Dellar et al, 2018

Effects of CC on forage production

- Overall effect depends on complex interacting processes between CO_2, temperature and water availability in the soil-water-plant system



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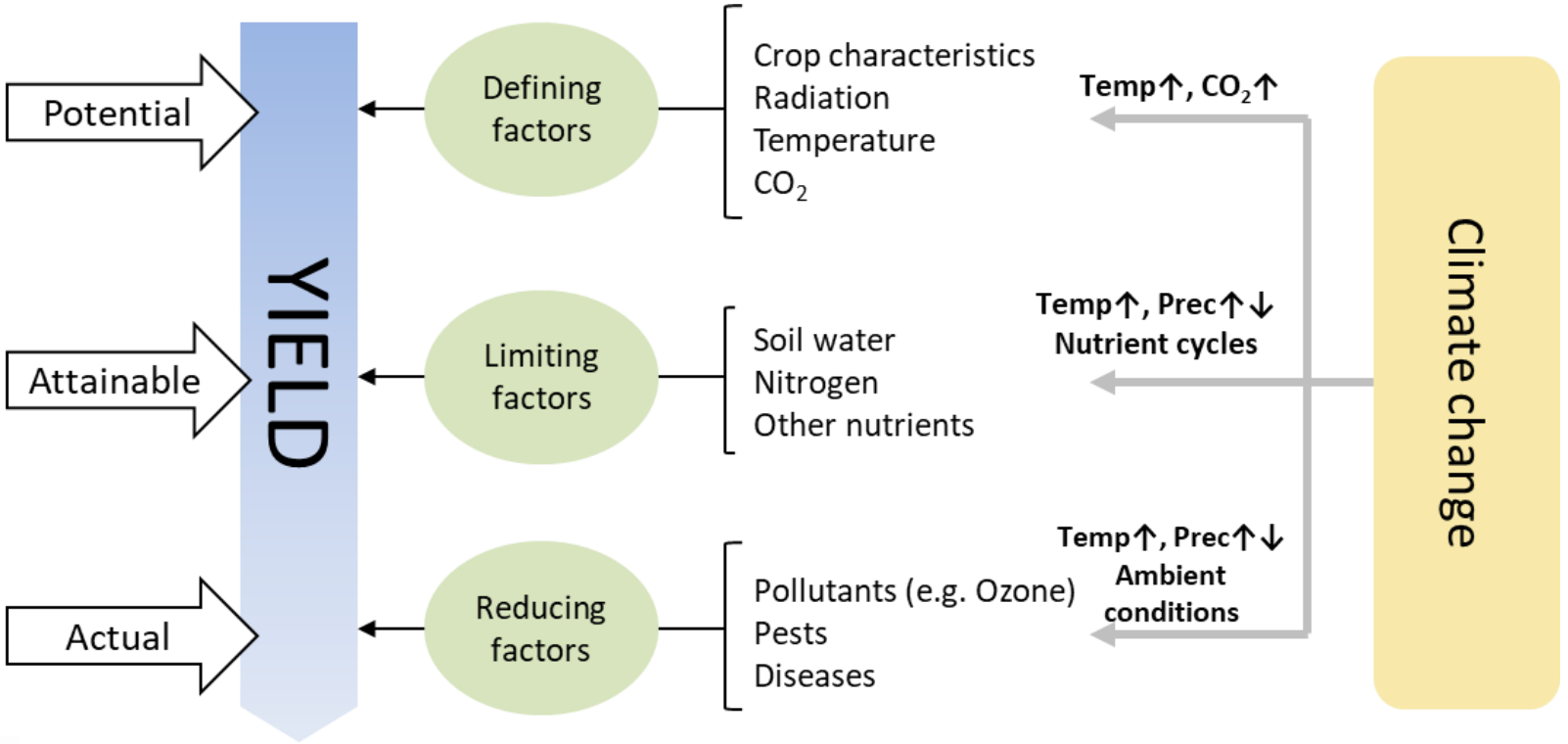

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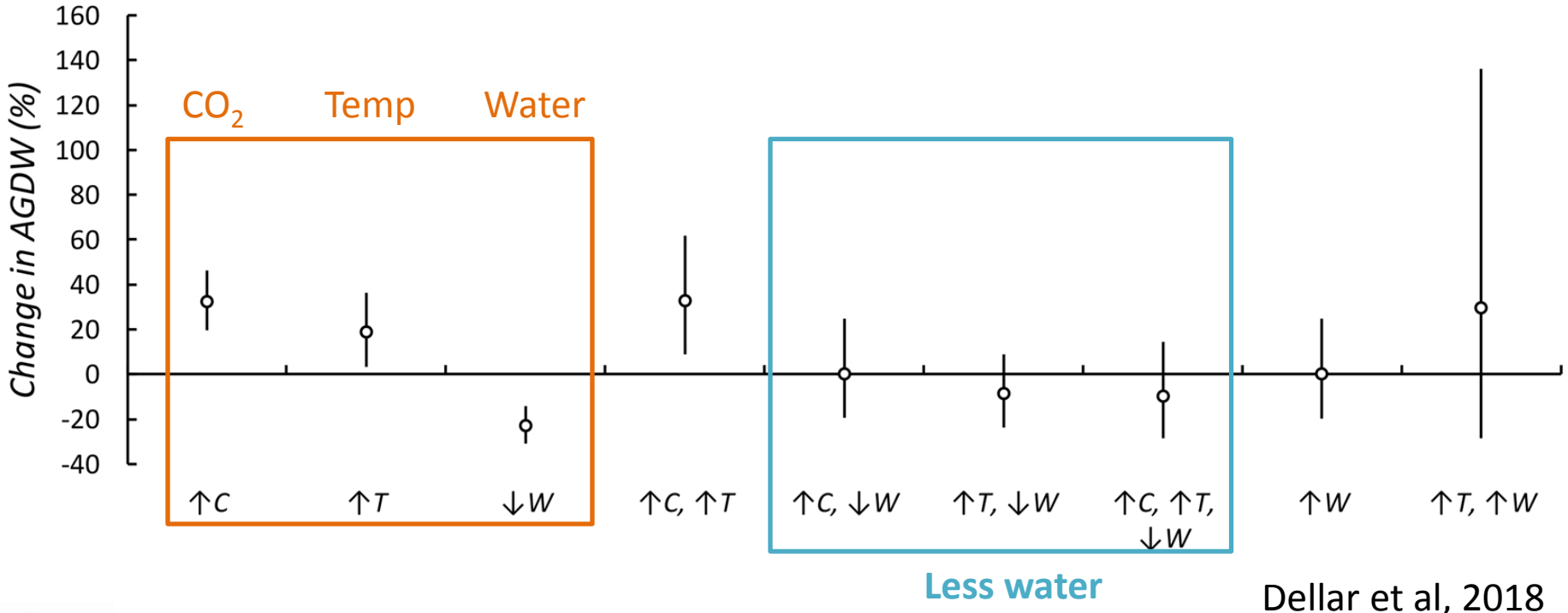


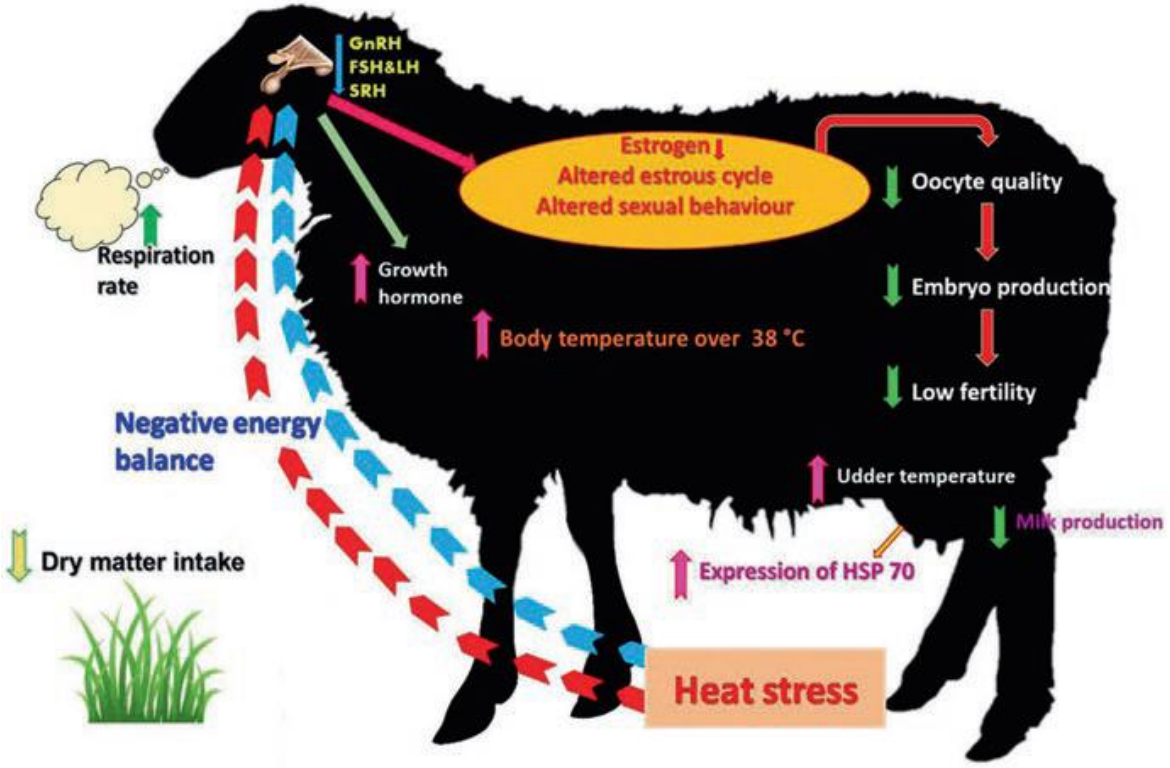
Dellar et al, 2018

Effects of climate change at the animal level

Effects of CC on small ruminants:

