iSAGE TRAINING COURSE

Innovation to enhance the sustainability of sheep and goat production systems

21–22 October 2019, Meknès (Morocco)

Impact of climate change on sheep and goat systems

bc3
BASQUE CENTRE FOR CLIMATE CHANGE
Klima Aldaketa Ikergai

Outline:

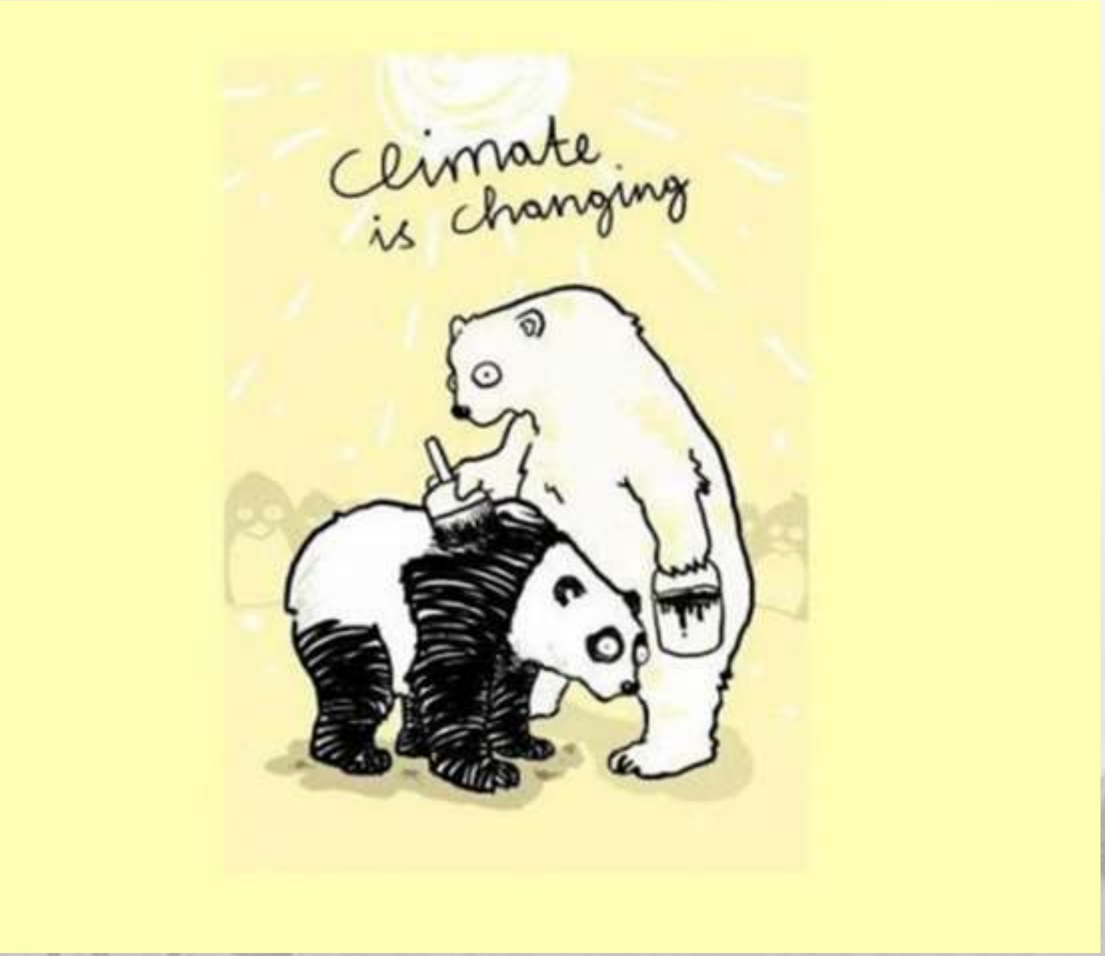
1. General overview of climate change (CC)

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

What is climate change?



Bio-physical Evidences

Impacts

Solutions:
- Mitigation
- Adaptation

What is climate change?

Met Office warns of global temperature rise exceeding 1.5C limit

In next five years greenhouse gases may push global warming past threshold set by Paris deal

tograph: The Washington

y agreed upper 1.5C
ritish scientists that
nate change.

Global warming made 2014 a record hot year – in animated graphics

2014 was the hottest year on record, without assistance f

The sun rises in Pleasant Plains, Illinois. Photograph: Seth Perlman/AP

NASA and NOAA have just reported that global surface ter
the hottest on record. That also means 2014 was likely the
been in millennia, and perhaps as much as 100,000 years.

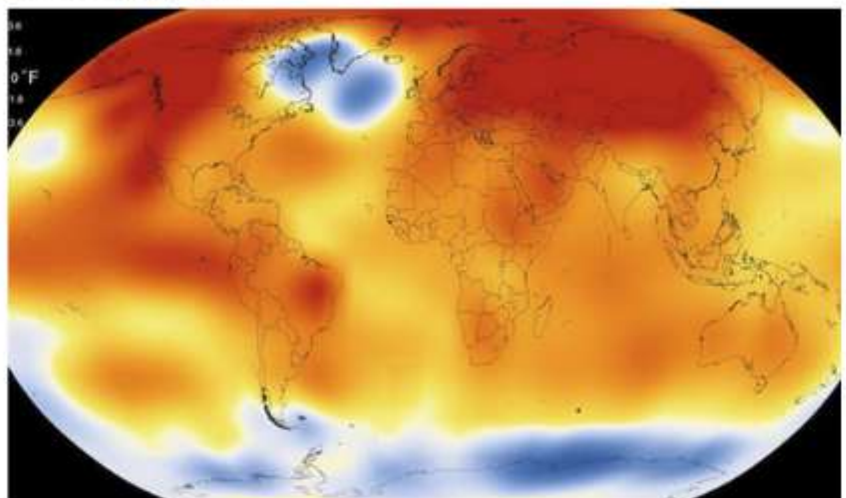
But what's really remarkable is that 2014 set this record w

64

79

Record hot 2015 gave us a glimpse at the future of global warming

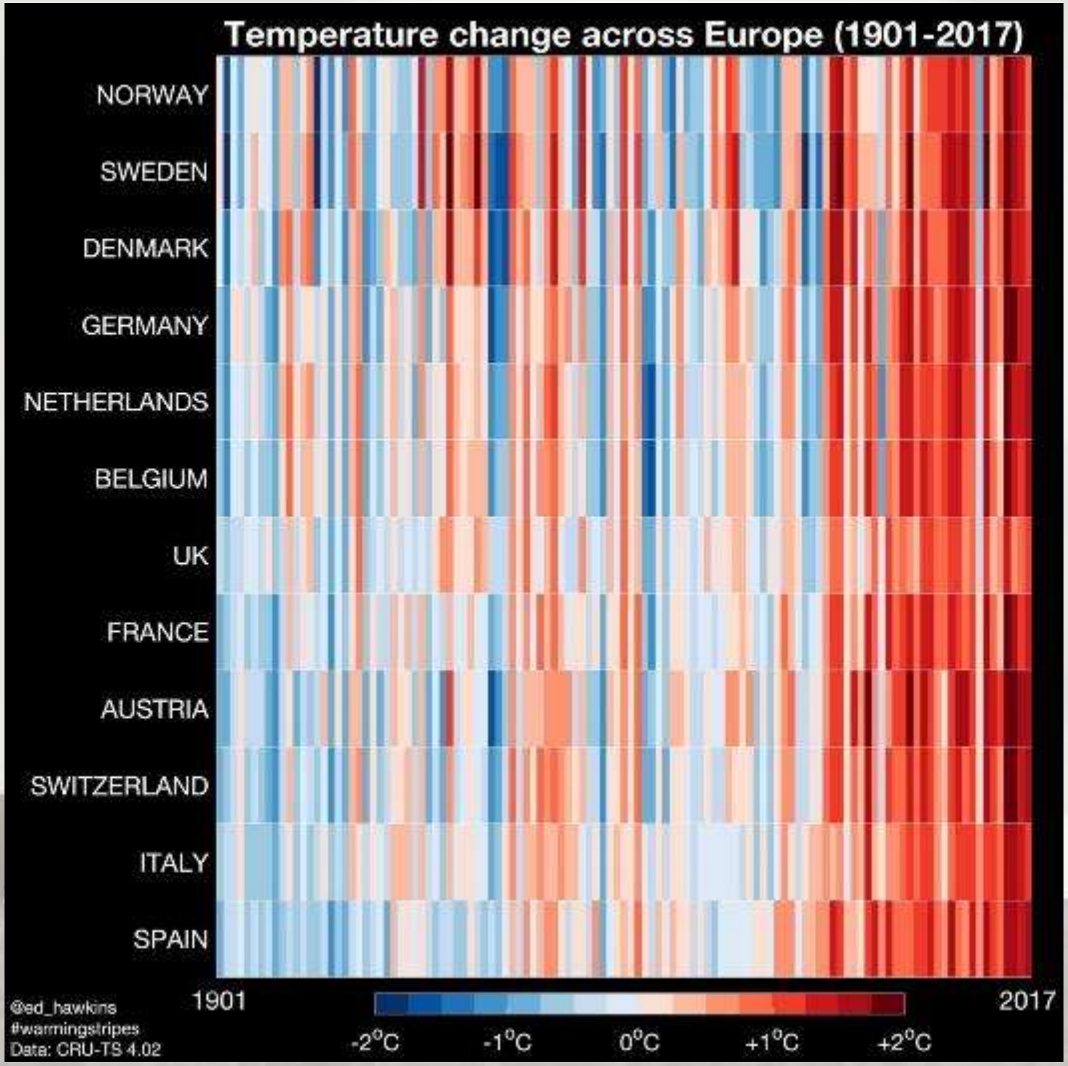
An exceptionally hot year, 2015 shattered records, but will just be the norm in 15 years' time



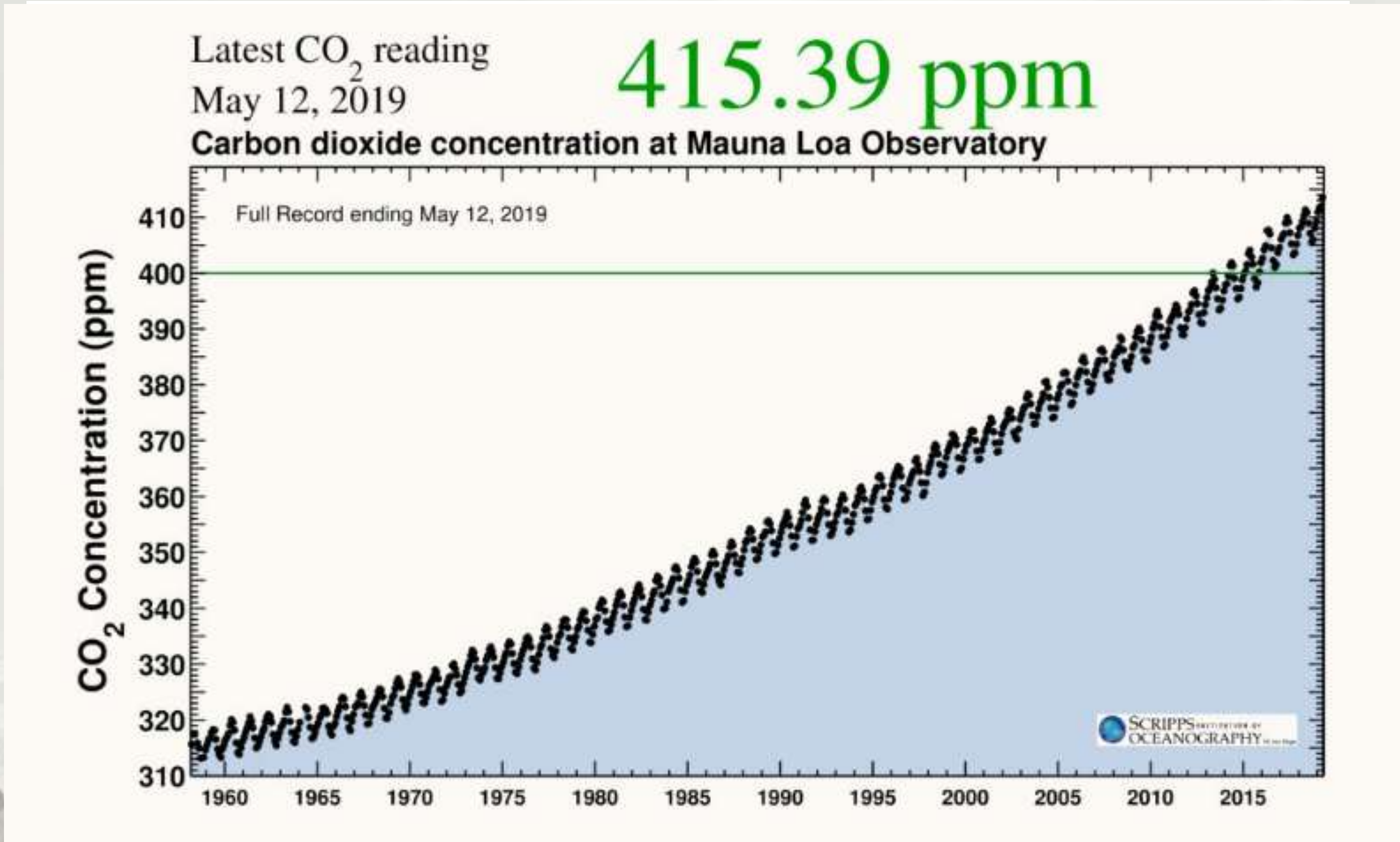
This illustration obtained from NASA on January 20, 2016 shows that 2015 was the warmest year since modern record-keeping began in 1880, according to a new analysis by NASA's Goddard Institute for Space Studies. Photograph: HANDOUT/AFP/Getty Images

2015 smashed the record for hottest year by about 0.14°C. To put that into perspective, the previous two hottest years (2014 and 2010) only broke the prior records by 0.002°C, according to Berkeley Earth data. The only time the

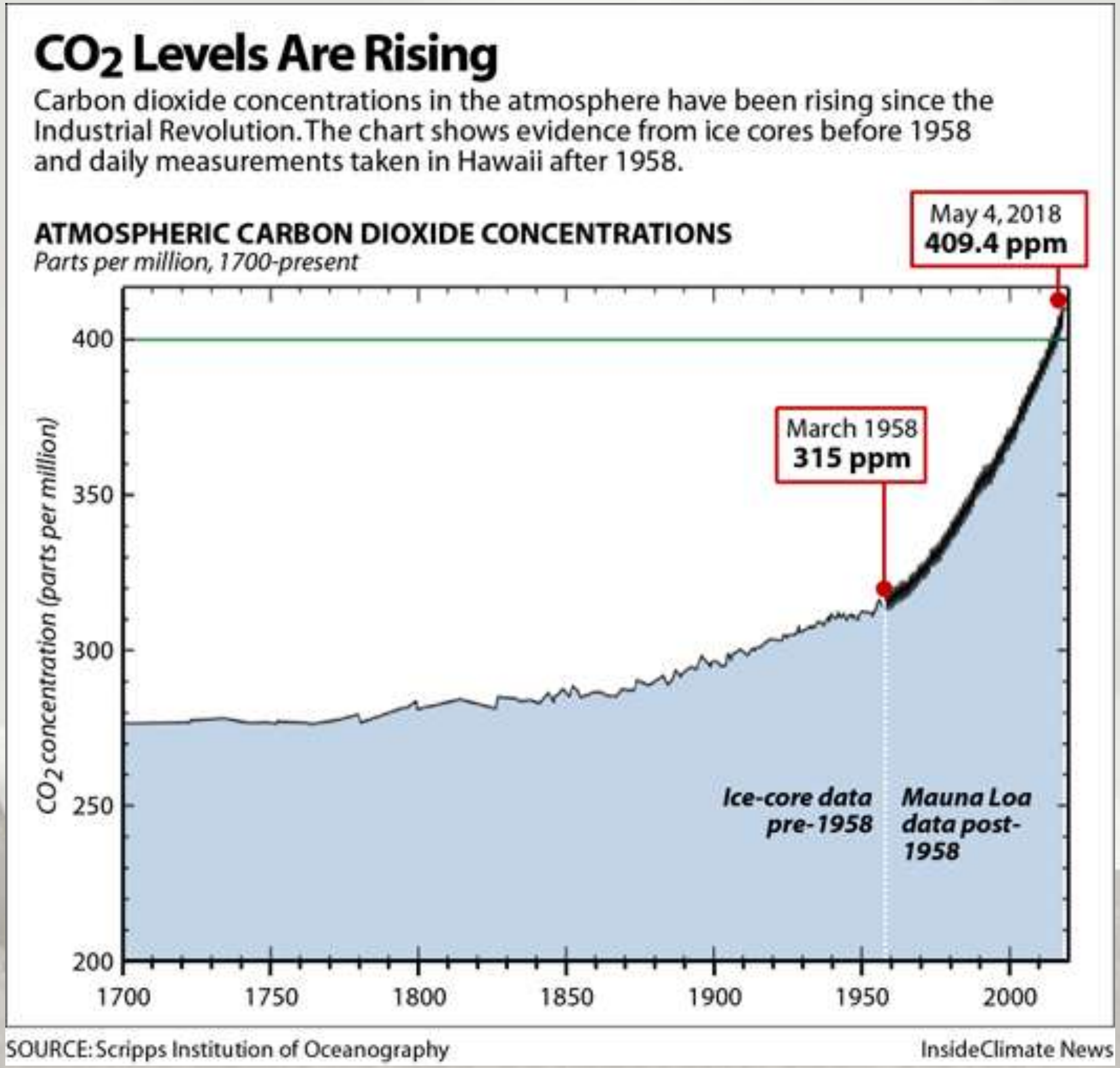
Global temperatures



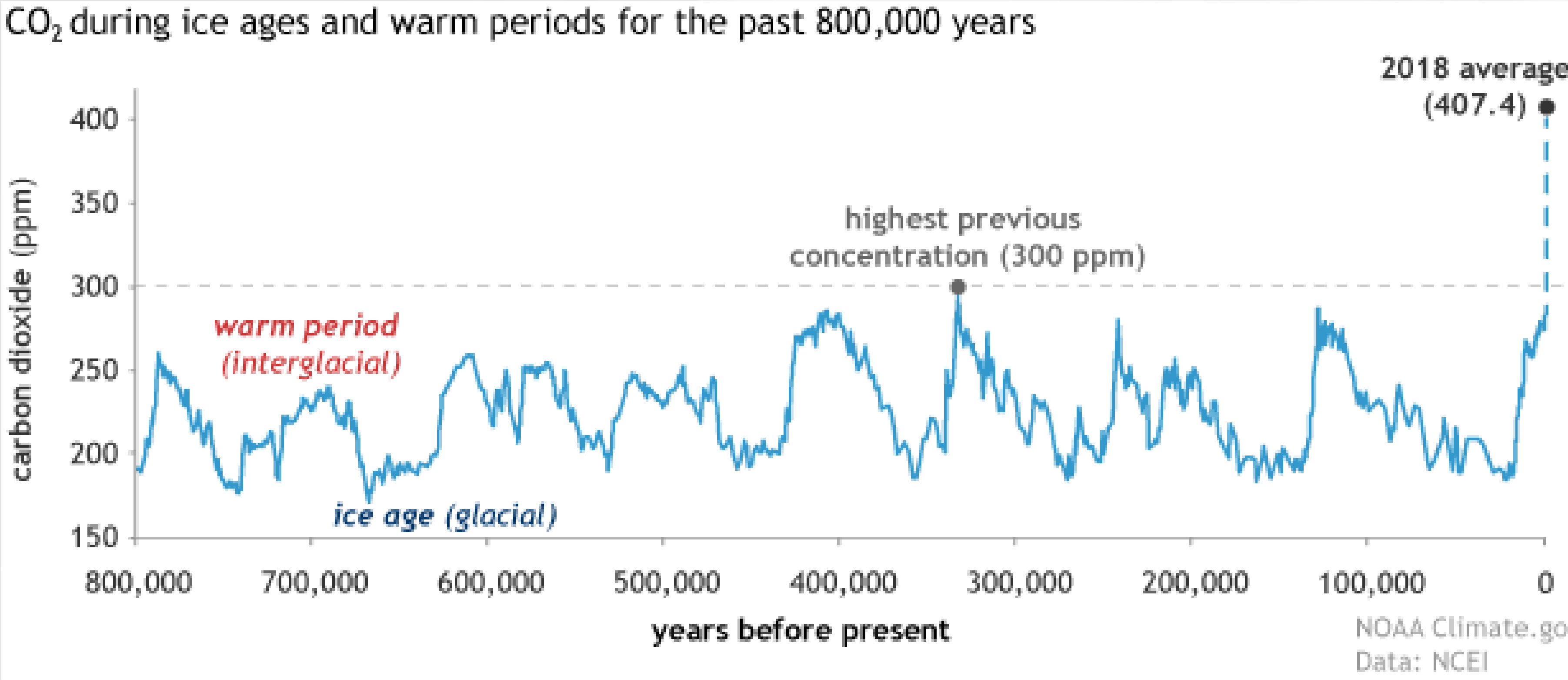
Carbon dioxide (CO_2)



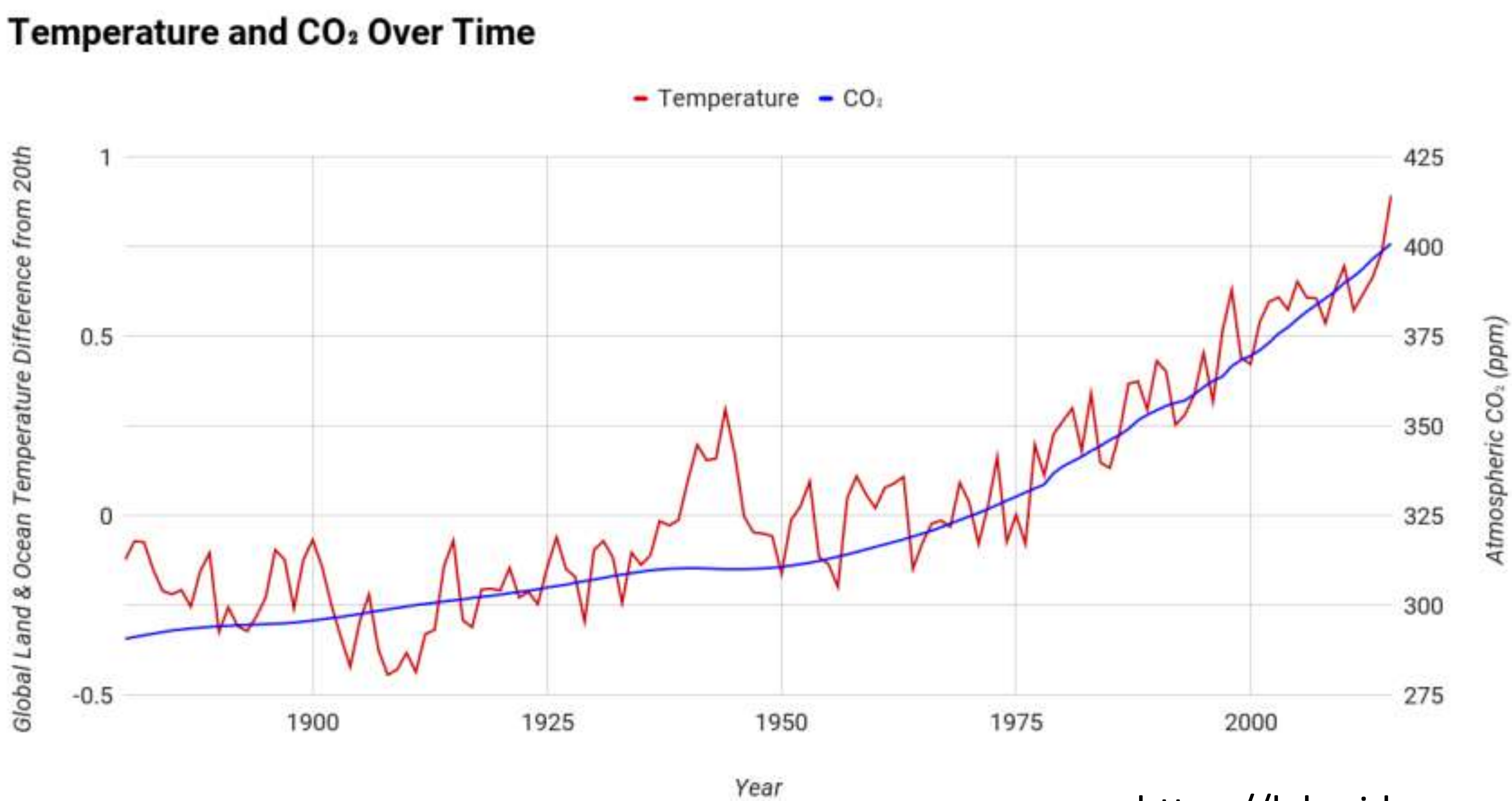
Carbon dioxide (CO_2)



Historic CO_2 trend



CO_2 emissions



https://lab-aids.com

Greenhouse effect

THE ARTIFICIAL PRODUCTION OF CARBON DIOXIDE 223

551.510.4 : 551.521.3 : 551.524.34

THE ARTIFICIAL PRODUCTION OF CARBON DIOXIDE AND ITS INFLUENCE ON TEMPERATURE

By G. S. CALLENDAR

(Steam technologist to the British Electrical and Allied Industries Research Association.)

(Communicated by Dr. G. M. B. Dobson, F.R.S.)

[Manuscript received May 19, 1937—read February 16, 1938.]

SUMMARY

By fuel combustion man has added about 150,000 million tons of carbon dioxide to the air during the past half century. The author estimates from the best available data that approximately three quarters of this has remained in the atmosphere.

The radiation absorption coefficients of carbon dioxide and water vapour are used to show the effect of carbon dioxide on "sky radiation." From this the increase in mean temperature, due to the artificial production of carbon dioxide, is estimated to be at the rate of 0·003°C. per year at the present time.

The temperature observations at 200 meteorological stations are used to show that world temperatures have actually increased at an average rate of 0·005°C. per year during the past half century.

THE

LONDON, EDINBURGH

PHILOSOPHICAL

AND

JOURNAL OF SCIENCE.

[FIFTH SERIES.]

APRIL 1896.

XXXI. *On the Influence of Carbonic Acid in the Air upon the Temperature of the Ground.* By Prof. SVANTE ARRHENIUS *.

I. *Introduction : Observations of* Langley *on Atmospherical Absorption.*

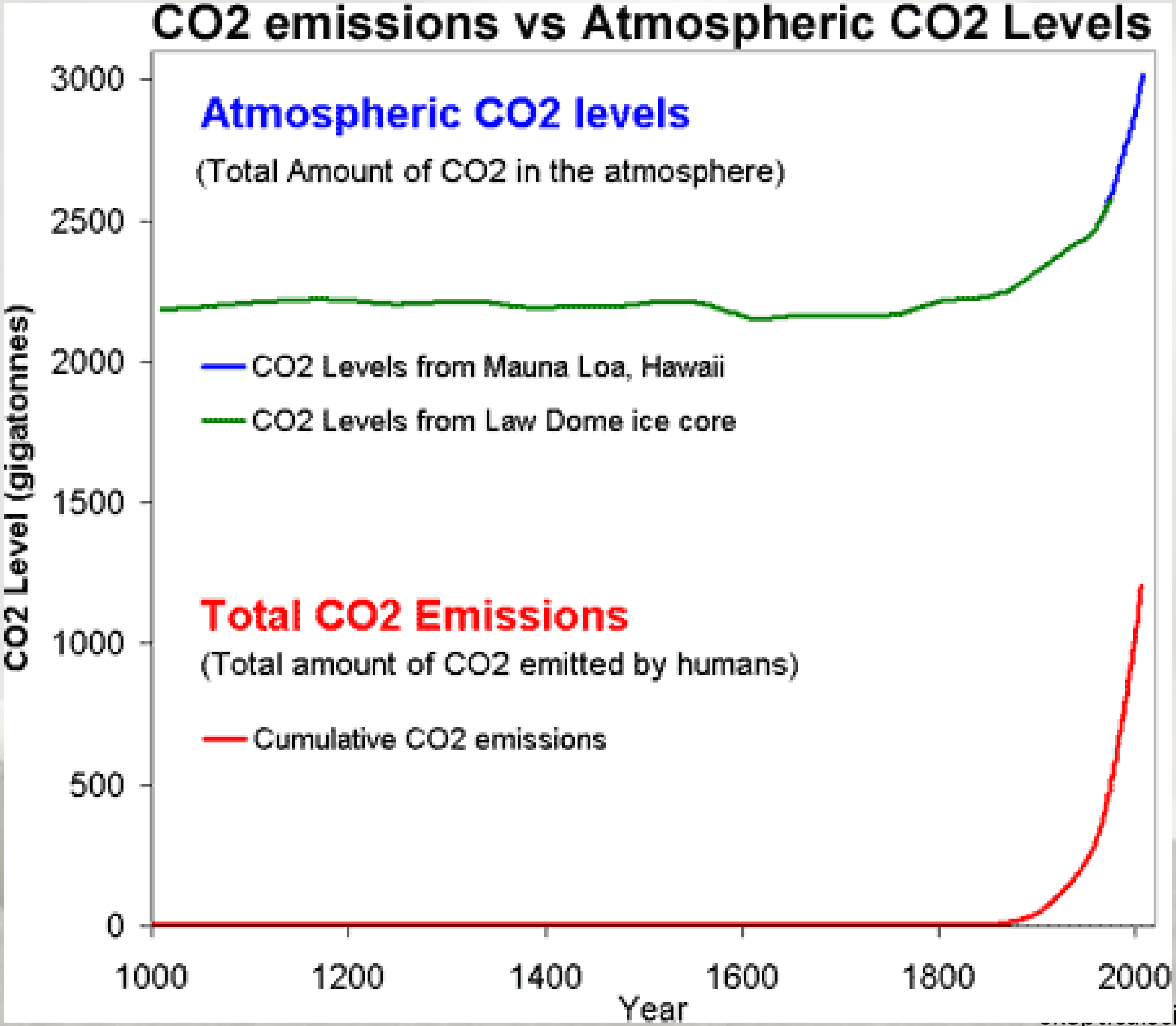
A GREAT deal has been written on the influence of the absorption of the atmosphere upon the climate. Tyndall † in particular has pointed out the enormous importance of this question. To him it was chiefly the diurnal and annual variations of the temperature that were lessened by this circumstance. Another side of the question, that has long attracted the attention of physicists, is this: Is the mean temperature of the ground in any way influenced by the presence of heat-absorbing gases in the atmosphere? Fourier‡ maintained that the atmosphere acts like the glass of a hot-house, because it lets through the light rays of the sun but retains the dark rays from the ground. This idea was elaborated by Pouillet § ; and Langley was by some of his researches led to the view, that "the temperature of the earth under direct sunshine, even though our atmosphere were present as now, would probably fall to −200° C., if that atmosphere did not possess the quality of selective

* Extract from a paper presented to the Royal Swedish Academy of Sciences, 11th December, 1895. Communicated by the Author.
† 'Heat a Mode of Motion,' 2nd ed. p. 405 (Lond., 1865).
‡ *Mém. de l'Ac. R. d. Sci. de l'Inst. de France*, t. vii. 1827.
§ *Comptes rendus*, t. vii. p. 41 (1838).