-Heat stress: Animal thermoregulatory responses

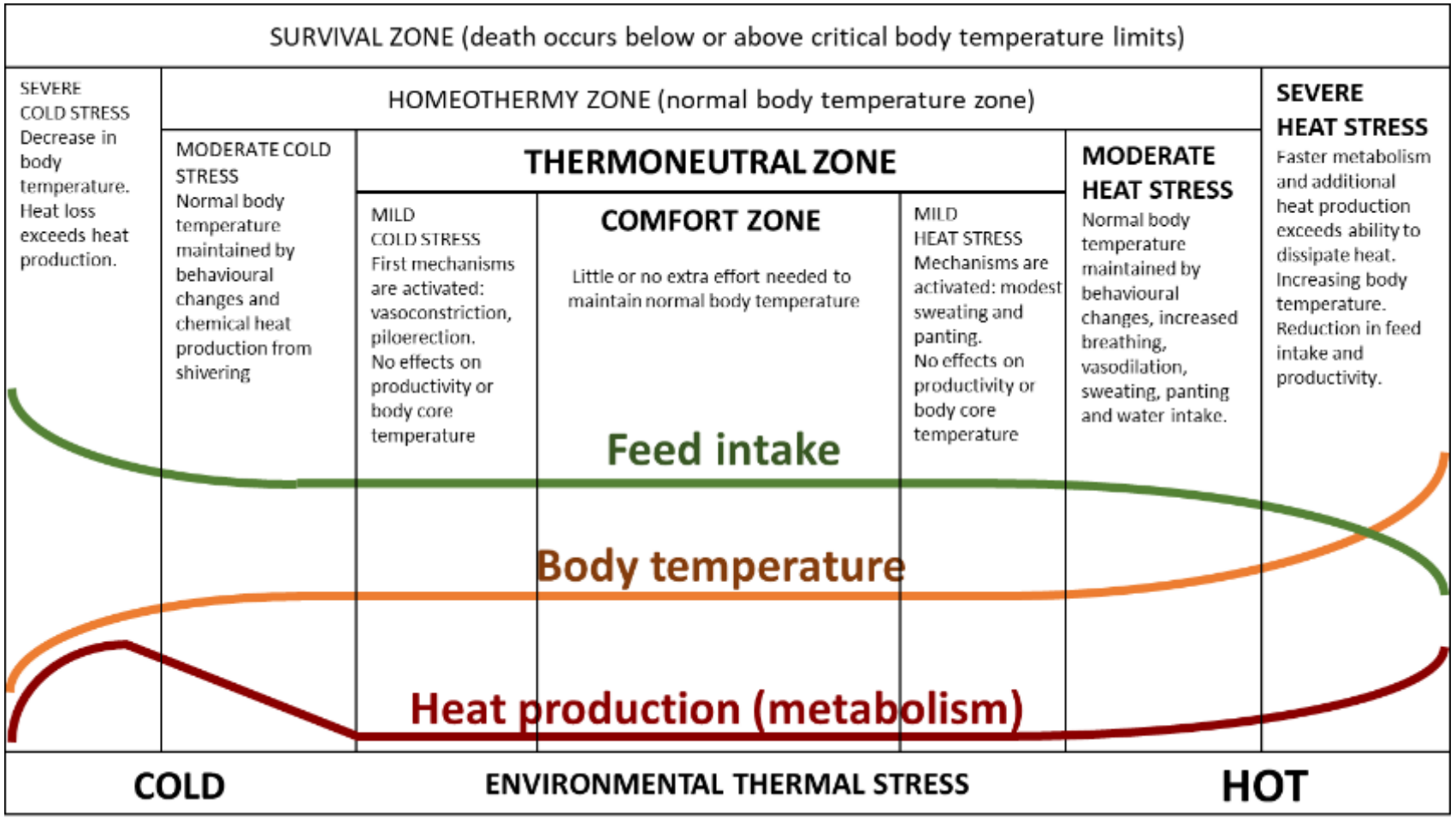
- Physiological (sweating, panting)
- Hormonal (cortisol, thyroid gland activity)
- Behavioural (increase water intake, decrease feed intake)



Sejian et al., 2017

Effects of CC on small ruminants:

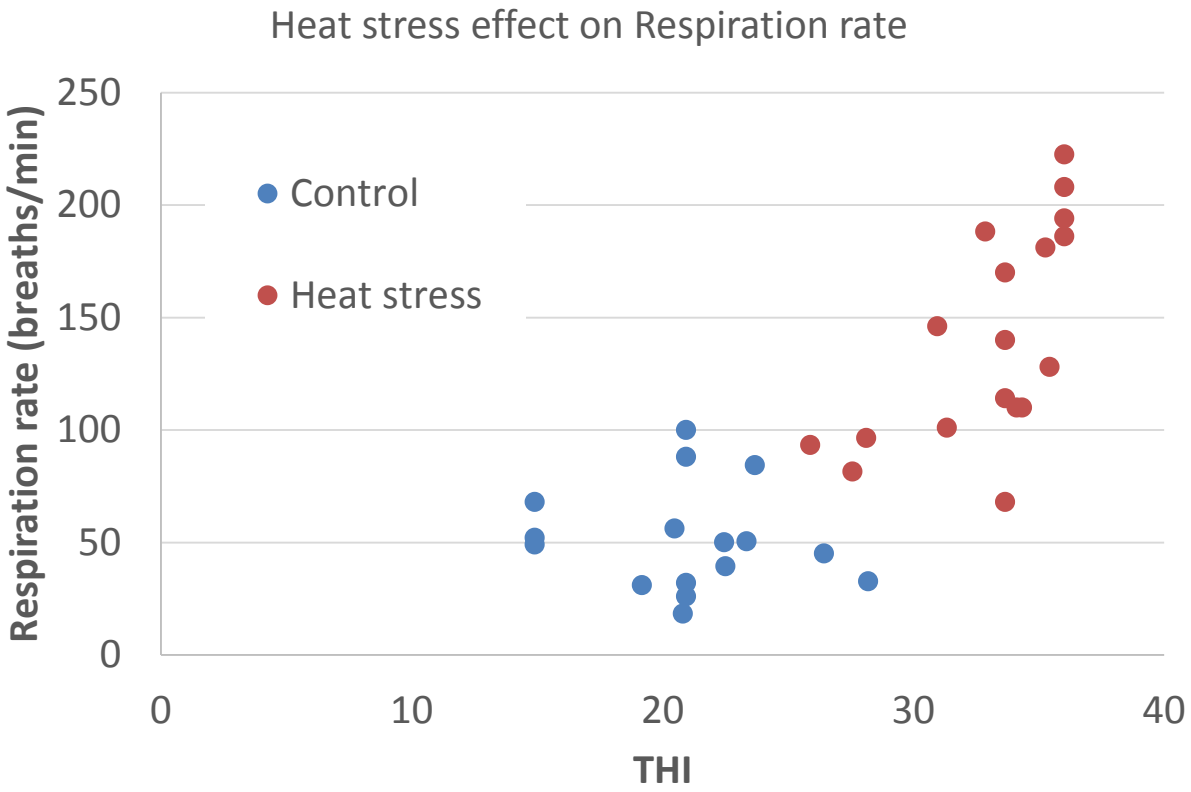
-Heat stress: Animal thermoregulatory responses



Adapted from Silanikove et al., 2015

Effects of CC on small ruminants:

-Heat stress: Animal thermoregulatory responses



Pardo et al. (in prep)

Effects of CC on small ruminants:

-Heat stress: How to measure the heat load exposure?

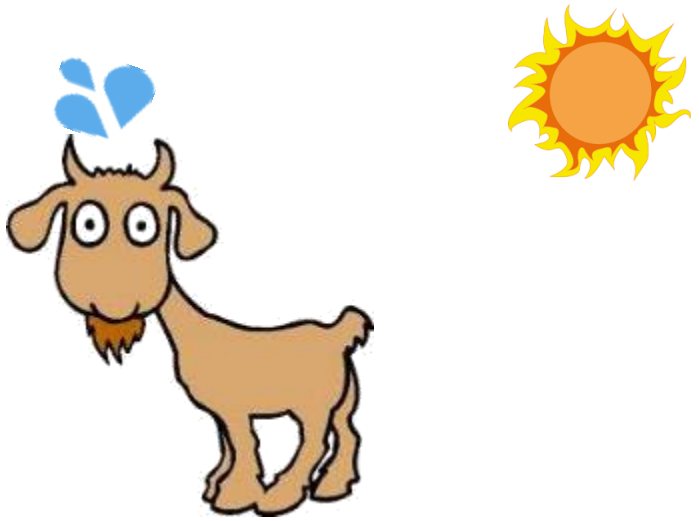
Effects of CC on small ruminants:

-Heat stress: How to measure the heat load exposure?

- Temperature?
- Temperature-humidity index (THI):

$$THI = (Tdb(ºC) - ((0.55 - 0.55 \cdot RH) \cdot (Tdb(ºC) - 14.4)$$

Kelly and Bond 1959



Effects of CC on small ruminants:

-Heat stress: How to measure the heat load exposure?