Phil. Mag. S. 5. Vol. 41. No. 251. *April* 1896. S

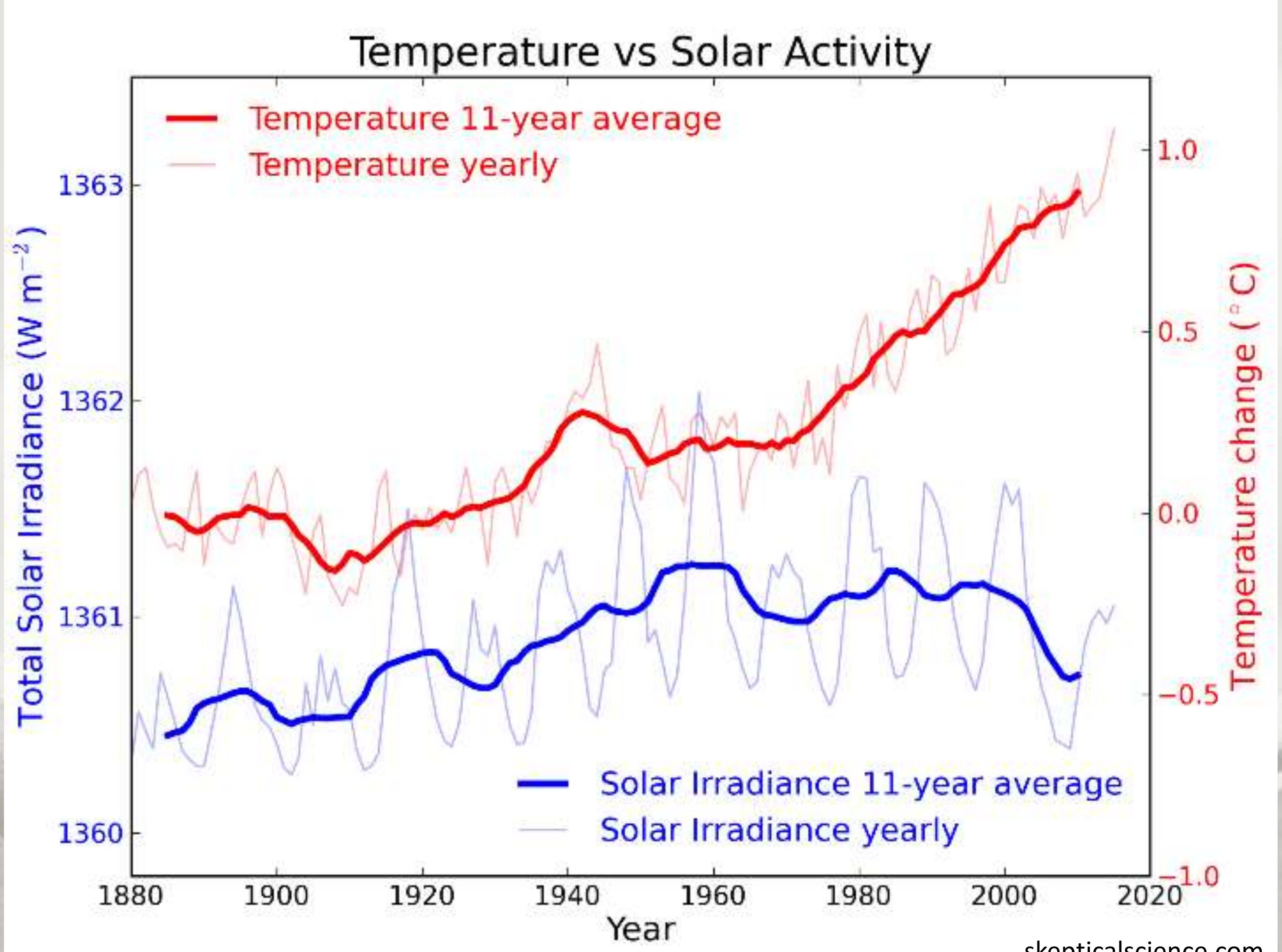
"At the turn of the 19th century, Svante Arrhenius calculated that emissions from human industry might someday bring a global warming. Other scientists dismissed his idea as faulty. In 1938, G.S. Callendar argued that the level of carbon dioxide was climbing and raising global temperature, but most scientists found his arguments implausible. It was almost by chance that a few researchers in the 1950s discovered that global warming truly was possible."
https://history.aip.org/climate/co2.htm

Human-caused global warming



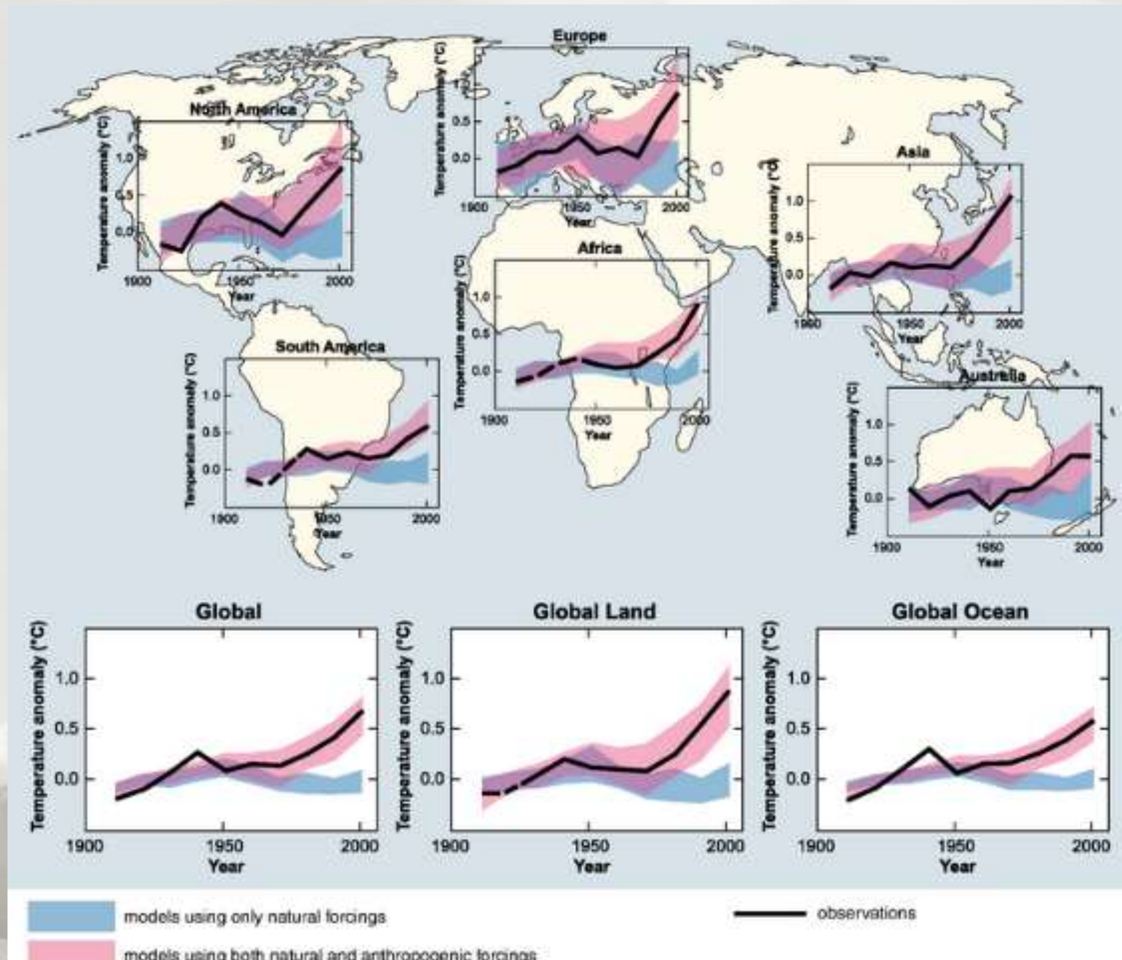
ience.com

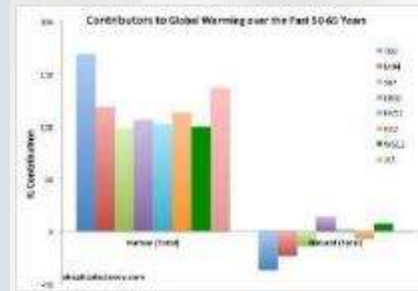
Human-caused global warming

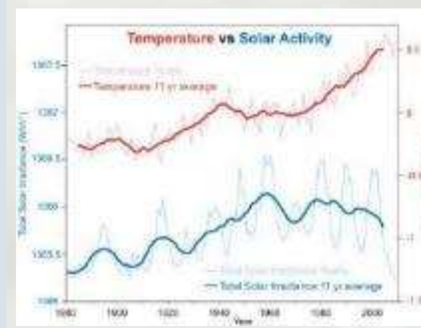


skepticalscience.com

Human-caused global warming



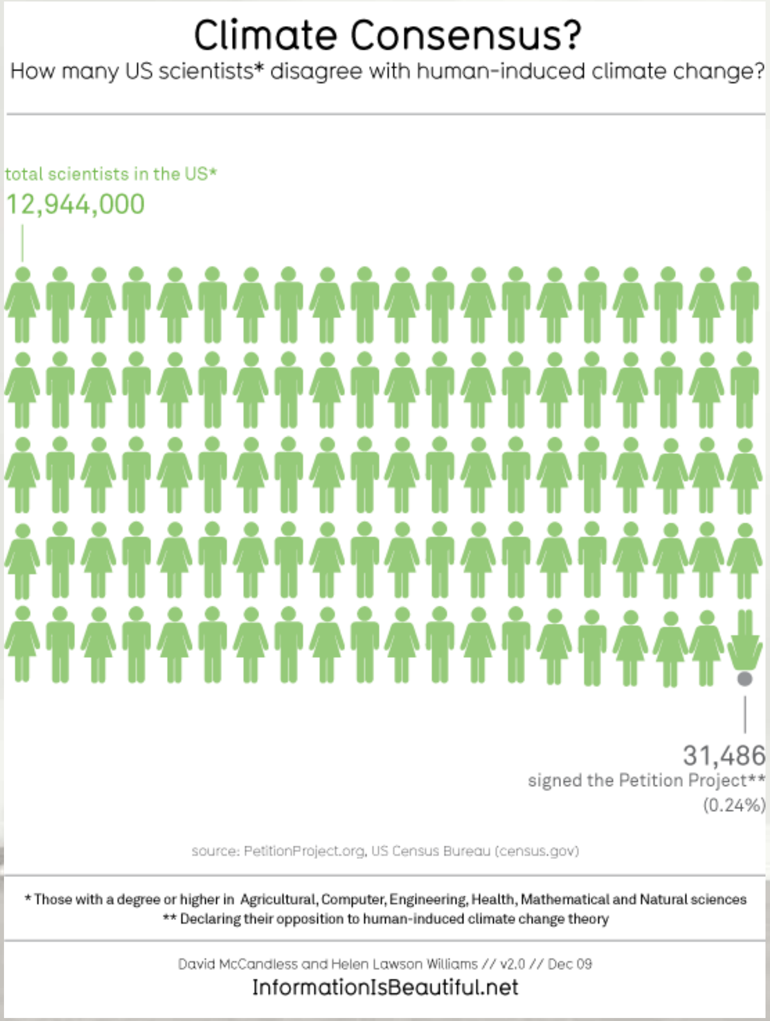




IPCC, 2007

https://www.ipcc.ch/publications_and_data/ar4/syr/en/spms2.html

Human-caused global warming

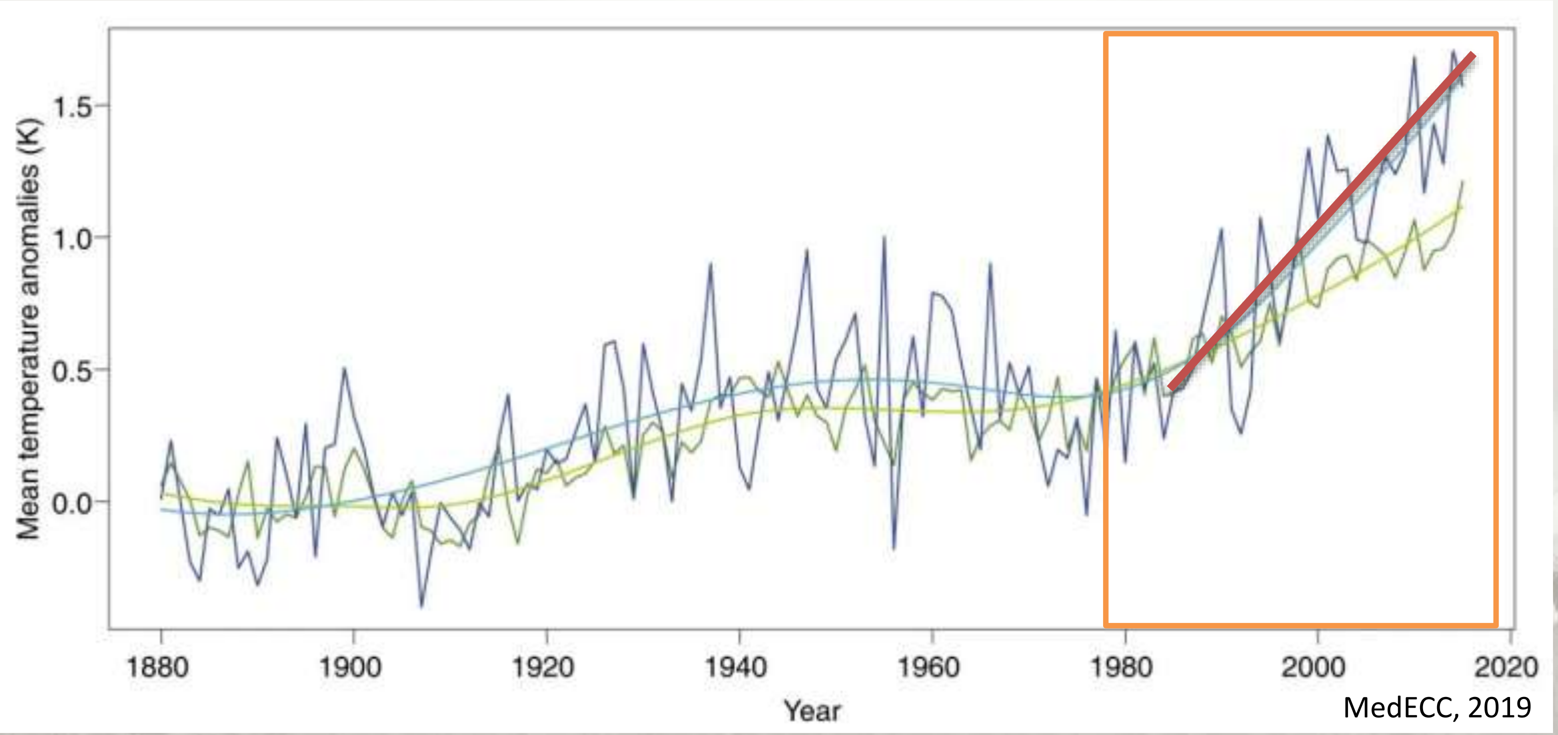


Impacts of climate change in the Mediterranean region

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)

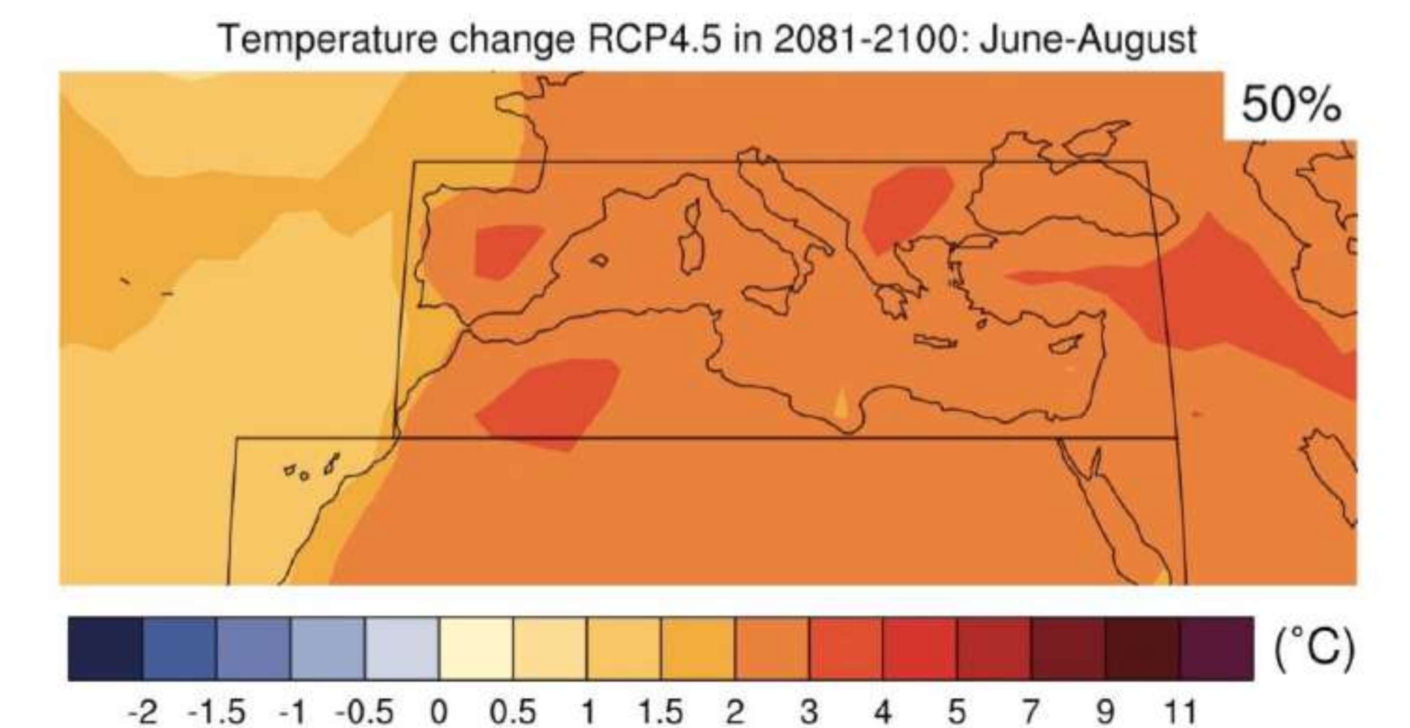


MedECC, 2019

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)

© Copyright : DR

28 mai 2019 - 20h20 - Maroc

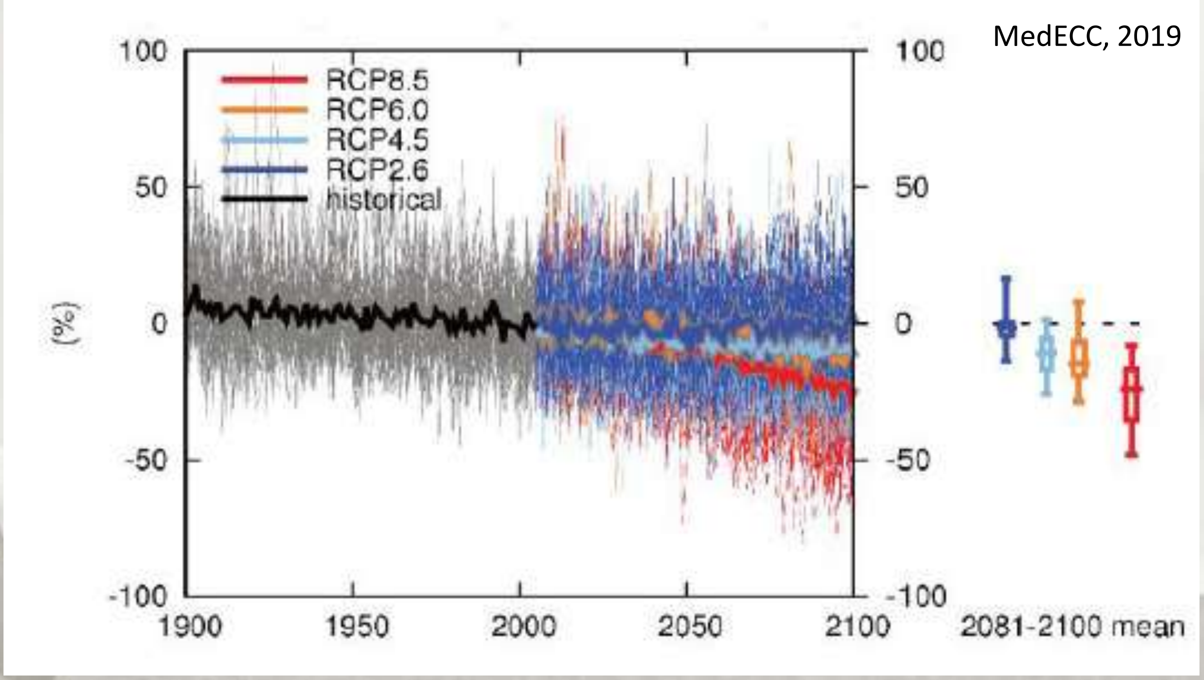
La vague de chaleur que connaît actuellement une bonne partie du Maroc va durer au moins jusqu'à dimanche, vient de prévenir la Direction de la météorologie nationale (DMN) dans un bulletin spécial.

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, Khouriga, 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)



Impacts of climate change

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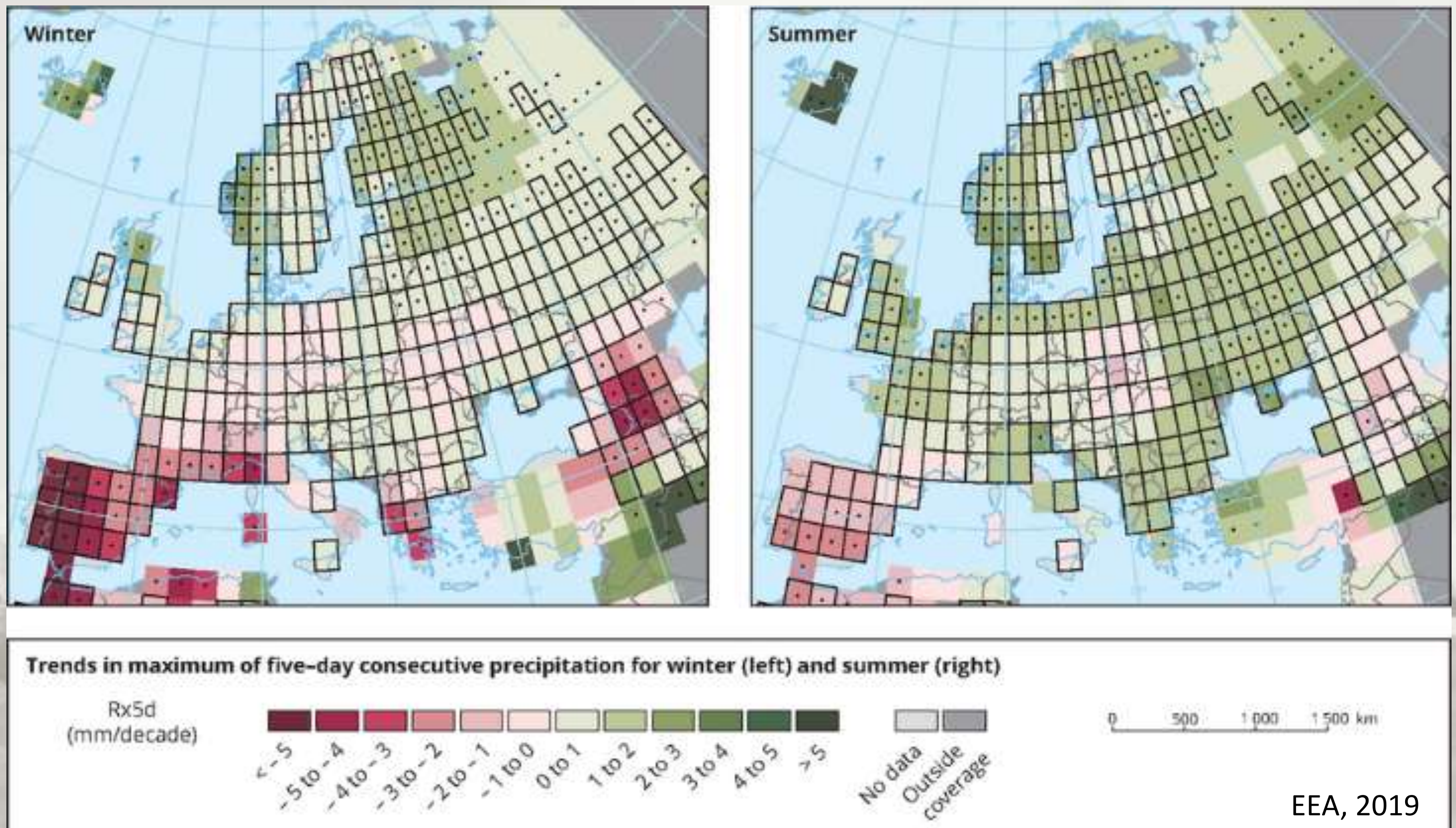

EEA, 2019

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)

The Guardian, 2017

Impacts of climate change

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elindependiente.com, 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)

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 reubicado. CARLOS ROSILLO

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

El País, 2017

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

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 5 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

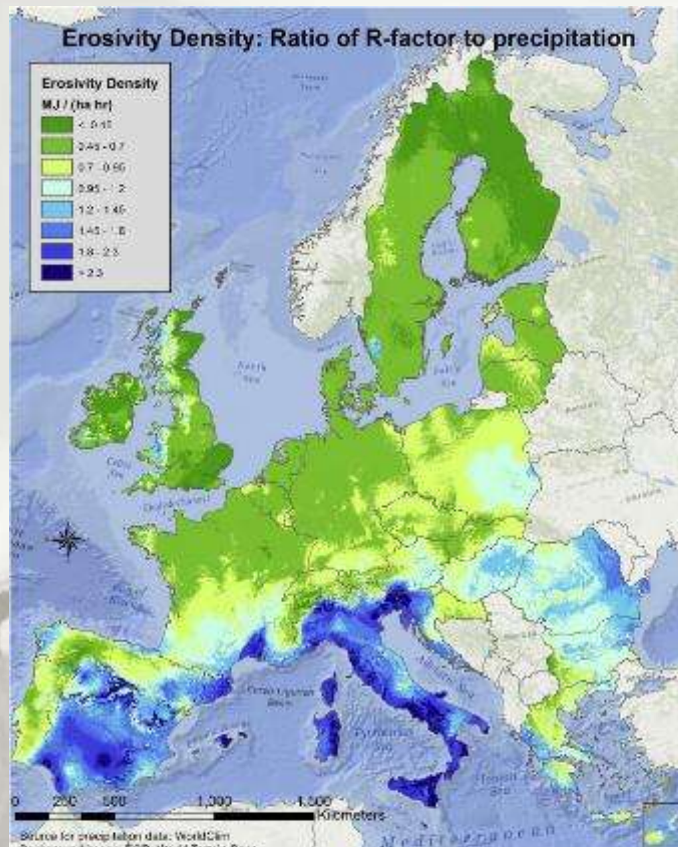
Human-caused climate change dramatically increased the likelihood of the

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

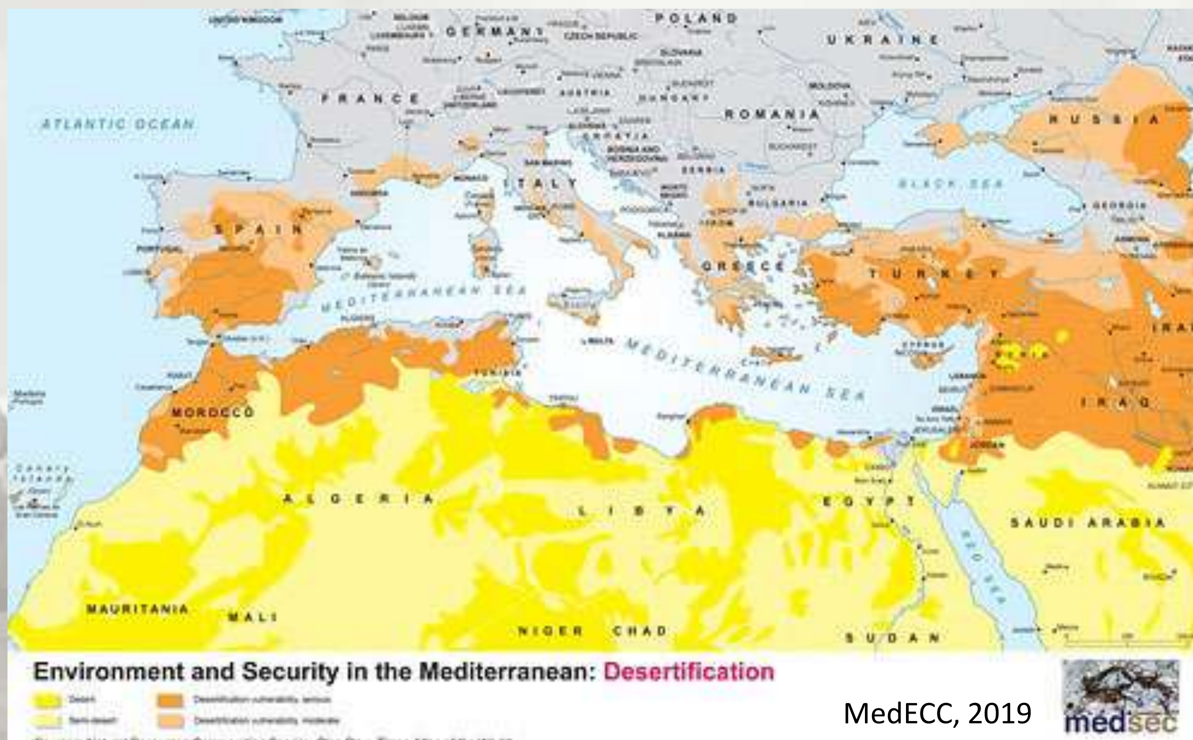


Panagos et al., 2015

Impacts of climate change

Other consequences:

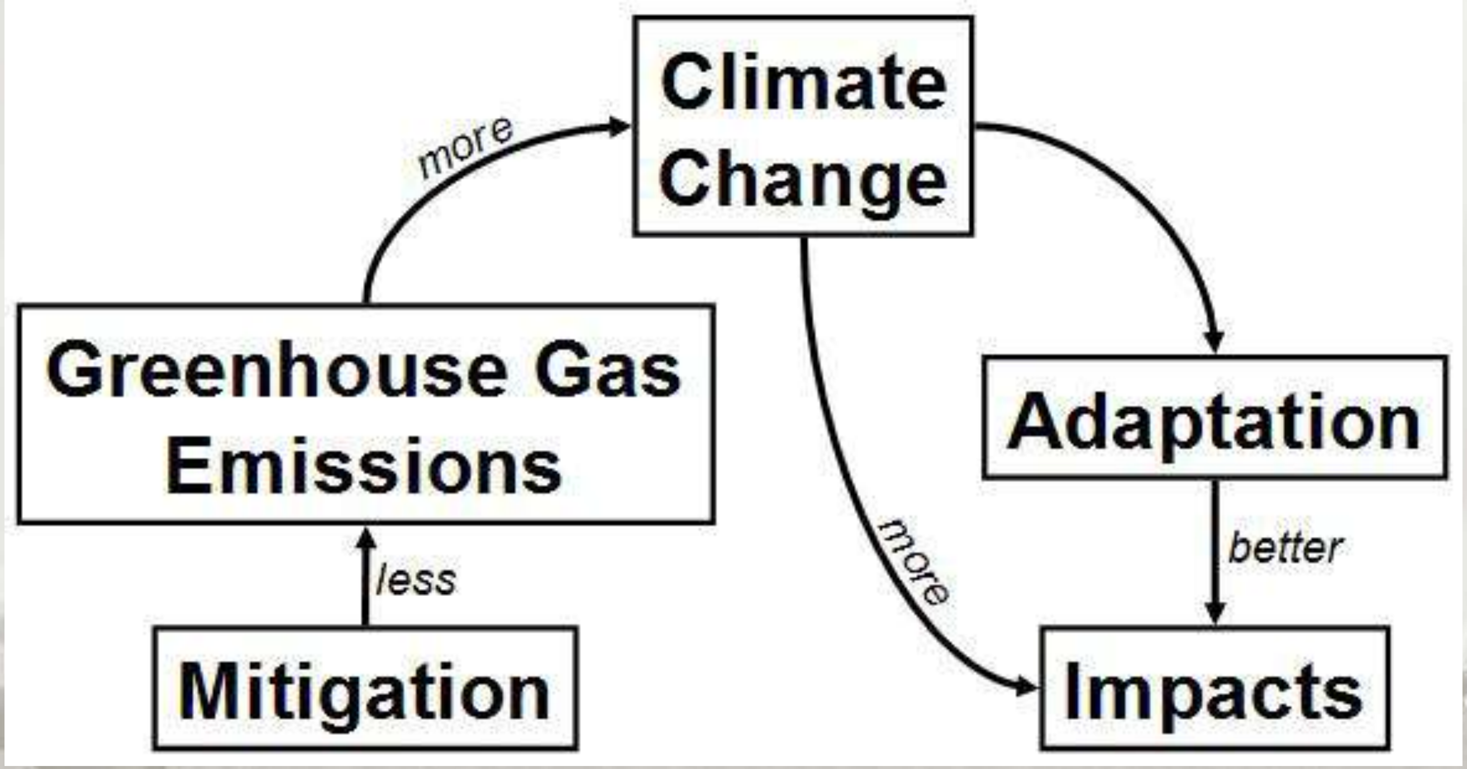
- **Increased risk of fires** due to drought and heat waves but also to changes in land management (MedECC, 2019)
- **Increased risk of erosion** due to couple effect of heavy rainfall events and fires
- **Desertification**: warming and drought is expected to increase aridity and subsequent desertification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

Climate change

Effects at animal level

Increased temperature & radiation

↓

Heat stress

↓

Behavioural & metabolic changes

Productivity & product quality | Reproduction | Animal health & welfare

Effects on feed supply

Increased temperature. Changes in precipitation. Extreme events

↓

Heat & water stress. Changes in growing season length & water availability

↓

Changes in crop & pasture growth

Productivity & quality of forage | Pests & diseases | Availability of concentrates

Effects on small ruminant systems

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

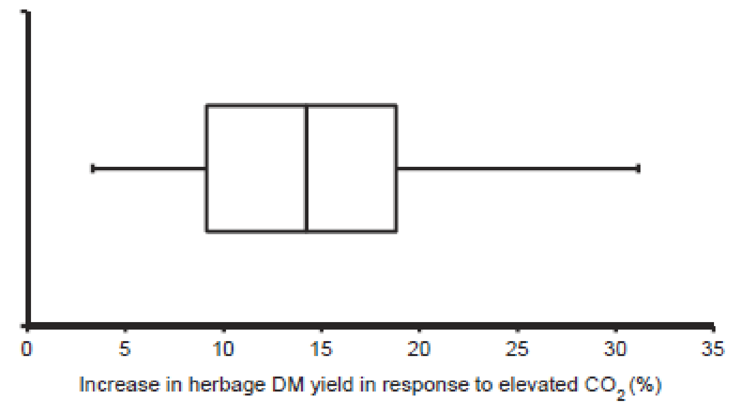


Figure I Variability in the annual herbage dry matter (DM) yield response of temperate pastures to elevated CO_2 (600–700 ppm) under optimal nutrient supply, displayed as ranges (whiskers), 25th percentile to the 75th percentile (boxes) and the median line. Created using 44 annual means from control 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