Temperature-humidity index (THI):

Temperature	% Relative Humidity																				
ºC	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
21	17	18	18	18	18	18	18	19	19	19	19	19	20	20	20	20	20	20	21	21	21
22	18	18	18	18	19	19	19	19	19	20	20	20	20	21	21	21	21	21	22	22	22
23	18	19	19	19	19	19	20	20	20	20	21	21	21	21	22	22	22	22	23	23	23
24	19	19	19	20	20	20	20	21	21	21	21	22	22	22	22	23	23	23	23	24	24
25	19	19	20	20	20	21	21	21	22	22	22	22	23	23	23	24	24	24	24	25	25
26	20	20	20	21	21	21	22	22	22	22	23	23	23	24	24	24	25	25	25	26	26
27	20	20	21	21	21	22	22	22	23	23	24	24	24	25	25	25	26	26	26	27	27
28	21	21	21	22	22	22	23	23	24	24	24	25	25	25	26	26	27	27	27	28	28
29	21	21	22	22	23	23	23	24	24	25	25	25	26	26	27	27	27	28	28	29	29
30	21	22	22	23	23	24	24	24	25	25	26	26	27	27	27	28	28	29	29	30	30
31	22	22	23	23	24	24	25	25	26	26	26	27	27	28	28	29	29	30	30	31	31
32	22	23	23	24	24	25	25	26	26	27	27	28	28	29	29	30	30	31	31	32	32
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34	23	24	24	25	25	26	26	27	28	28	29	29	30	30	31	31	32	32	33	33	34
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38	25	26	26	27	28	28	29	30	30	31	32	32	33	33	34	35	35	36	37	37	38
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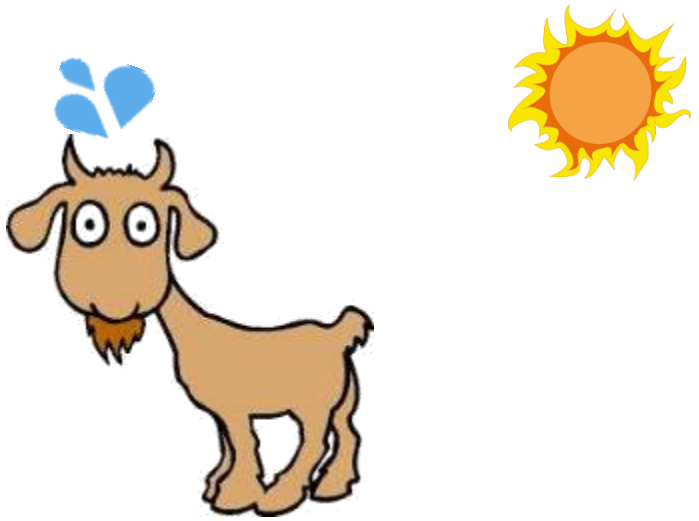
40	26	27	27	28	29	29	30	31	32	32	33	34	34	35	36	36	37	38	39	39	40
41	26	27	28	29	29	30	31	31	32	33	34	34	35	36	37	37	38	39	40	40	41
42	27	28	28	29	30	31	31	32	33	34	34	35	36	37	37	38	39	40	40	41	42
43	27	28	29	30	30	31	32	33	34	34	35	36	37	37	38	39	40	41	41	42	43
44	28	29	29	30	31	32	33	33	34	35	36	37	37	38	39	40	41	42	42	43	44
45	28	29	30	31	32	32	33	34	35	36	37	37	38	39	40	41	42	42	43	44	45

Effects of CC on small ruminants:

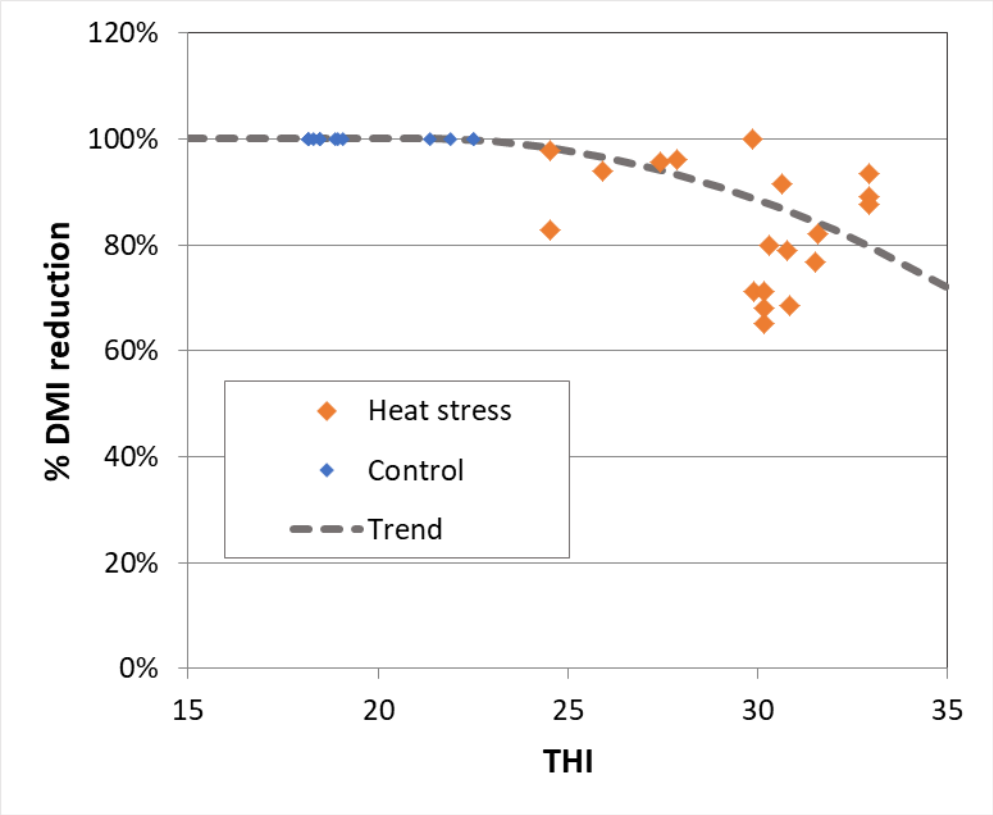
-Heat stress: How to measure the heat load exposure?

- Temperature?
- Temperature-humidity index (THI)
- Black globe temperature
- Other approaches: Temp, %RH, radiation, wind…



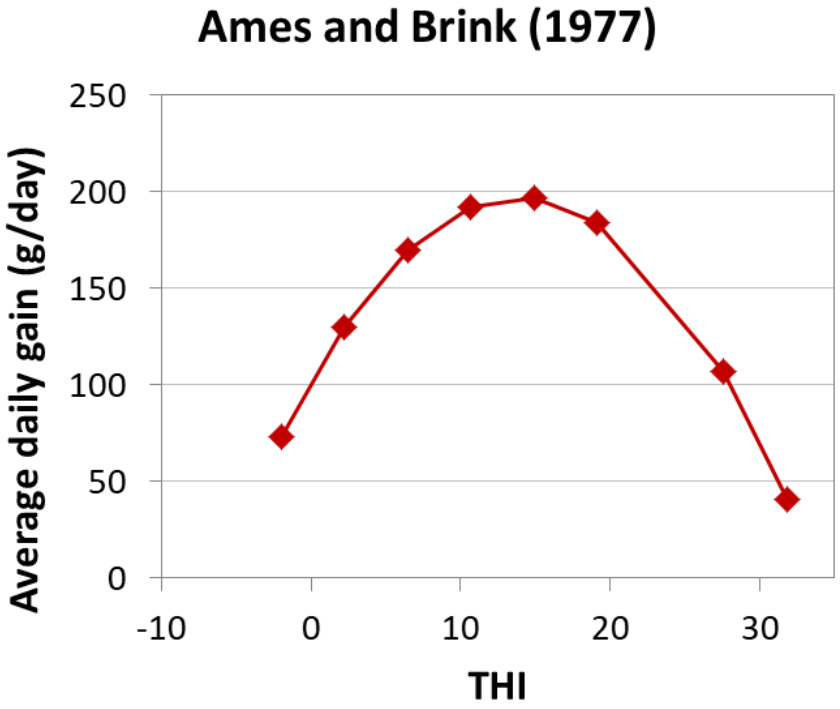
Effects of CC on small ruminants: -Productivity and product quality (milk+meat)

- Sheep and goat subject to heat stress often show reduction in **feed intake** and impaired productivity



Effects of CC on small ruminants: -Productivity and product quality (milk+meat)

- Sheep and goat subject to heat stress often show reduction in feed intake and **impaired productivity: Meat**
- **Lamb impaired growth rate**