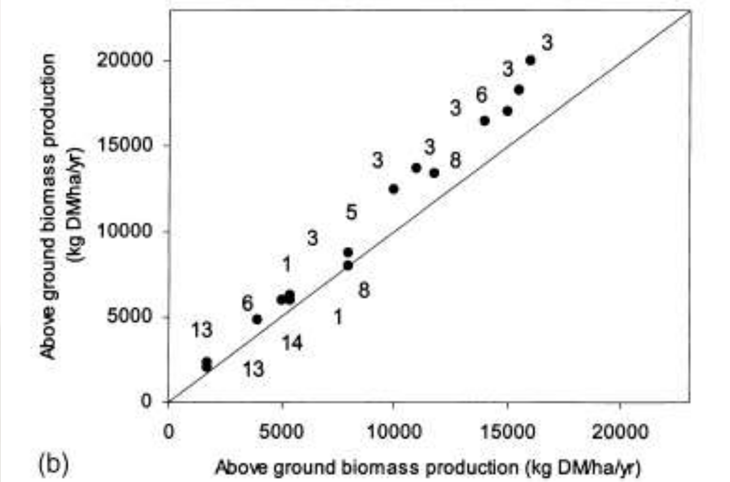
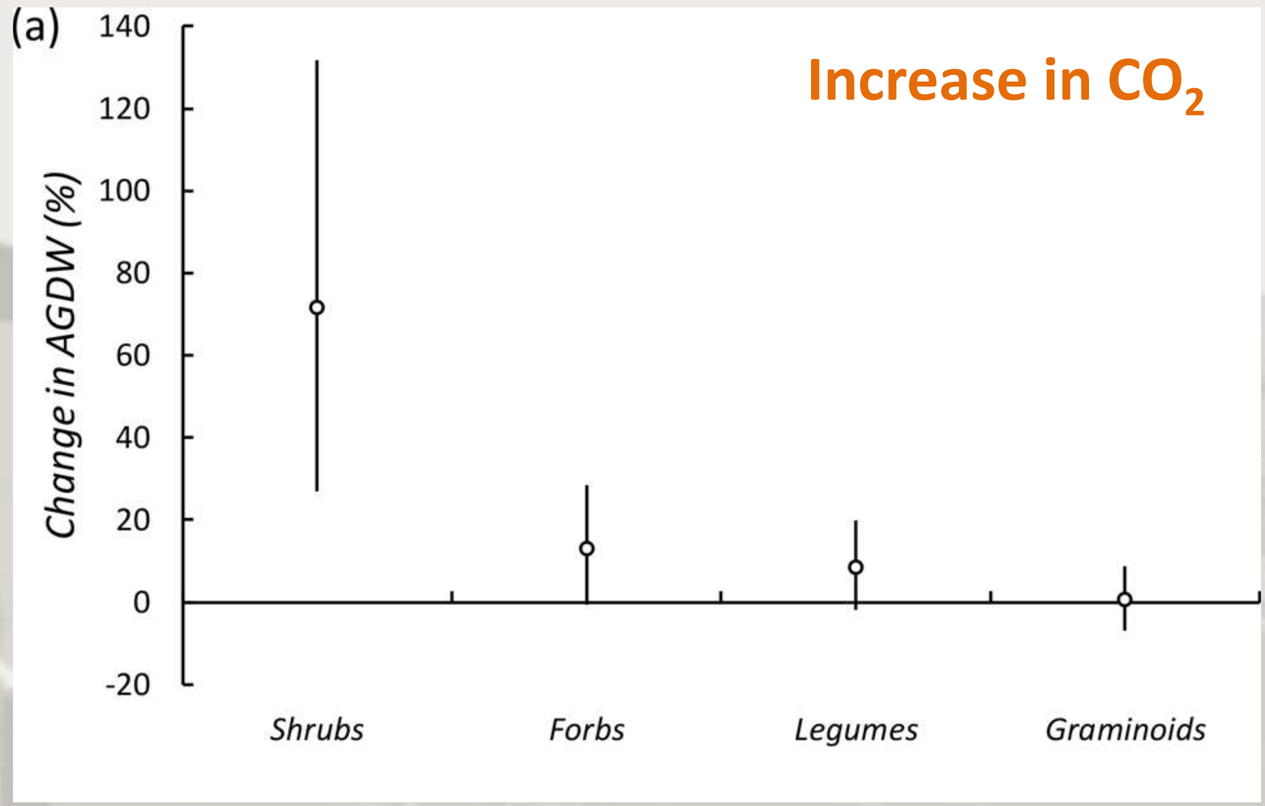


Fig. 2. Effect of doubled ambient CO_2 on above-ground biomass production plotted against above-ground biomass production at the current CO_2 concentration for different pasture and rangeland systems: (a) percentage effect; (b) absolute effect. Numbers refer to studies listed in Table 1: (1) M. Jones, 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.

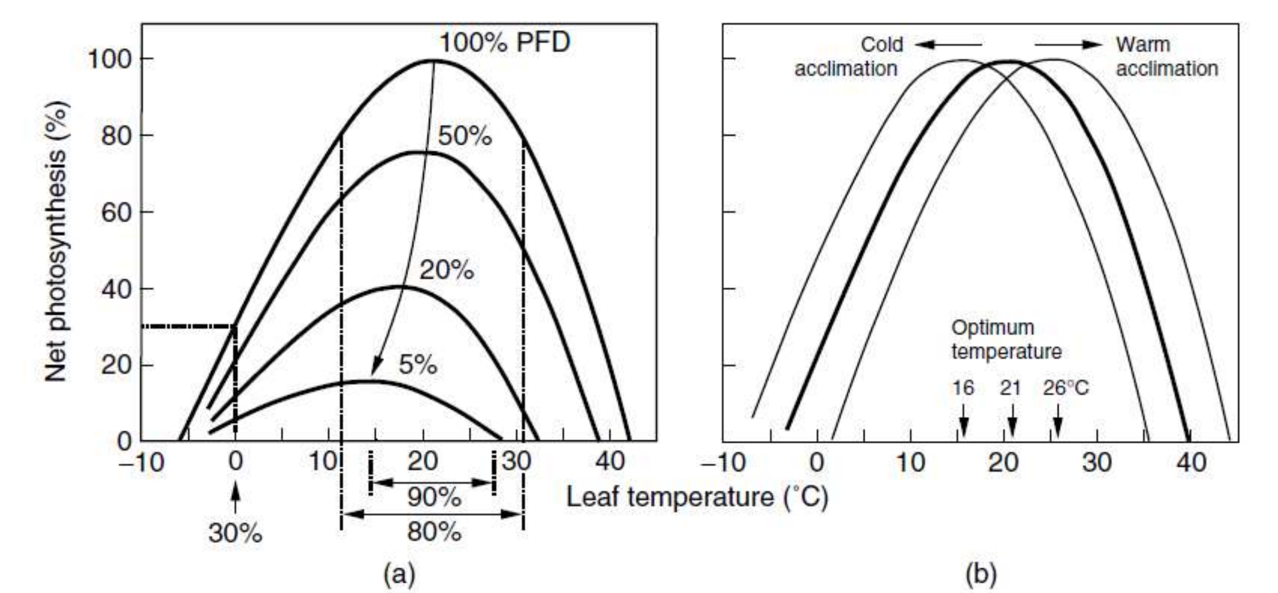
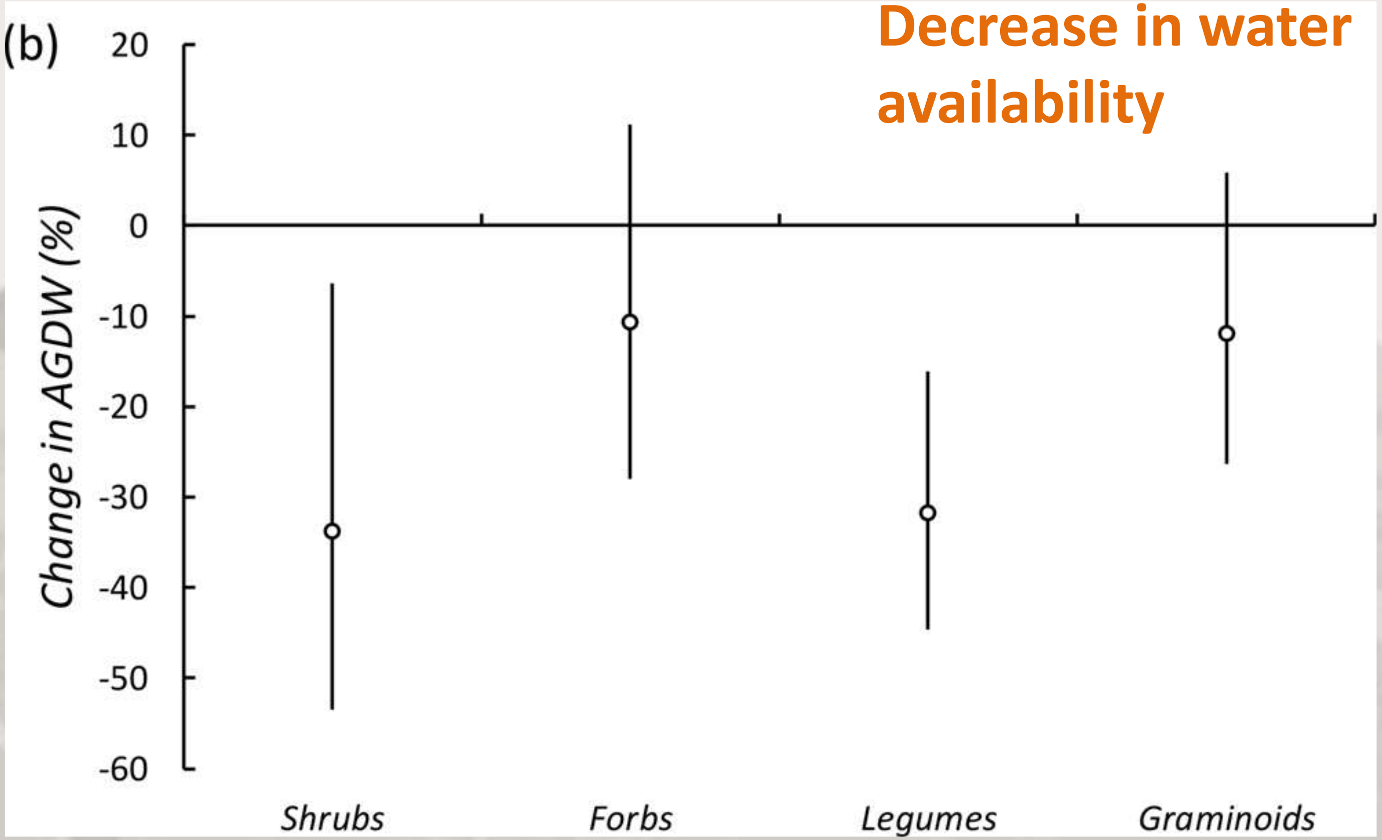


Figure 3.1 The 'classical' responses of net photosynthesis of leaves (A) to temperature (cf. Larcher, 1969, 2003). (a) Typical response curves for a temperate plant species measured at different light

Körner et al., 2006

Effects of CC on forage production

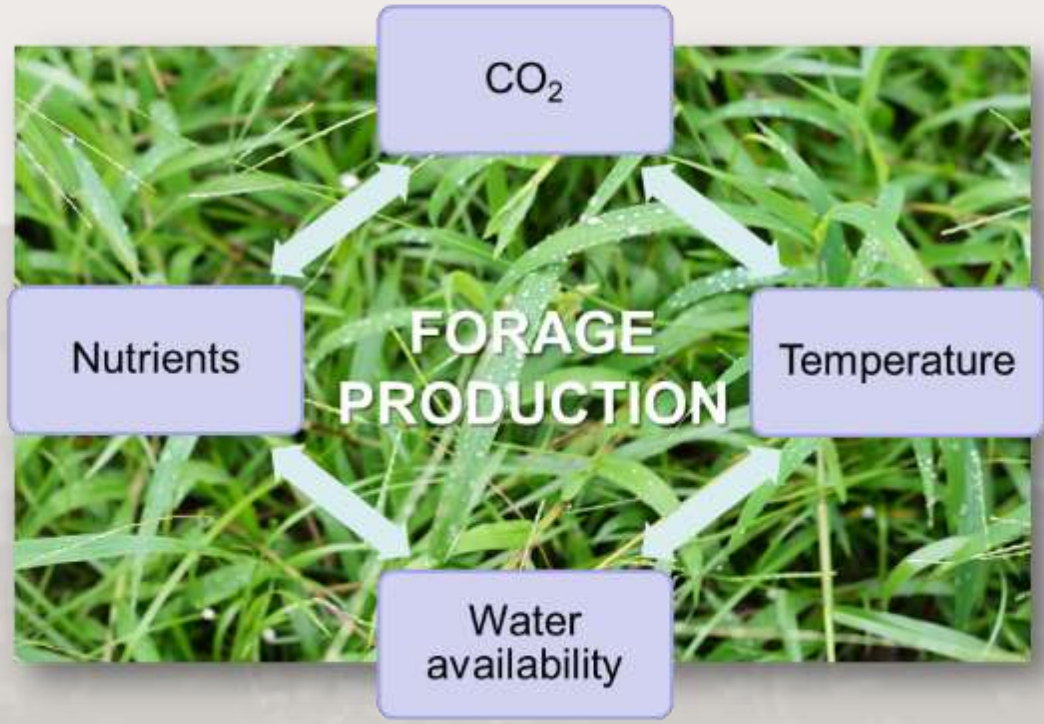
- Reduced water availability decrease production



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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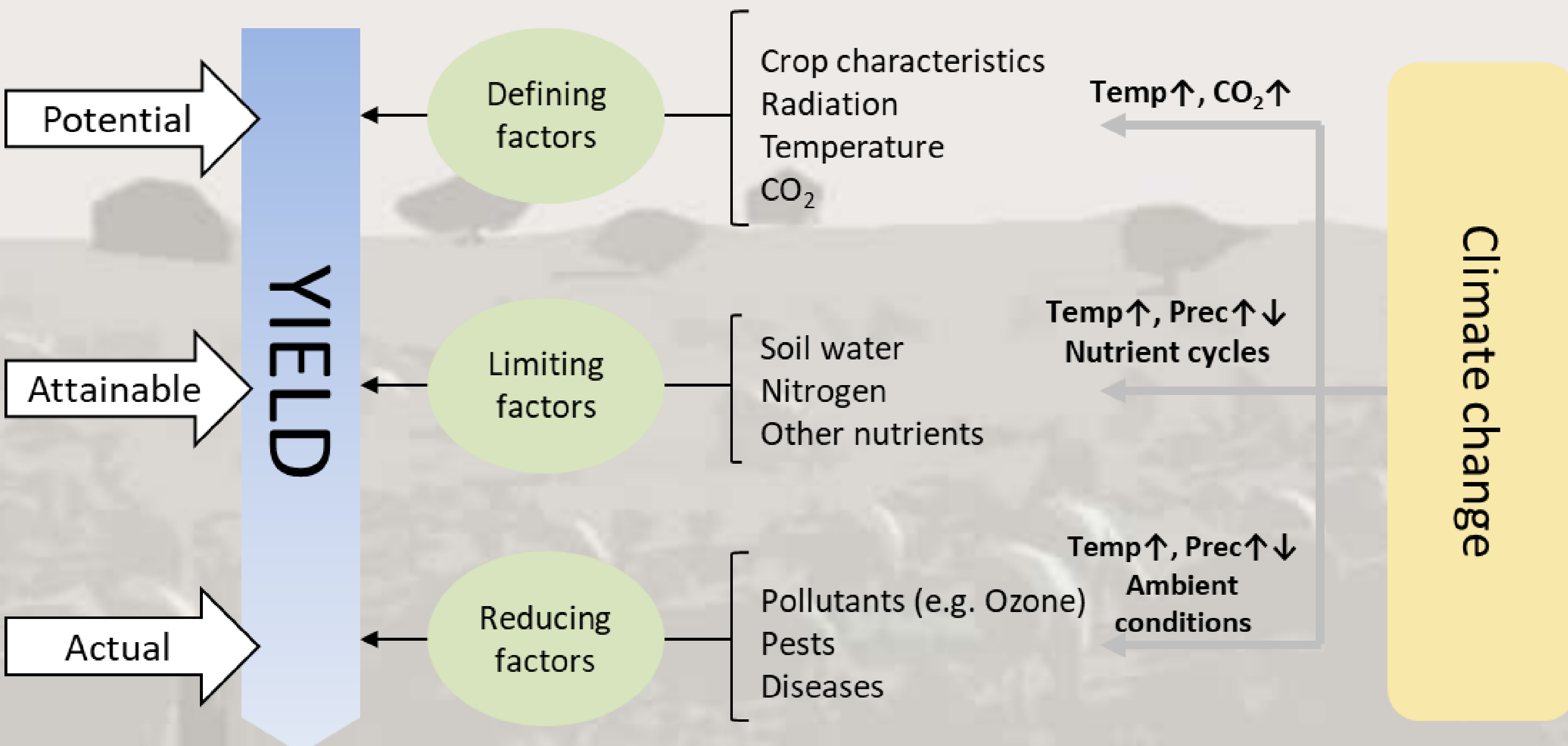

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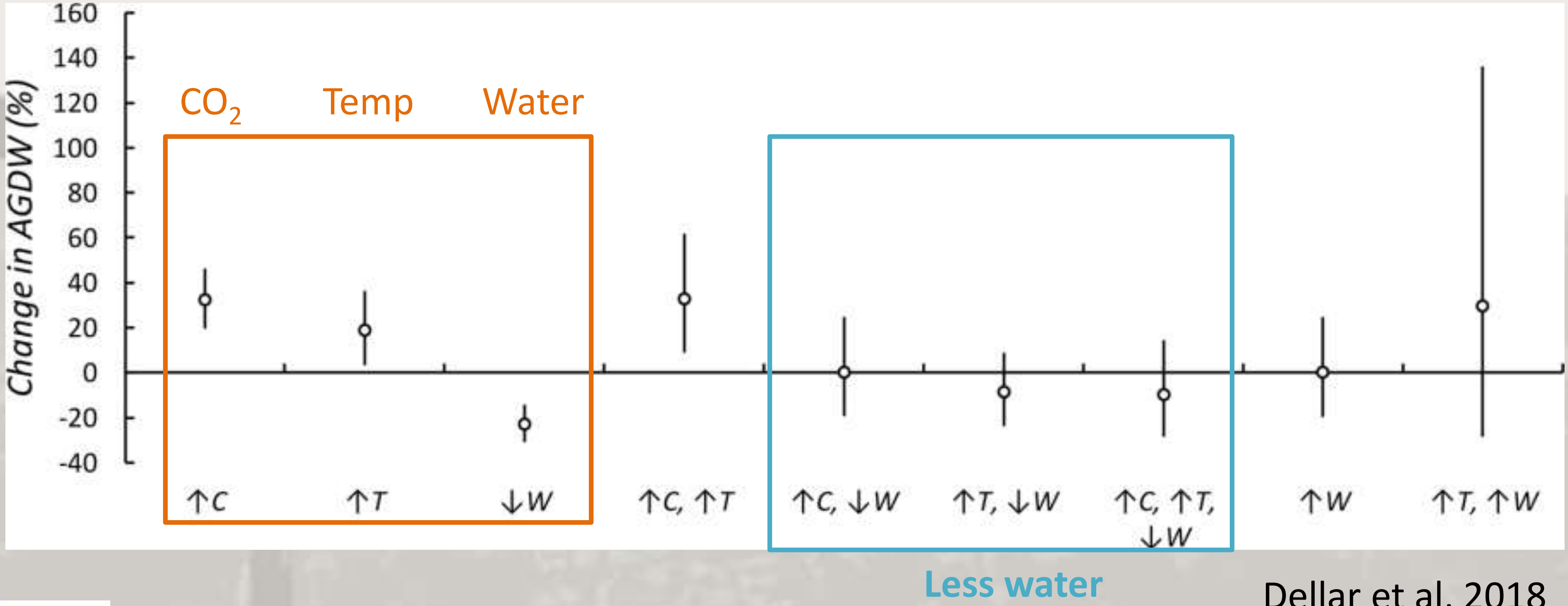
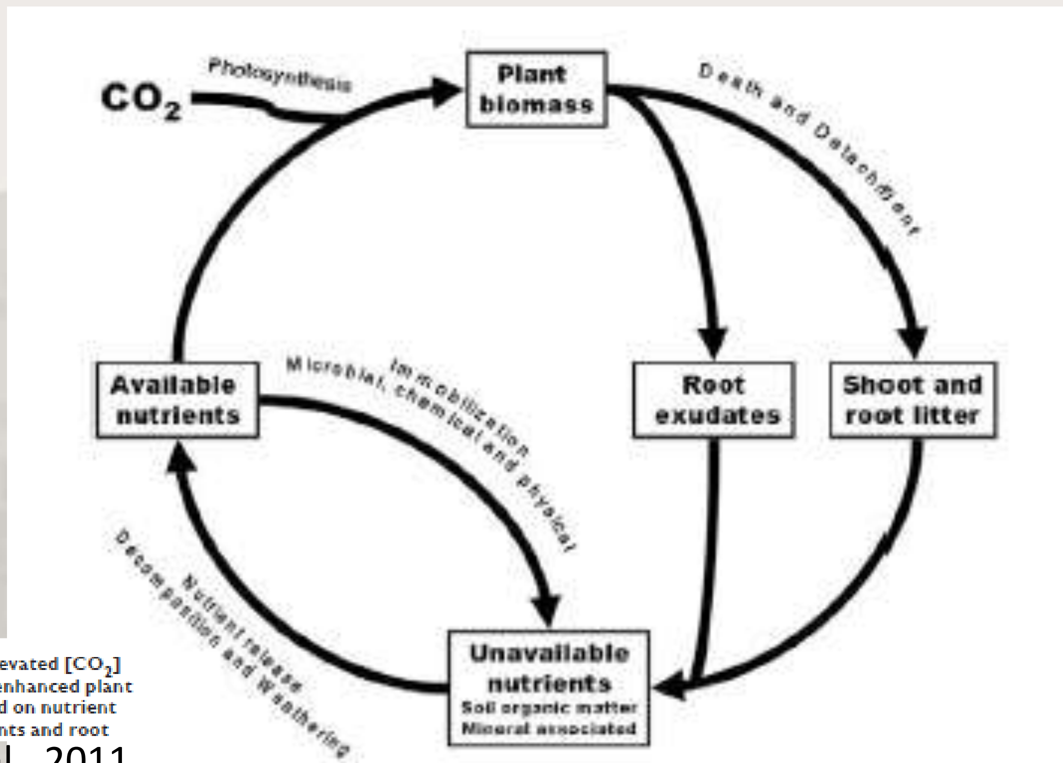


Dellar et al, 2018

Effects of CC on forage production

- Little or negligible response has been observed in pastures with low N supply. Increased production may not be sustained in **natural and semi-natural ecosystems** due to nutrient limitations (Luo et al., 2004)



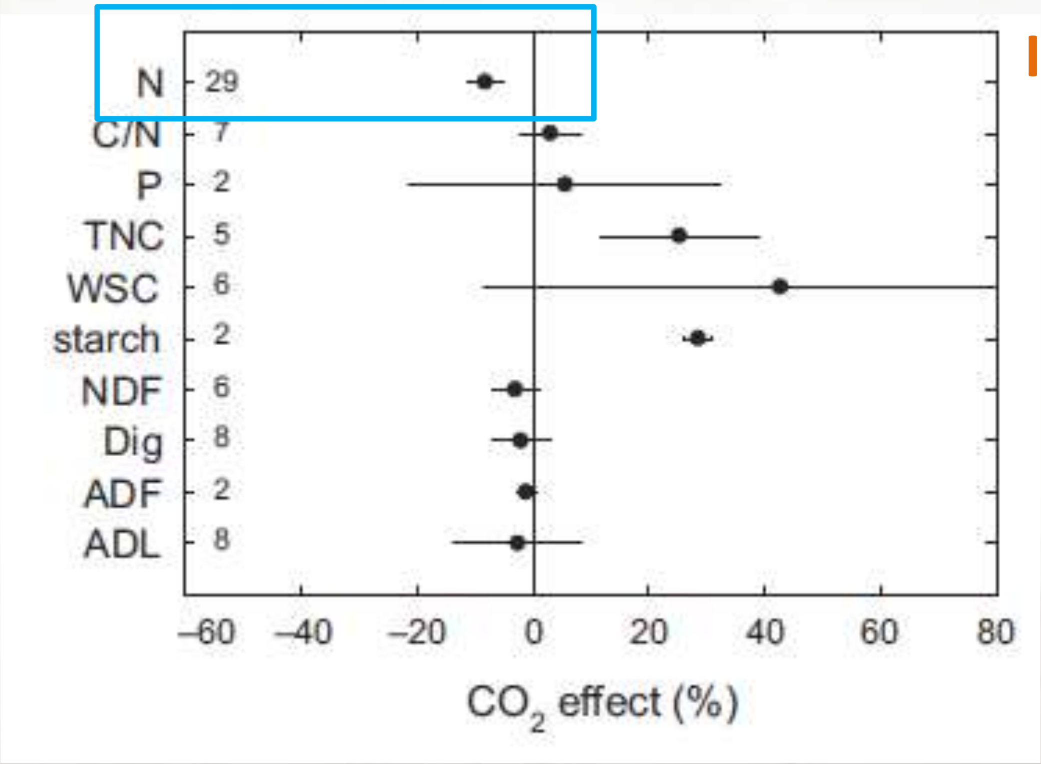
Morgan, 2002

Fig. 3. Nutrient cycling feedbacks. While elevated [CO_2] may lead to increased photosynthesis and enhanced plant growth; the long-term response will depend on nutrient cycling feedbacks. Litter from decaying plants and root

Izaurralde et al., 2011

Effects of CC on forage quality

- Increased CO_2 concentration and temperature tend to decrease forage protein (N) content and increase total non-structural carbohydrate. No significant effect on forage digestibility (Dumont et al., 2015).



Increase in CO_2

Dumont et al., 2015

Effects of CC on forage quality

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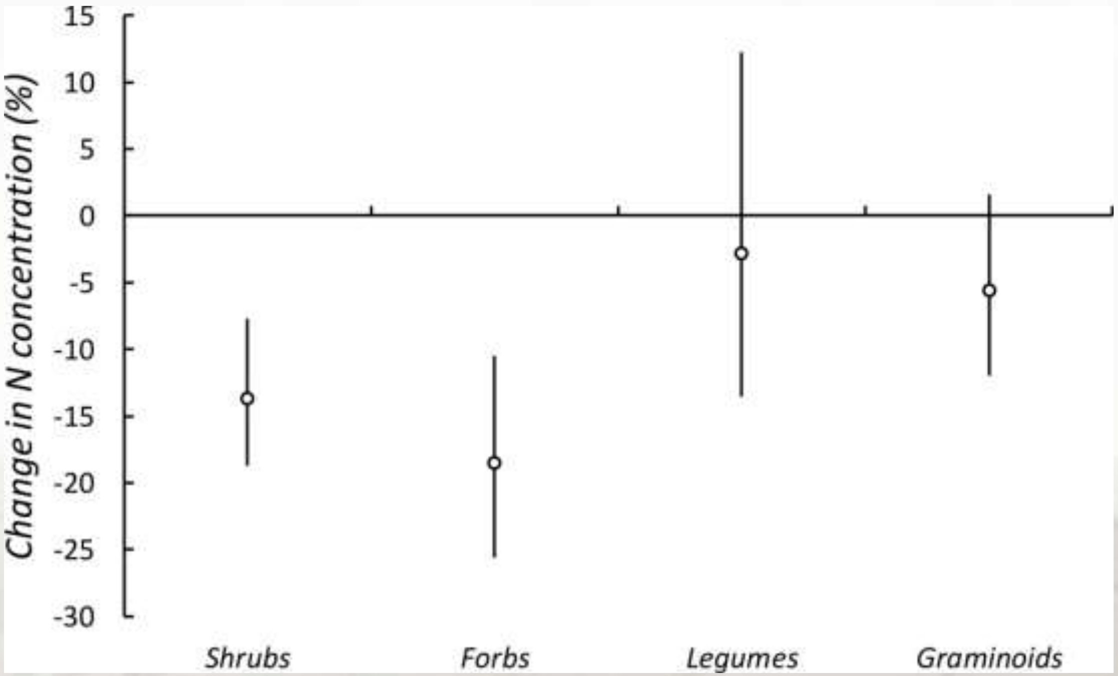
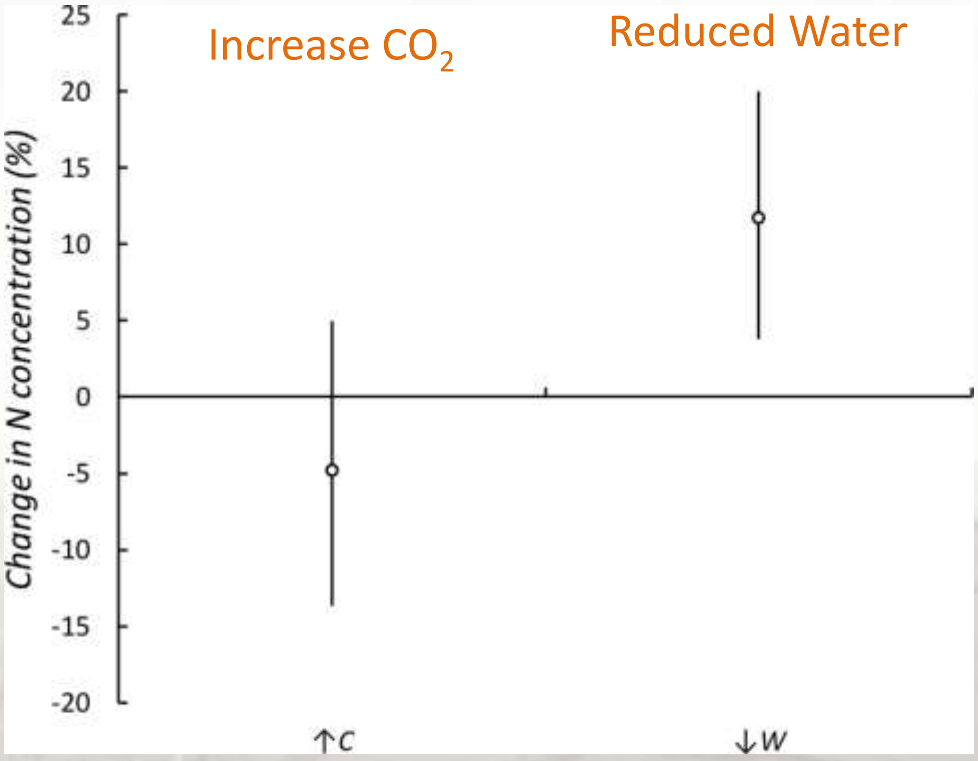
Increase in temperature



Dellar et al., 2019

Effects of CC on forage quality

- Increased CO_2 concentration and temperature tend to decrease forage protein (N) content and increase total non-structural carbohydrate. No significant effect on forage digestibility
- Reduced water availability tend to increase protein (N) content



Dellar et al., 2019

Effects of CC on forage quality

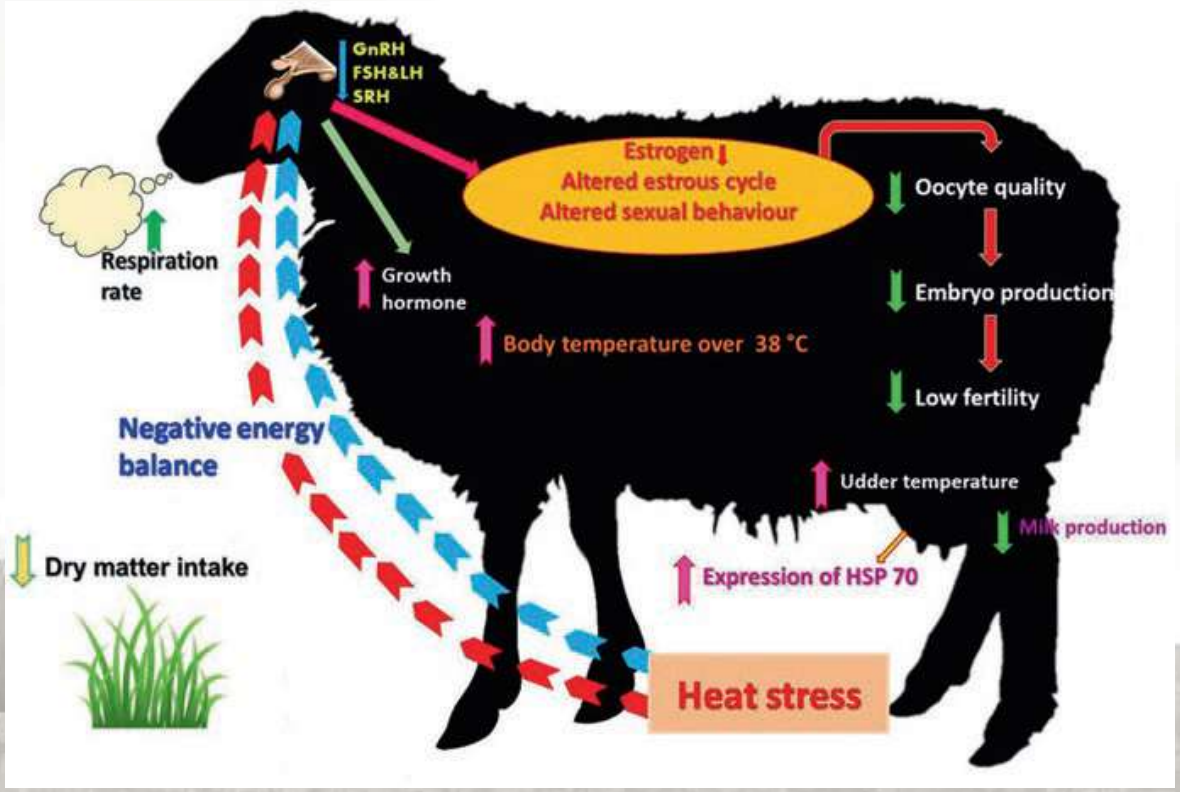
- Increased CO_2 concentration and temperature tend to decrease forage protein (N) content and increase total non-structural carbohydrate. No significant effect on forage digestibility
- Reduced water availability tend to increase protein content
- Warming and high CO_2 levels favour species that fix N_2 (i.e. **legumes**) over non-fixing species.
- The protein content is expected to decrease in non-leguminous plants, but this may be partially counteracted by the expected increase in the legume content of swards.