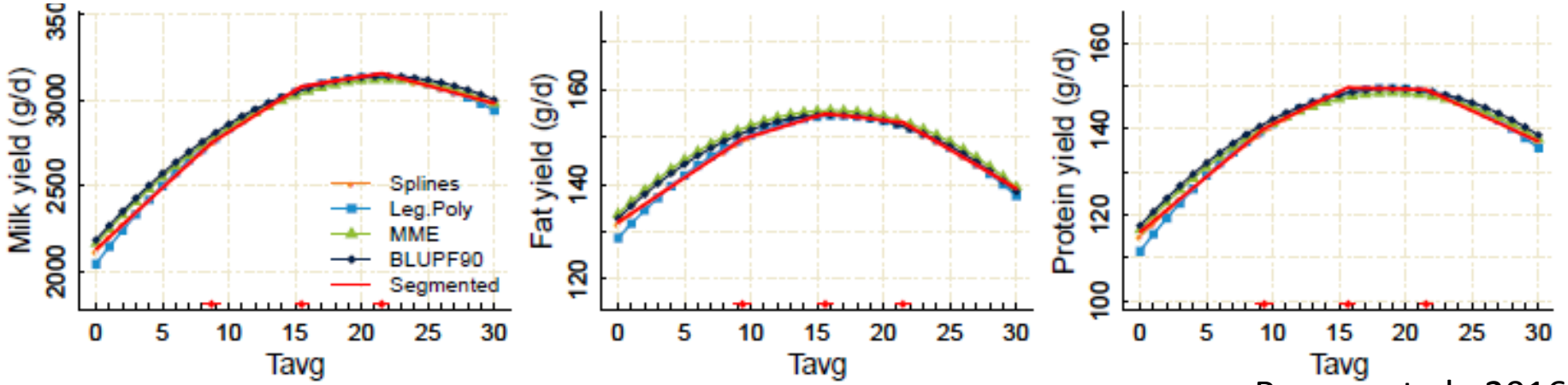


Effects of CC on small ruminants:
-Productivity and product quality (milk+meat)

- Sheep and goat subject to heat stress often show reduction in feed intake and **impaired productivity: Meat**
- **Lamb impaired growth rate**
- **Meat quality:** abnormal odour and taste, greater water holding capacity and susceptible to spoilage by microorganism

Effects of CC on small ruminants: -Productivity and product quality (milk+meat)

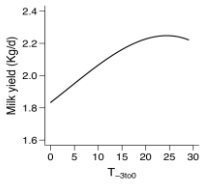
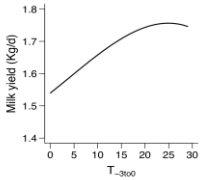
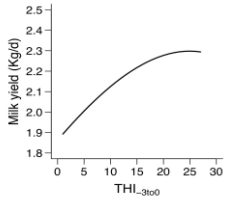
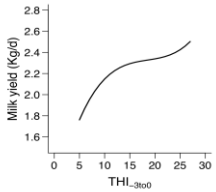
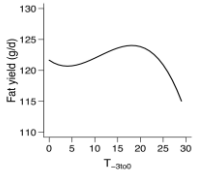
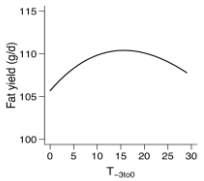
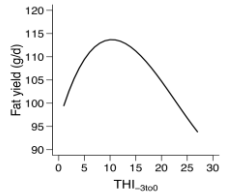
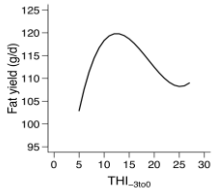
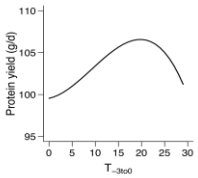
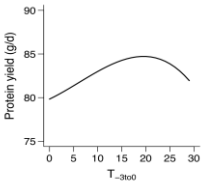
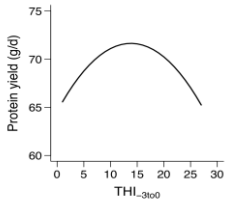
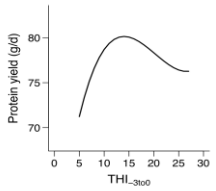
- Sheep and goat subject to heat stress often show reduction in feed intake and **impaired productivity**
- Reduction in milk yield (l/d)
- Milk quality: reduction of protein, total fat and fatty acid profile, reduction of coagulating properties



Ramon et al., 2016

Effects of CC on small ruminants: -Productivity and product quality (milk+meat)

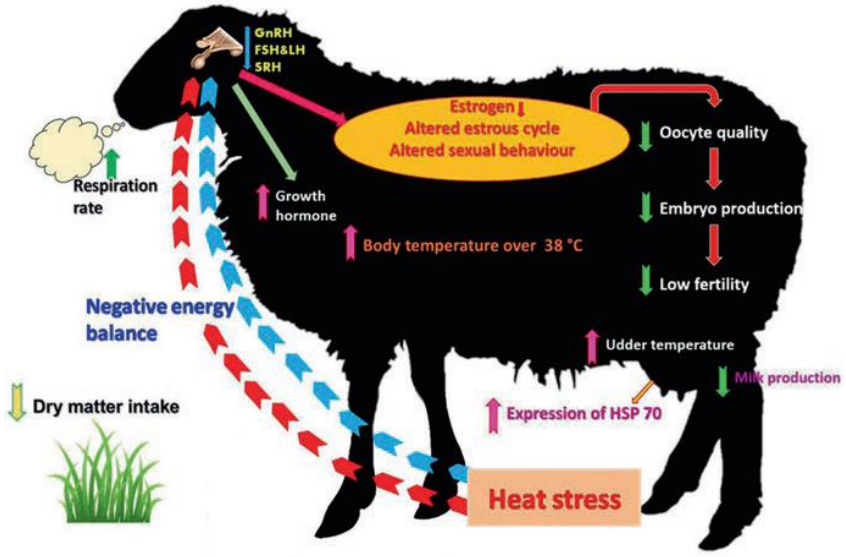
- Depends on breed:

	Intensive dairy sheep	Semi-intensive dairy sheep	Intensive dairy goat	Semi-intensive dairy goat
	Assaf	Manchega	Murciano-Granadina	Florida
Milk				
Fat				
Protein				

Ramon et al., in prep

Effects of CC on small ruminants: Reproduction

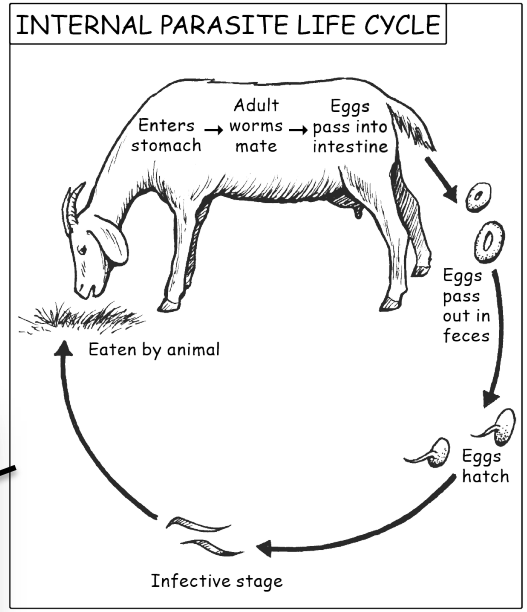
- Heat stress affects negatively fertility:
  - Females: impacts ovarian function, duration of gestation, conception rate and birth weight of lambs.
  - Males: reduced quantity and quality of sperm, changes in sexual activity.



Sejian et al., 2017

Effects of CC on small ruminants: Animal health & welfare

- Warmer conditions may increase the incidence of infectious diseases (gastrointestinal nematode, udder health)



Parasite life cycle. Illustration: Robert Armstrong,
An Illustrated Guide to Sheep and Goat Production

Regional implications and climate change adaptation strategies

Regional implications for small ruminant production systems in Europe:

- Climate change impacts will vary among the different European sub-regions

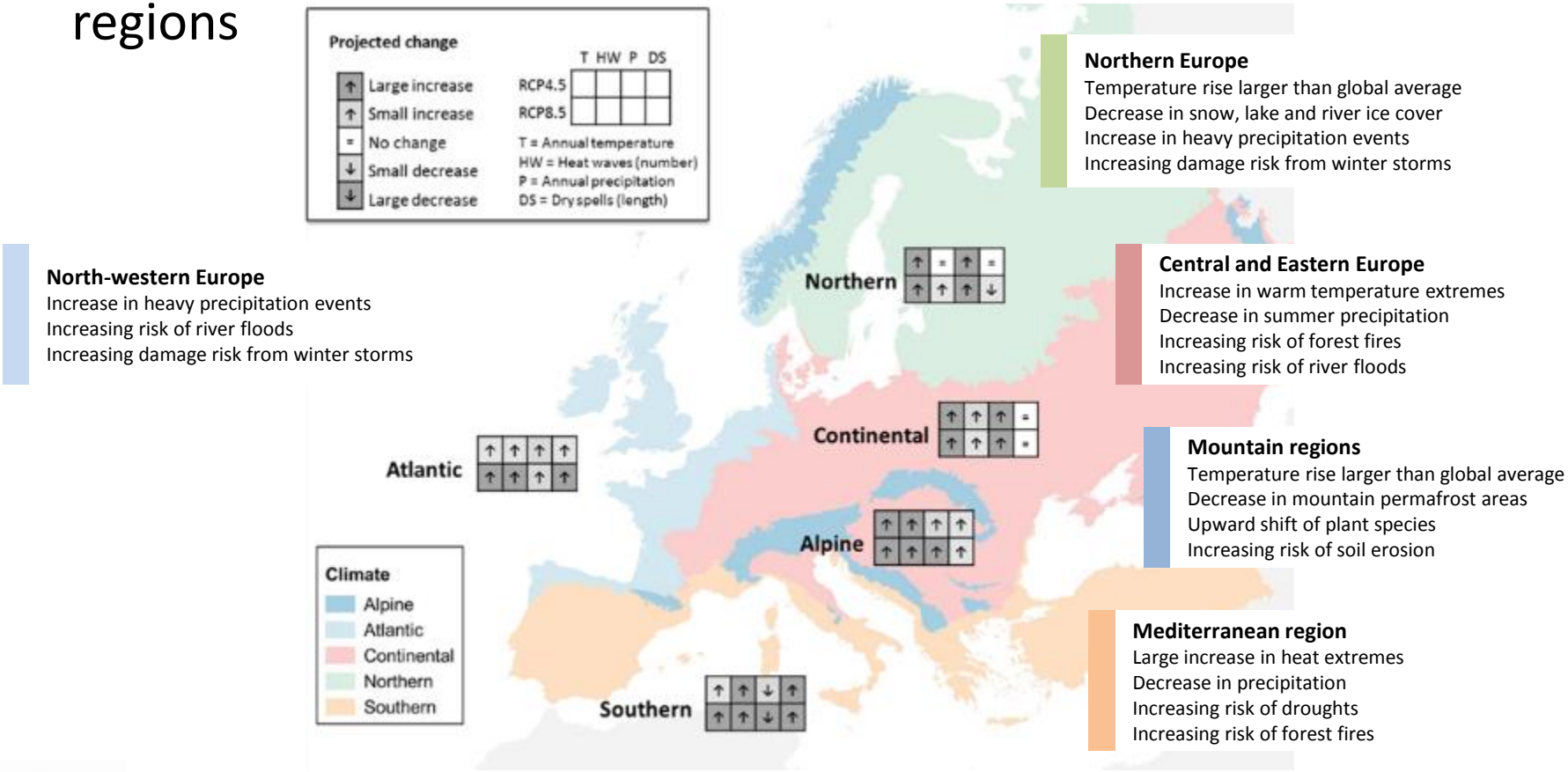


Figure - General trends of several climate variables for European sub-regions. Indices represent changes for 2071-2100 with respect to 1971-2000 based on RCP4.5 and RCP8.5 scenarios (Pardo et al 2017 based on Jacob et al, 2014).

Regional implications for small ruminant production systems in Europe:

- Climate influences distribution of vegetation and small ruminant systems across Europe

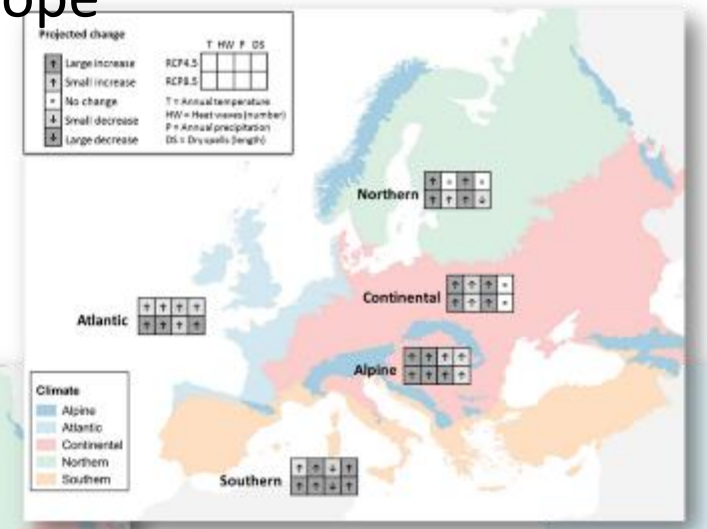


Fig.1- Climate change projections

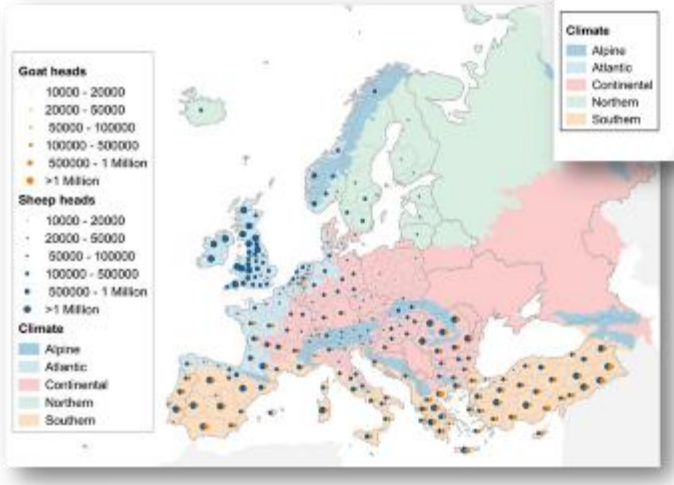


Fig.2 - Distribution of small ruminant livestock in Europe

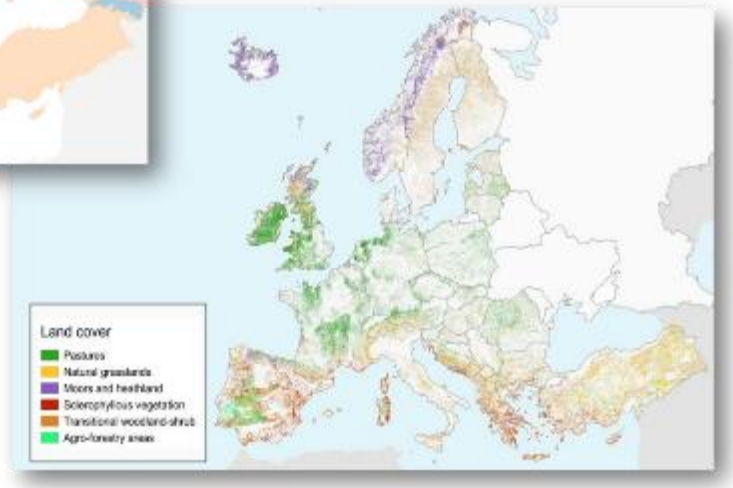


Fig.3 - Distribution of grasslands and scrublands in Europe

Regional impacts of climate change:
E) Southern (Mediterranean) region

- Reduction in forage yields due to less rainfall and risk of drought projection
- Grazing season is expected to be shortened. Grazing activity will suffer from irregular patterns due to extreme events.
- Encroachment (increase of shrubs)
- Soil erosion and degradation
- Heat stress in animals: more frequency and length of heat waves

Southern (Mediterranean) region

General adaptation strategies for forage production to face CC

- Increase pasture diversity:
  - to enhance resilience under variable climatic conditions
  - to adapt to potential shortages of protein sources (mixed legume-grass)
- Reduce tillage:
  - soil moisture conservation
  - long-term productivity (increase soil organic matter)
- Improved plant breeding (long-term):
  - developing varieties that can survive long drought periods and recover rapidly following autumn rains (e.g. tall fescue, cocksfoot and Lucerne varieties)

Southern (Mediterranean) region

Adaptation measures: Flexible grazing and alternative feed resources:

- Crop residues: Post-harvest cereals, olive leaves
- Underutilized feedstuffs from agro-industry by-products
  - Olive cake
  - Citrus pulp
  - Tomato by-products
  - Other vegetables and fruits (e.g. cucumbers, pomegranate)

E) Southern (Mediterranean) region

Adaptation measures: Flexible grazing and alternative feeds:

- Integrated approaches:
  - soil and water protection (cover crops)

E) Southern (Mediterranean) region

Adaptation measures: Flexible grazing and alternative feeds:

- Integrated approaches:
  - soil and water protection (cover crops)
  - different feeds aligned to different seasonal constraints (agro-forestry)

- In winter grass growth preferably beneath tree canopy
- In early summer grasses dry later beneath canopy because the shelter/buffering effect of trees on temperature

Pasture under trees in winter

Pasture under trees in early June

Pictures taken in Iberian dehesas (CW Spain) by D. Howlett and A. Carrara, respectively

E) Southern (Mediterranean) region

Adaptation measures: Flexible grazing and alternative feeds:

- Integrated approaches:
  - soil and water protection (cover crops)
  - different feeds aligned to different seasonal constraints (agro-forestry)
  - fire-risk protection (grazing management)

E) Southern (Mediterranean) region

Adaptation measures to cope with heat stress:

- Prevention/mitigation of heat stress conditions

  -Indoors: stock density, barn orientation/dimensions, ventilation, spraying

  -Outdoors: provide protection with trees or artificial shelters

- Feeding/Nutritional management:

  -shifting meals to late afternoon or evening, increasing number of meals

  -low fibre diets (decrease forage:concentrate), increase energy density, supplements (fat-rich feeds, whole flaxseed)

E) Southern (Mediterranean) region

Adaptation measures to cope with heat stress:

- Animal breeding:

  -Breeds from tropical/arid areas are more resilient due to low body mass and metabolism: tend to minimize water and maintenance requirements