Effects of climate change at the animal level

Effects of CC on small ruminants:

-Heat stress: Animal thermoregulatory responses

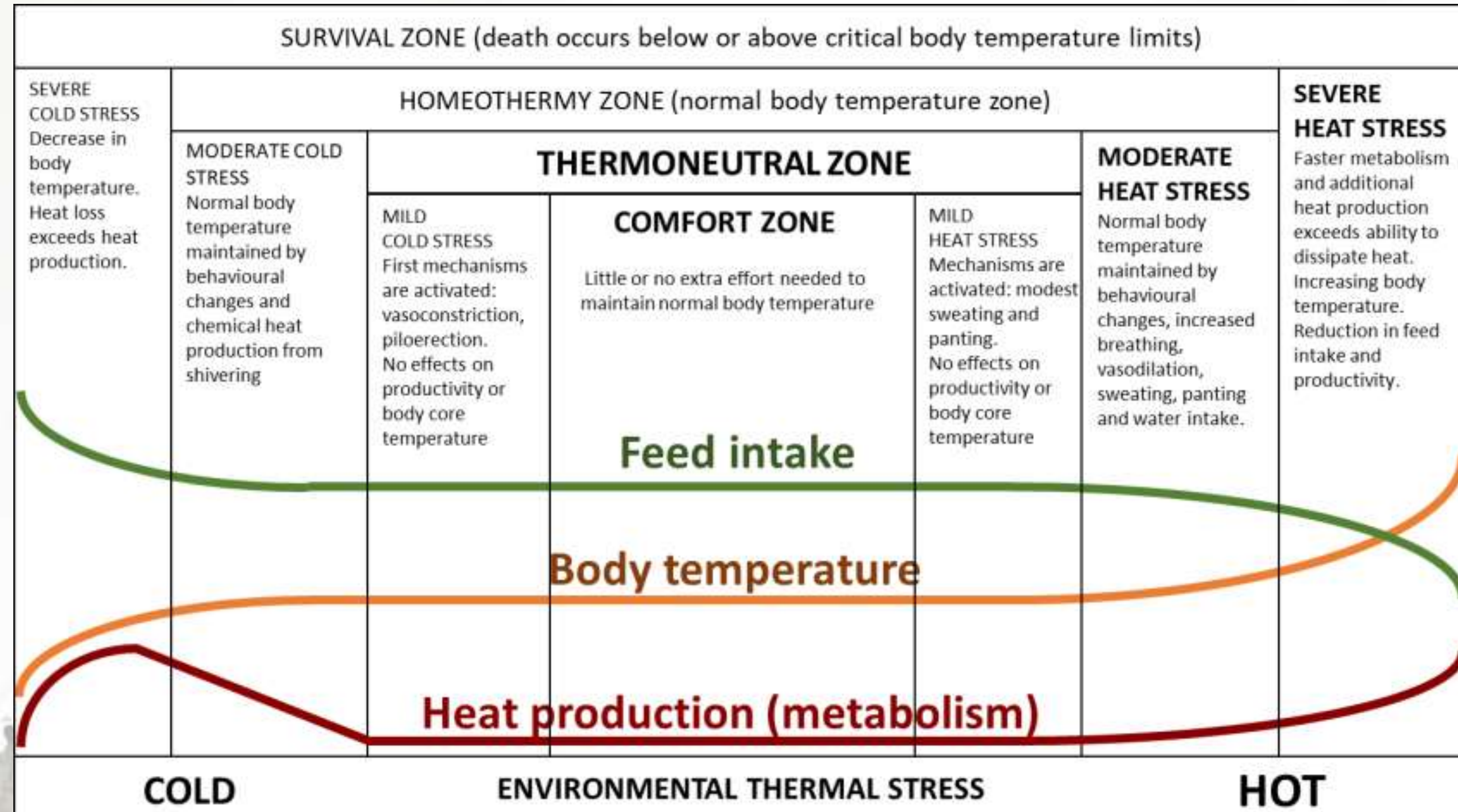
- Physiological (sweating, panting)
- Hormonal (cortisol, thyroid gland activity)
- Behavioural (increase water intake, decrease feed intake)



Sejian et al., 2017

Effects of CC on small ruminants:

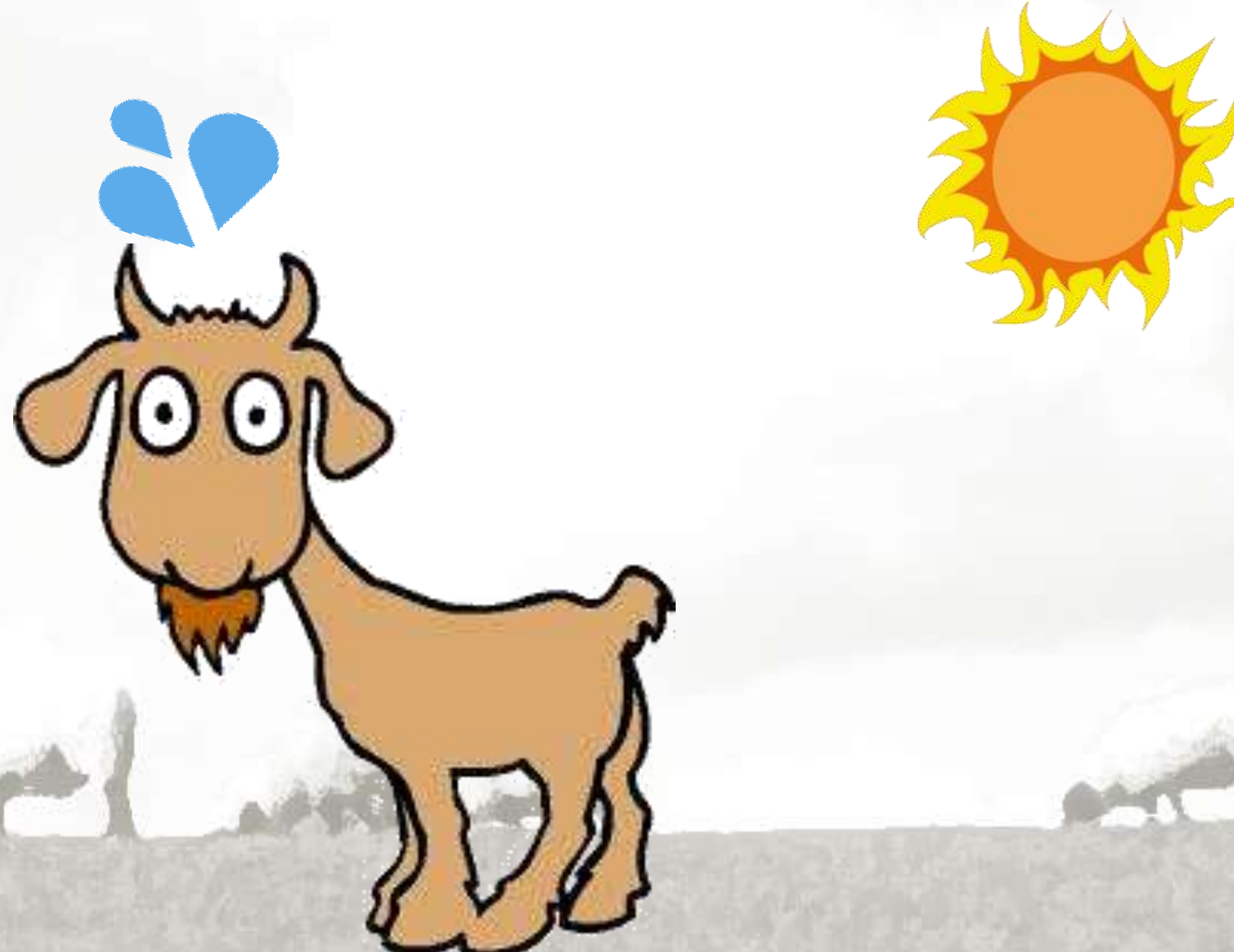
-Heat stress: Animal thermoregulatory responses



Adapted from Silanikove et al., 2015

Effects of CC on small ruminants:

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



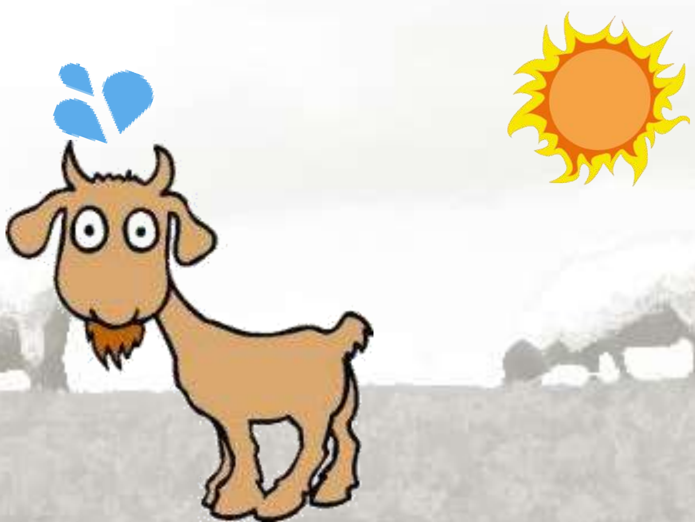
Effects of CC on small ruminants:

-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
33	23	23	24	24	25	25	26	26	27	27	28	28	29	29	30	30	31	31	32	32	33
34	23	24	24	25	25	26	26	27	28	28	29	29	30	30	31	31	32	32	33	33	34
35	24	24	25	25	26	27	27	28	28	29	29	30	30	31	32	32	33	33	34	34	35
36	24	25	25	26	26	27	28	28	29	29	30	31	31	32	32	33	34	34	35	35	36
37	25	25	26	26	27	28	28	29	30	30	31	31	32	33	33	34	35	35	36	36	37
38	25	26	26	27	28	28	29	30	30	31	32	32	33	33	34	35	35	36	37	37	38
39	25	26	27	27	28	29	30	30	31	32	32	33	34	34	35	36	36	37	38	38	39
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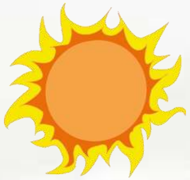
42	27	28	28	29	30	31	31	32	33	34	34	35	36	37	37	38	39	40	40	41	42
43	27	28	29	30	30	31	32	33	34	34	35	36	37	37	38	39	40	41	41	42	43
44	28	29	29	30	31	32	33	33	34	35	36	37	37	38	39	40	41	42	42	43	44
45	28	29	30	31	32	32	33	34	35	36	37	37	38	39	40	41	42	42	43	44	45

Effects of CC on small ruminants:

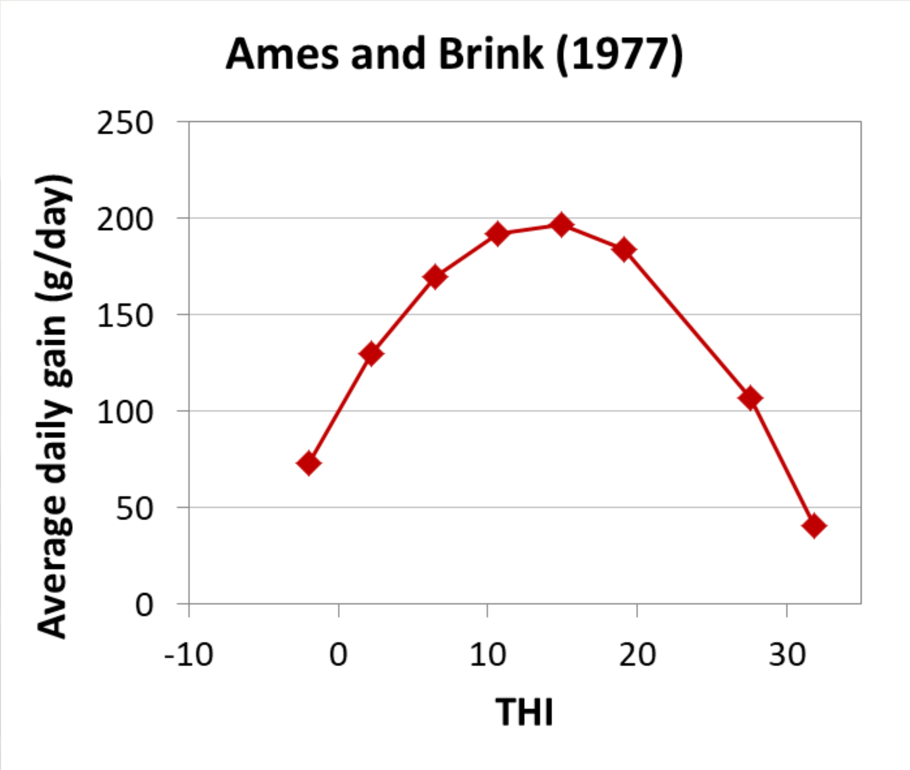
-Heat stress: How to measure the heat load exposure?