  -Artificial selection to increase milk yield has shown to reduce heat tolerance

  -Goats with loose skin, long legs, floppy ears tend to be most heat tolerant

  -Light coloured

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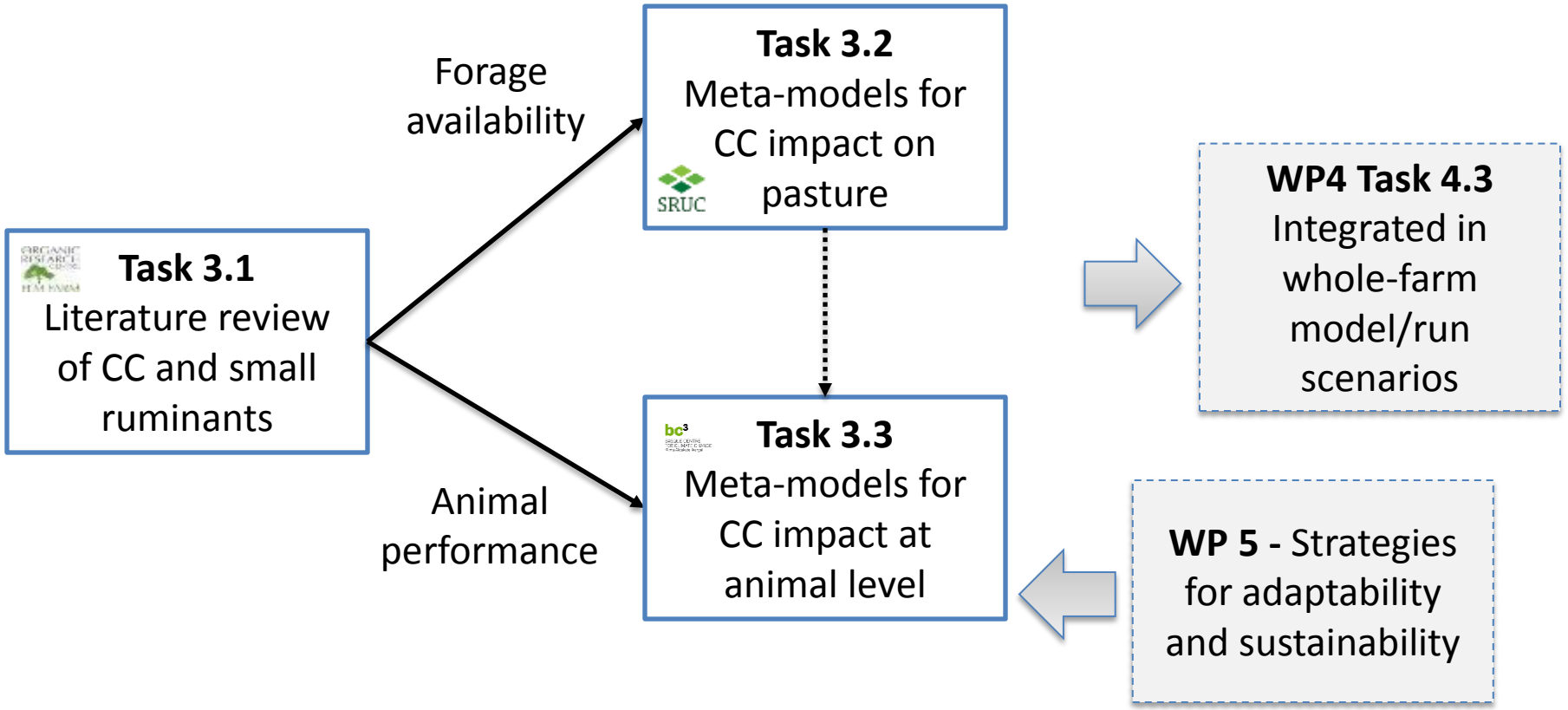
CIHEAM
IAM ZARAGOZA

Development of methods/models to predict impact of change

bc3
BASQUE CENTRE FOR CLIMATE CHANGE
Klima Aldaketa Ikergai

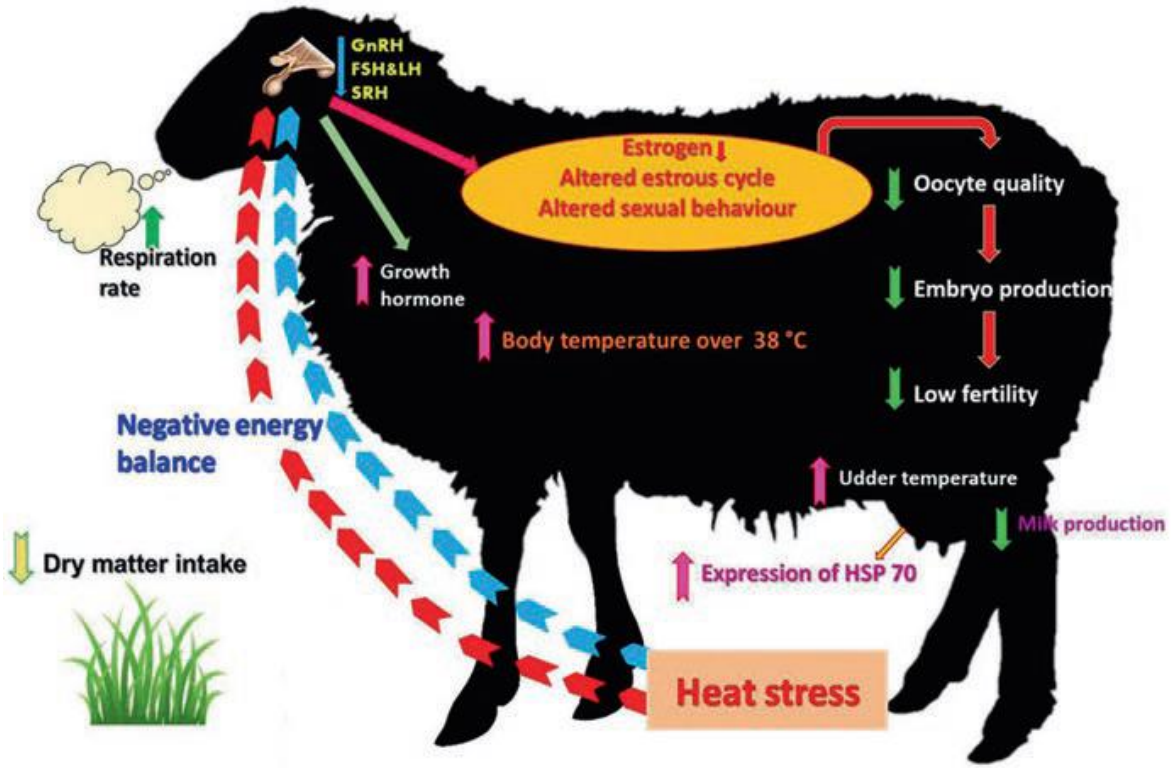
Development of models to capture the impact of climate change on small ruminant systems:



Effects of CC on small ruminants:

-Heat stress: Animal thermoregulatory responses

- Physiological (sweating, panting)
- Behavioural (increase water intake, decrease feed intake)
- Hormonal (cortisol, thyroid gland activity)

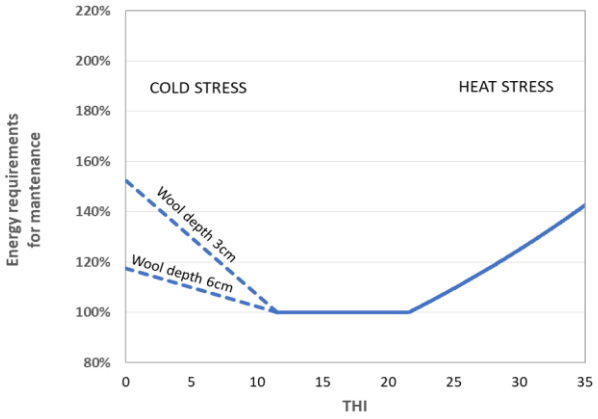


Sejian et al., 2017

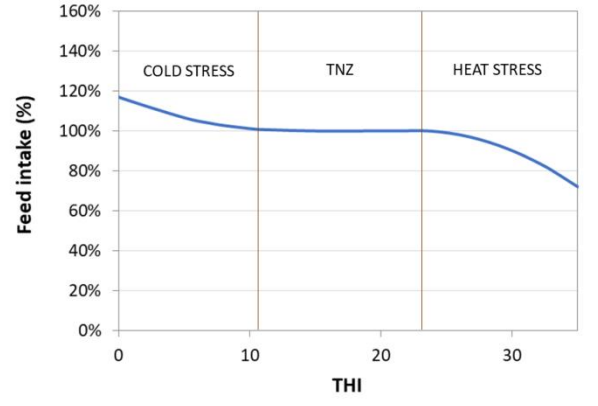
Development of models on animal performance:

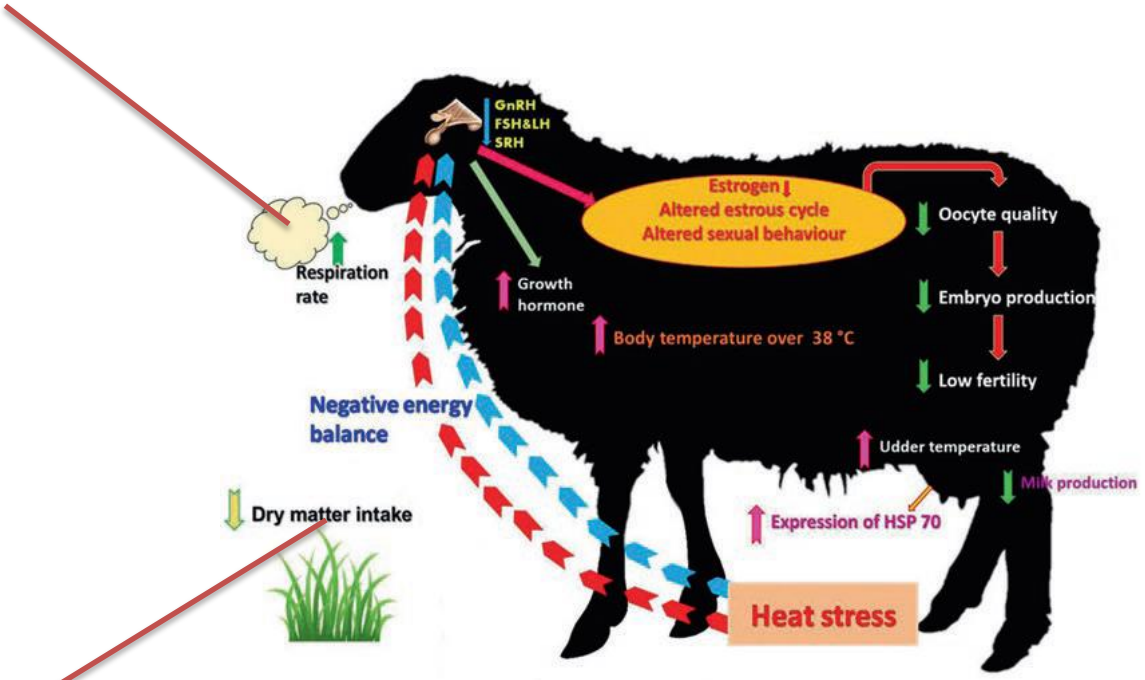
Semi-mechanistic model:

Effect on energy requirements



Effect on feed intake





Sejian et al., 2017

Development of models on animal performance:

Semi-mechanistic model:

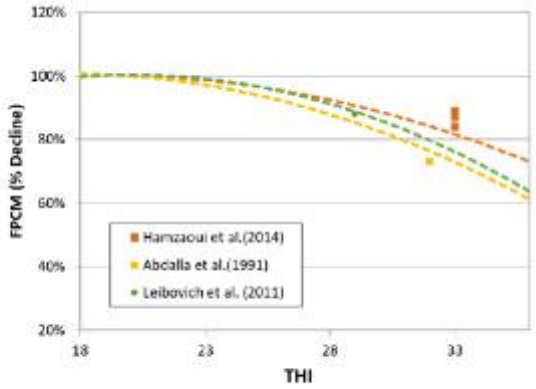


Figure 13 – Estimated (dotted lines) vs measured reduction (%) of FPCM of dairy small ruminants under heat stress (Datasets from Abdalla et al 1993; Hamzaoui et al 2014; Leibovich et al 2011)

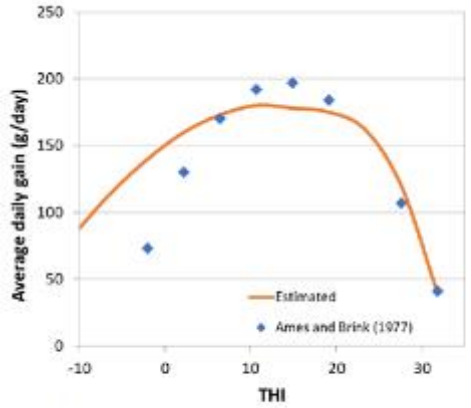


Figure 15 – Estimated (line) vs measured average daily gain of growing lambs under heat stress (Datasets from Ames and Brink, 1977)

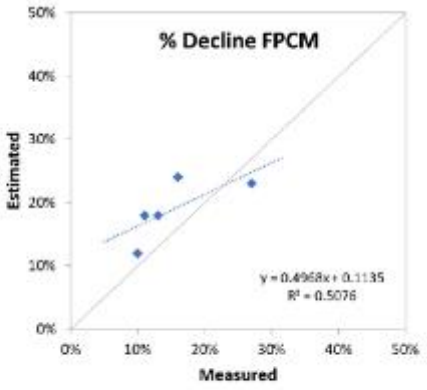


Figure 14 - Estimated vs measured reduction (%) of FPCM of dairy small ruminants under heat stress (Datasets from Abdalla et al 1993; Hamzaoui et al 2014; Leibovich et al 2011)

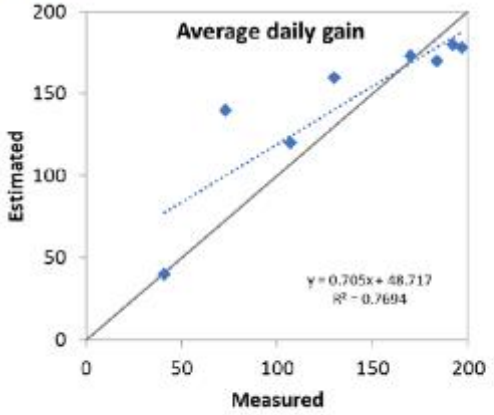


Figure 16 – Estimated vs measured average daily gain of growing lambs under heat stress (Datasets from Ames and Brink, 1977)

Testing the modelling approach (lamb growth)

- Breed: rasa Aragonesa
- Location: Zaragoza (Spain) (June-July 2017)
- Effect of heat on Lamb growth (born in May)
- Period of study: from weaning (13.9 kg LW) to slaughter (22 kg LW)
- Number of ewes: 550, 650 lambs sold/yr (40% born in May)

Diet composition (wean to slaughter)

FEED	%	GE MJ/kg DM	DE MJ/kg DM	ME MJ/kg DM
Barley	33.6%	18.4	14.8	12.4
Maize	27.3%	18.7	16.1	13.6
Soybean Meal	23.6%	19.7	18.2	13.6
Wheat	6.4%	18.2	15.6	13.1
straw	9.0%	18.2	8	6.5

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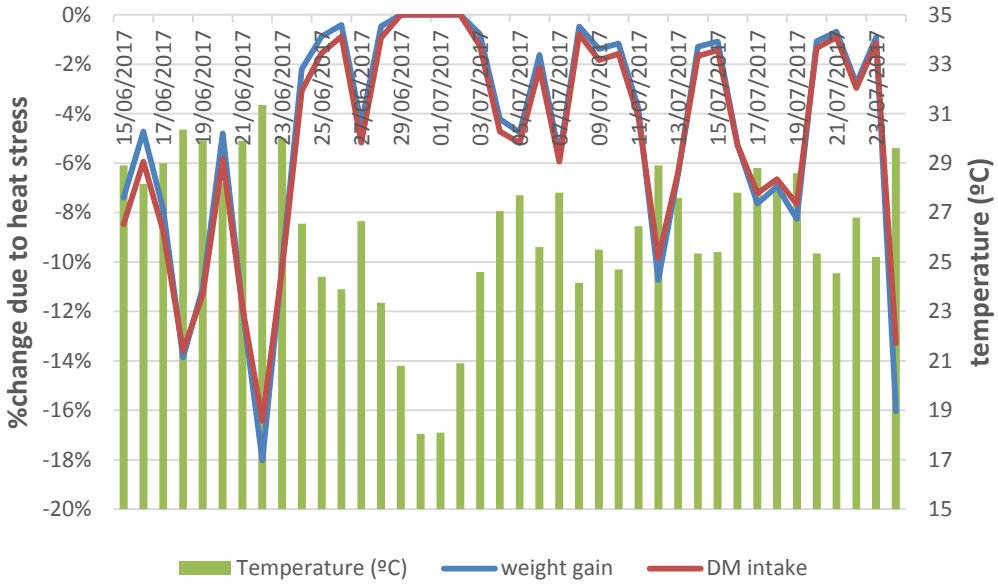
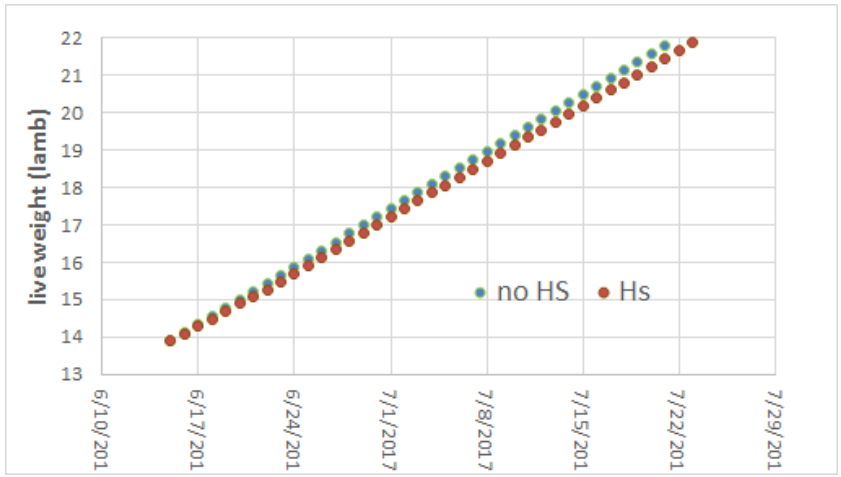
Effect of heat on Lamb growth & DM Intake

Lamb growth reduction and DM intake (%)





2 extra days with heat stress

450 g DM extra/lamb

228 kg extra concentrates

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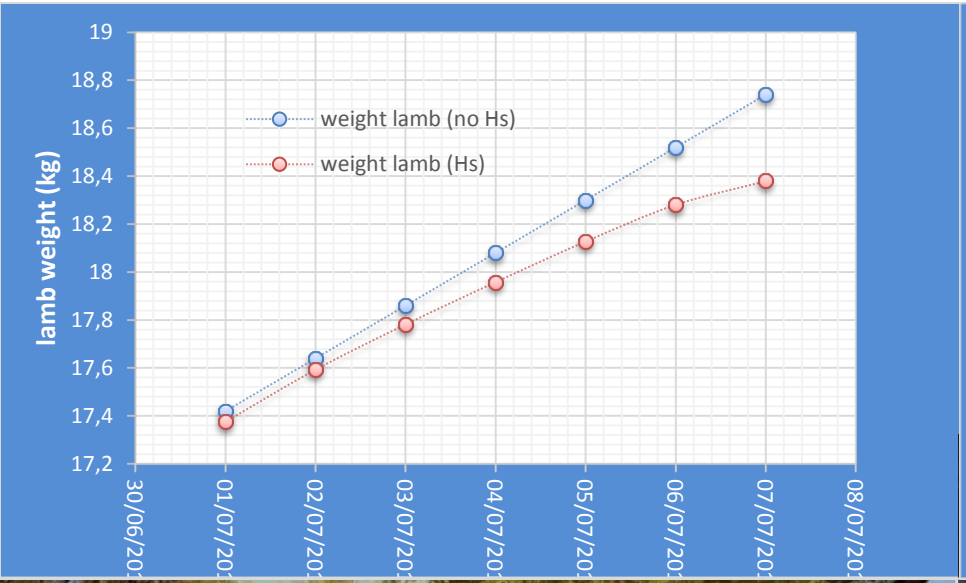
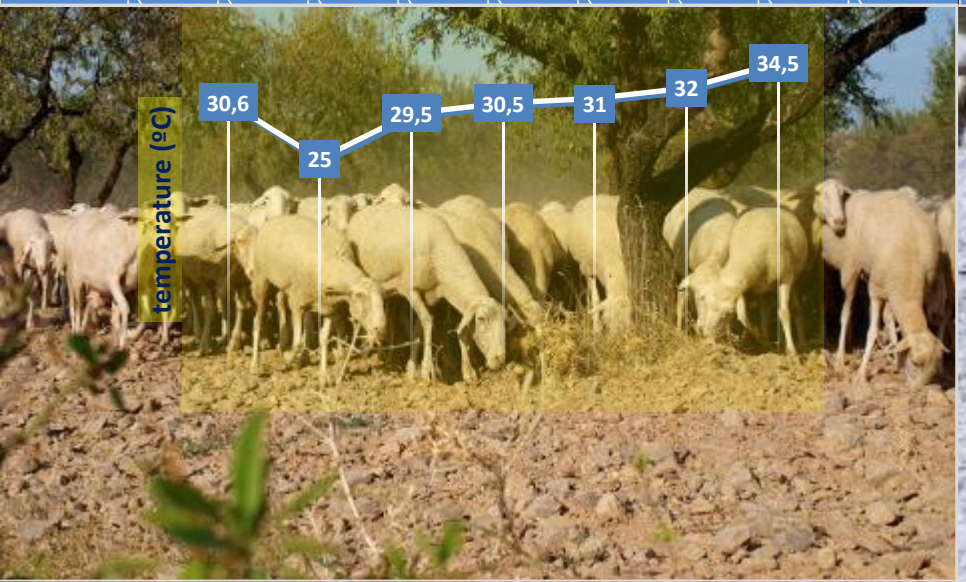
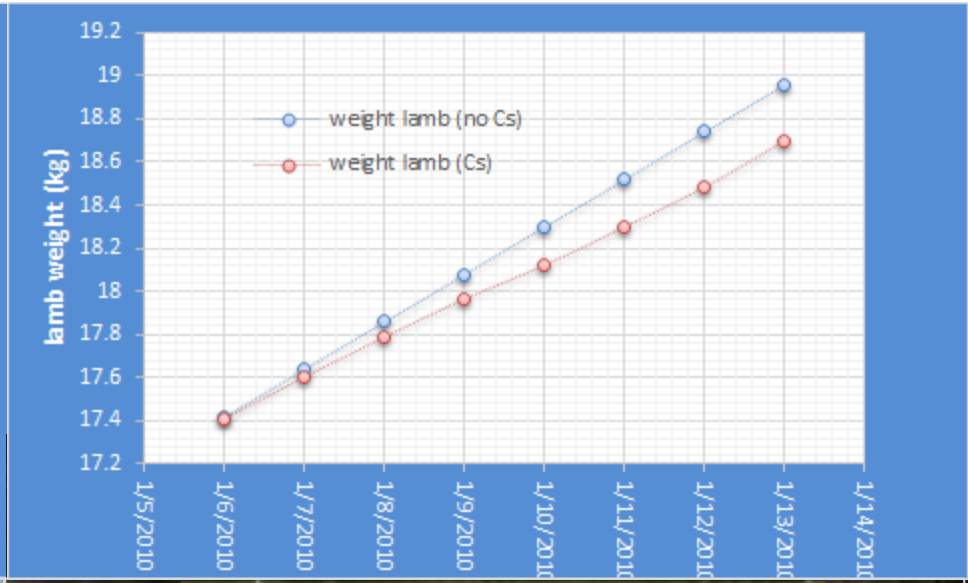
Extremes (heat and cold wave)

Born in May (Heat stress)





Born in January (Cold stress)



Testing the modelling approach (impact on milk& adaptation)

- Breed: Manchega (Spain)
- Effect of heat on milk productivity on Summer period
- Housed

Diet composition

FEED		GE	DE	ME
	%	MJ/kg DM	MJ/kg DM	MJ/kg DM
Alfalfa hay	90%	18.2	10.6	8.4
Corn	10%	18.7	16.1	13.6

4 scenarios

- No HS
- HS (non-adapted)
- HS (adapted-diet)
- HS (Adapted-spraying)

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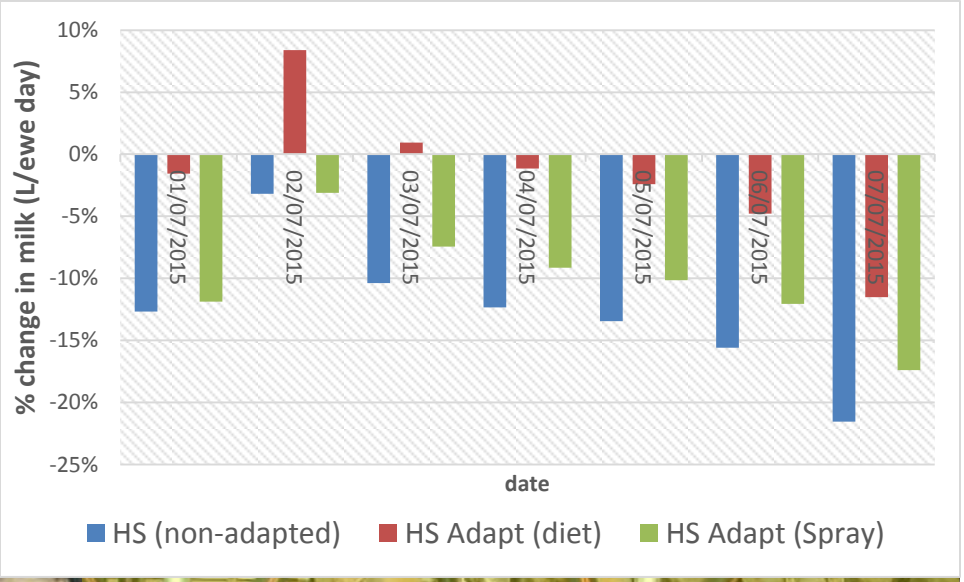
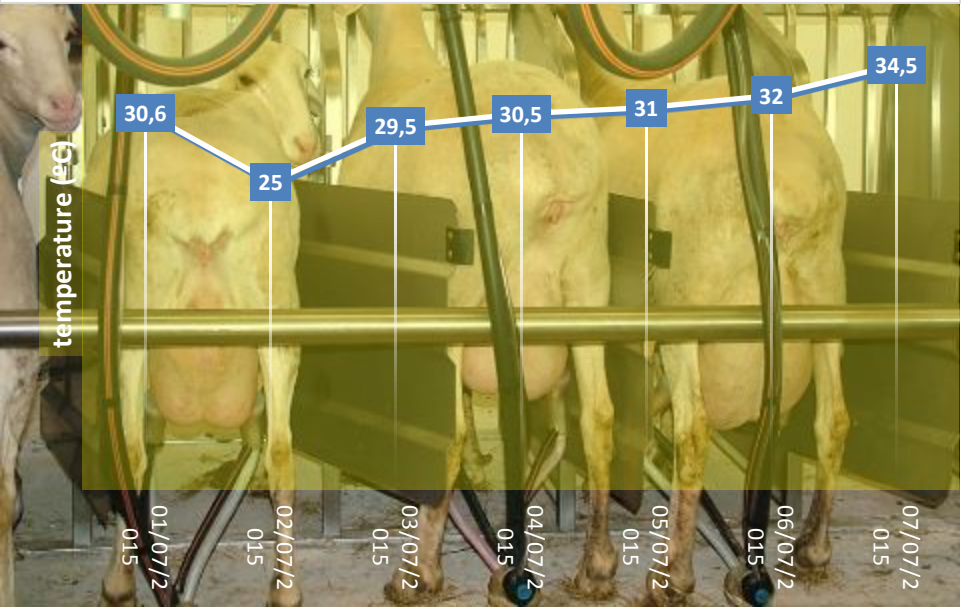
Effect of heat on milk production & DM intake





HS (non-adapted)

Aprox. 13% reduction in milk,
0.12 kgDM extra/L milk

HS (adapt-diet)

More dense diet: more soybean meal
Aprox. 2% reduction in milk,

HS (adapt-spraying)

Small positive effect, aprox. 10% reduction in milk

Southern (Mediterranean) region

Adaptation measures:

- Mediterranean systems traditionally had to adapt

Thank you!

iSAGE Training Course

10-13 December, Zaragoza, Spain

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