- 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: Meat**
- **Lamb impaired growth rate**



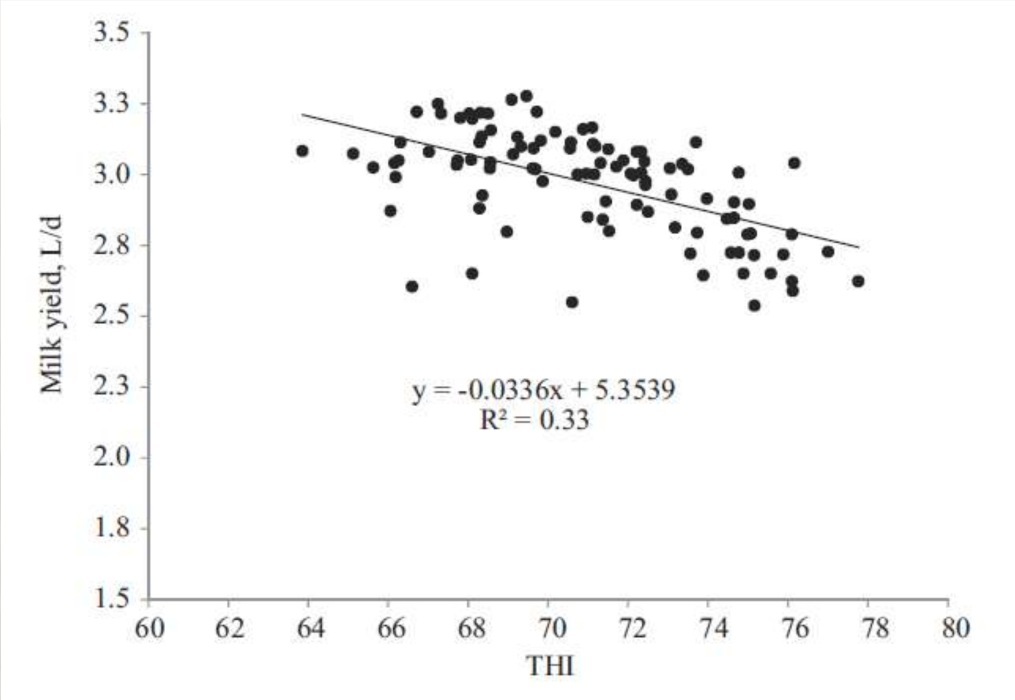
Effects of CC on small ruminants:
-Productivity and product quality (milk+meat)

- 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)

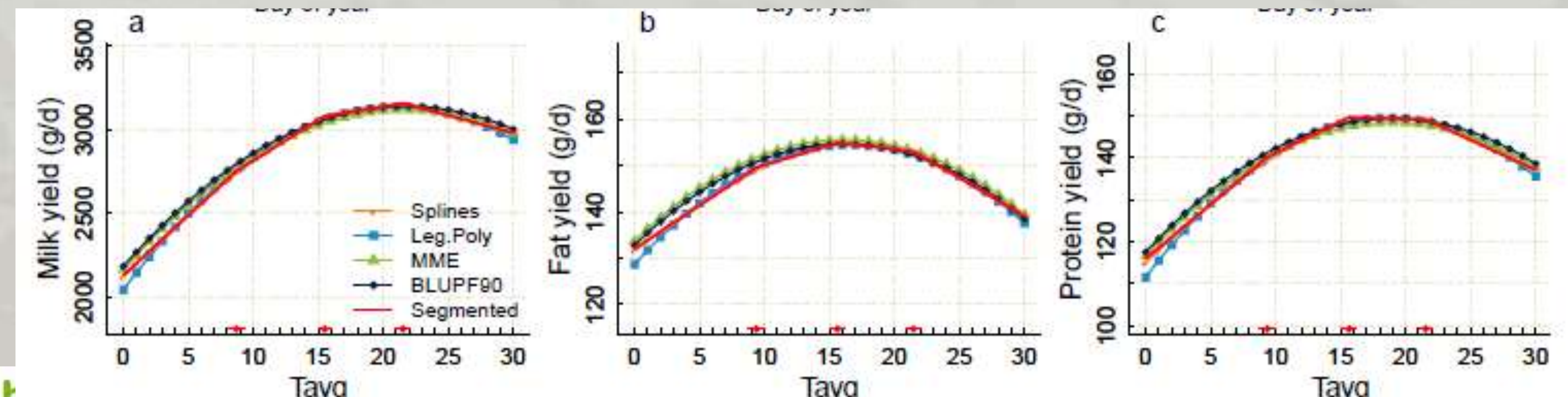
- Sheep and goat subject to heat stress often show reduction in feed intake and **impaired productivity**
- Reduction in milk yield (l/d): 10-30%



Salama et al., 2014

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

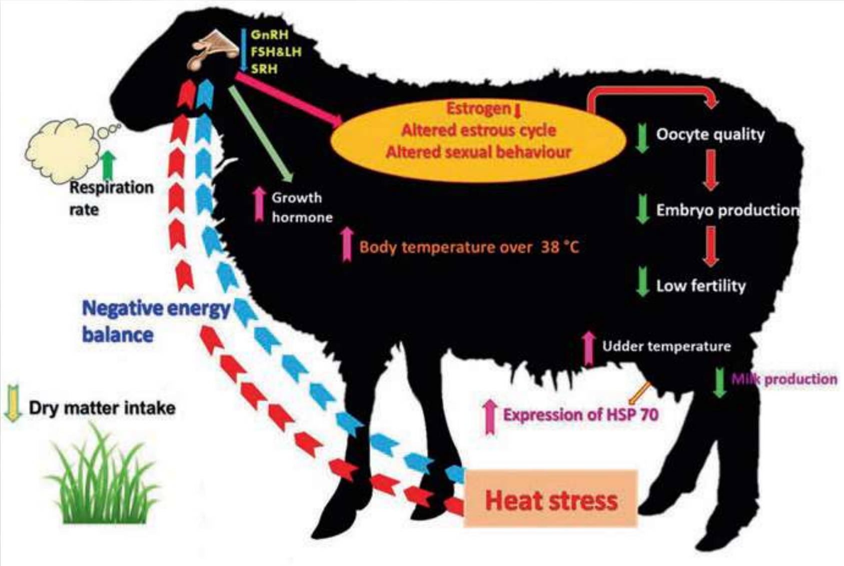
- Sheep and goat subject to heat stress often show reduction in feed intake and **impaired productivity**
- Reduction in milk yield (l/d)
- Milk quality: reduction of protein, total fat and fatty acid profile, reduction of coagulating properties



Ramon et al., 2016

Effects of CC on small ruminants: Reproduction

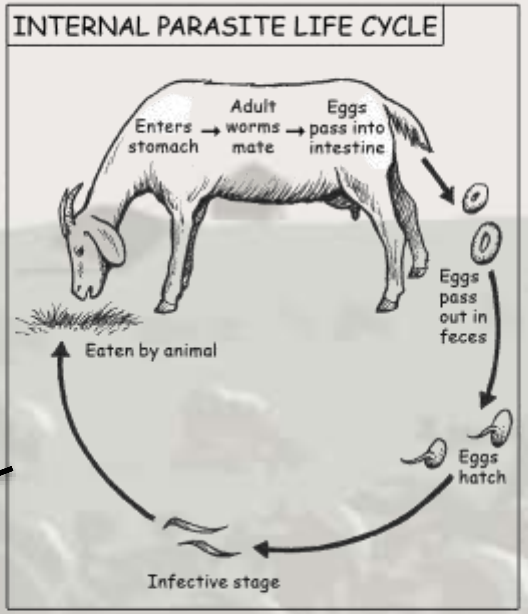
- Heat stress affects negatively fertility:
  - Females: impacts ovarian function, duration of gestation, conception rate and birth weight of lambs.
  - Males: reduced quantity and quality of sperm, changes in sexual activity.



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)

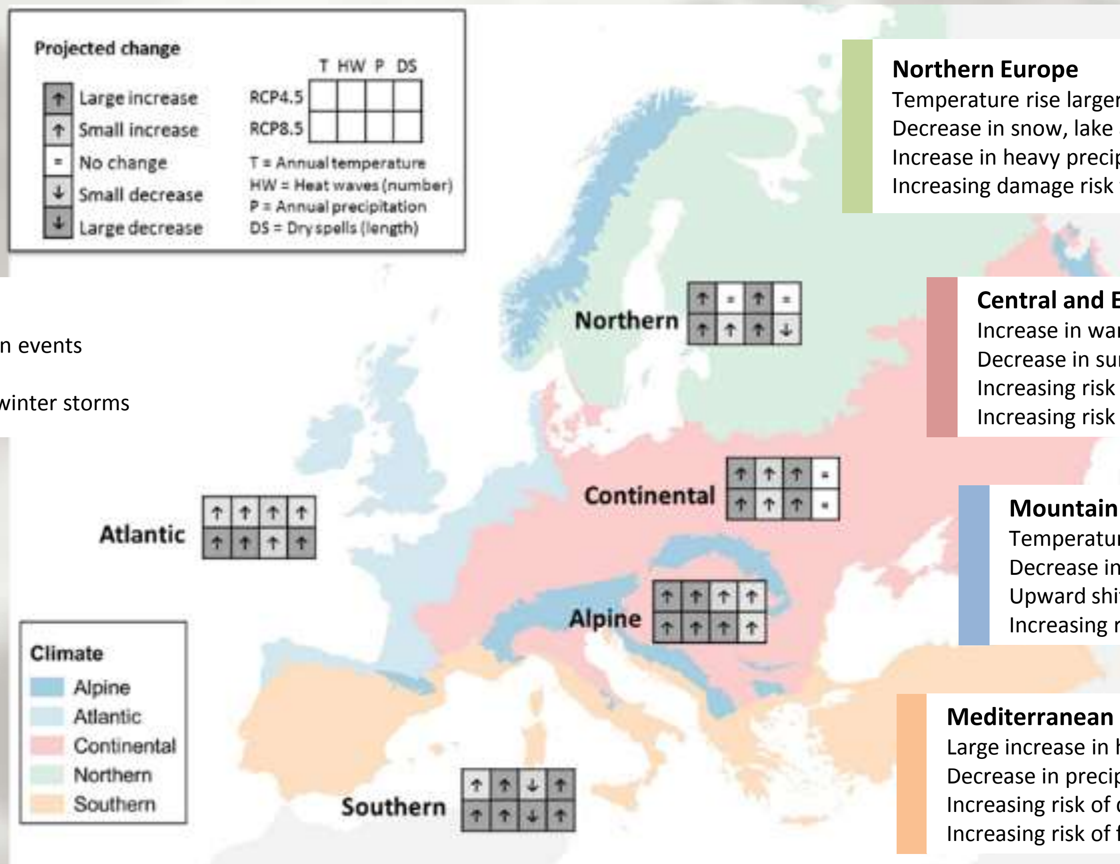


Parasite life cycle. Illustration: Robert Armstrong, An Illustrated Guide to Sheep and Goat Production

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



Northern Europe
Temperature rise larger than global average
Decrease in snow, lake and river ice cover
Increase in heavy precipitation events
Increasing damage risk from winter storms

North-western Europe
Increase in heavy precipitation events
Increasing risk of river floods
Increasing damage risk from winter storms

Central and Eastern Europe
Increase in warm temperature extremes
Decrease in summer precipitation
Increasing risk of forest fires
Increasing risk of river floods

Mountain regions
Temperature rise larger than global average
Decrease in mountain permafrost areas
Upward shift of plant species
Increasing risk of soil erosion

Mediterranean region
Large increase in heat extremes
Decrease in precipitation
Increasing risk of droughts
Increasing risk of forest fires

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

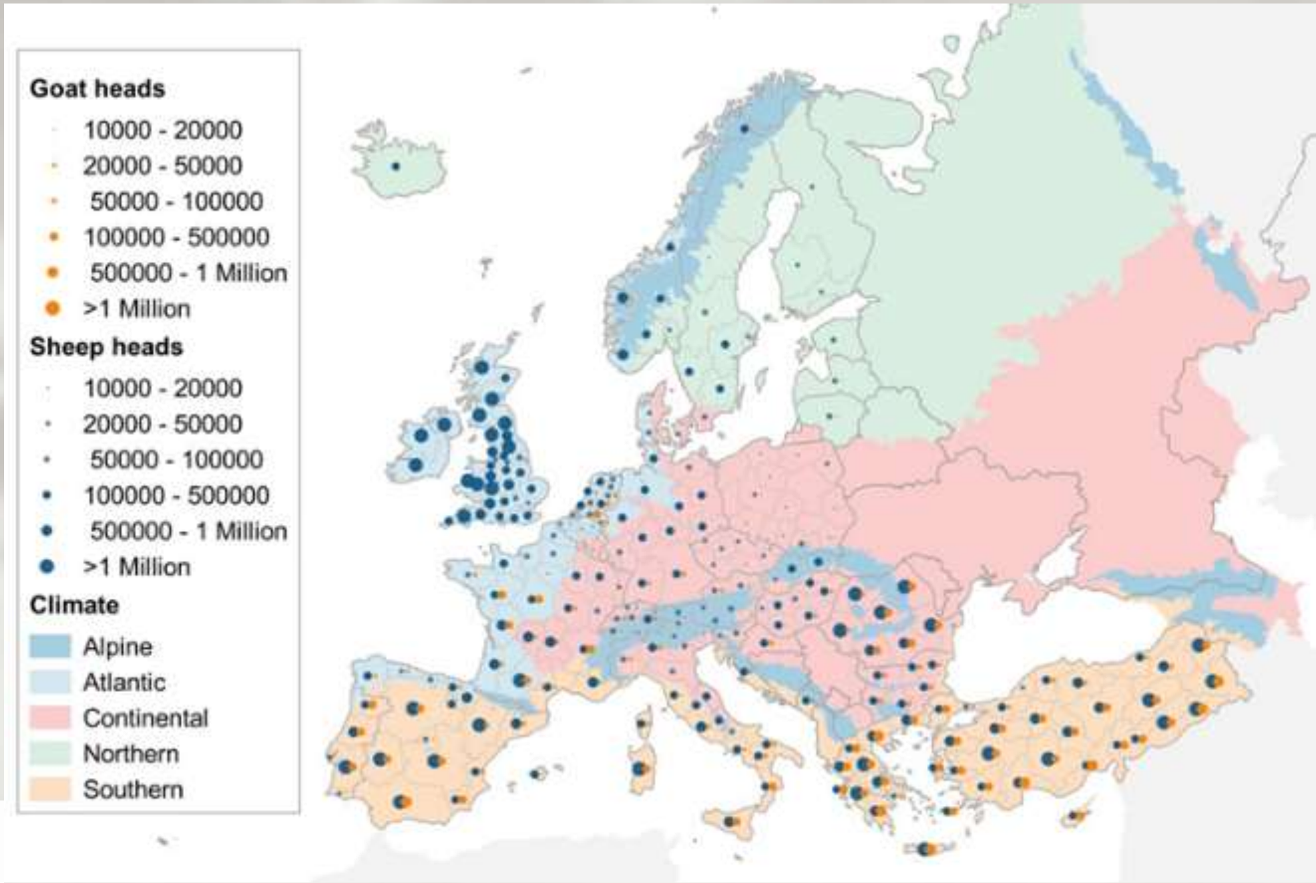
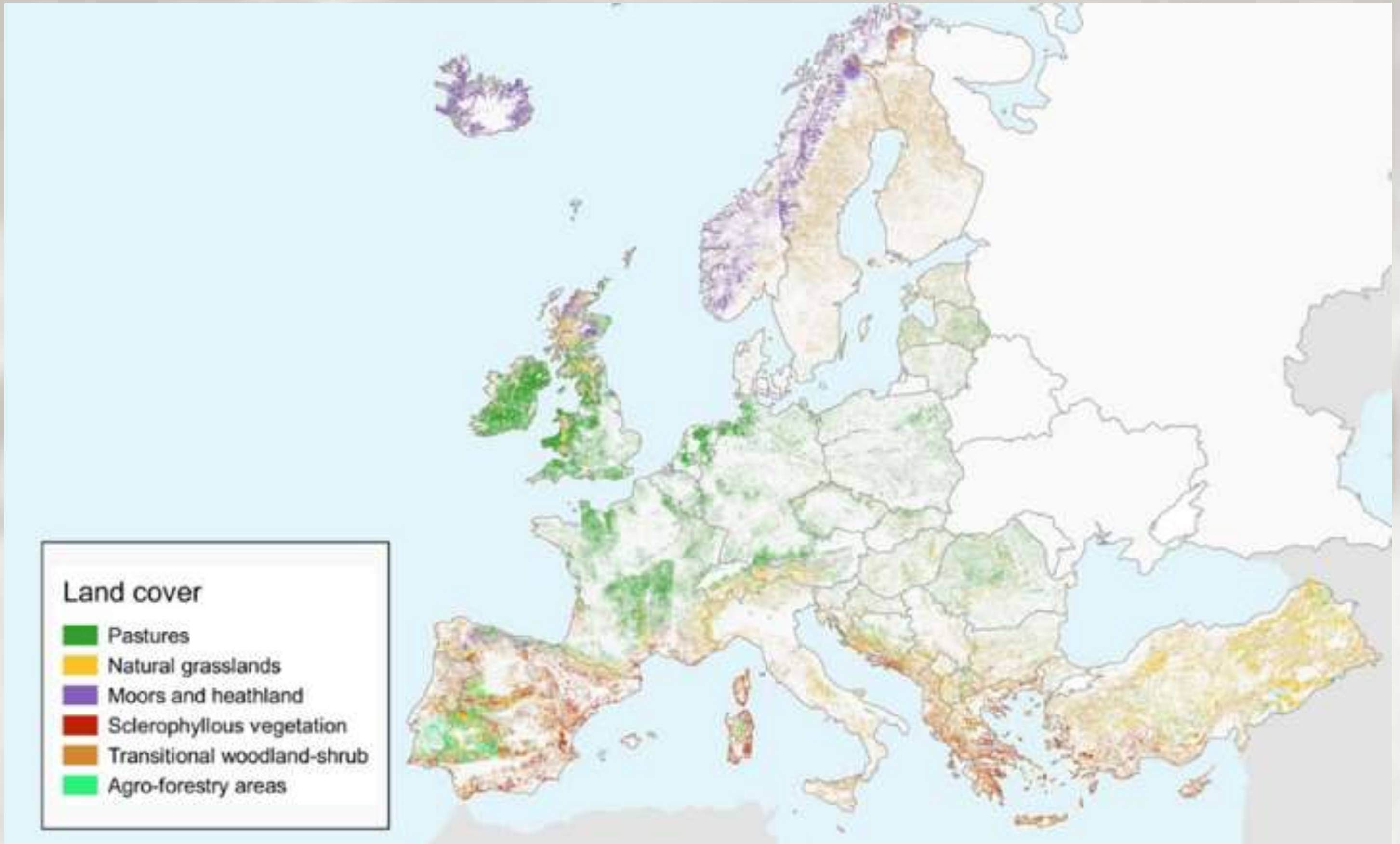


Figure - Distribution of small ruminant livestock in Europe (Pardo et al, 2017 based on Eurostat, 2015)

Regional implications for small ruminant production systems in Europe:

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



Regional implications for small ruminant production systems in Europe:

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

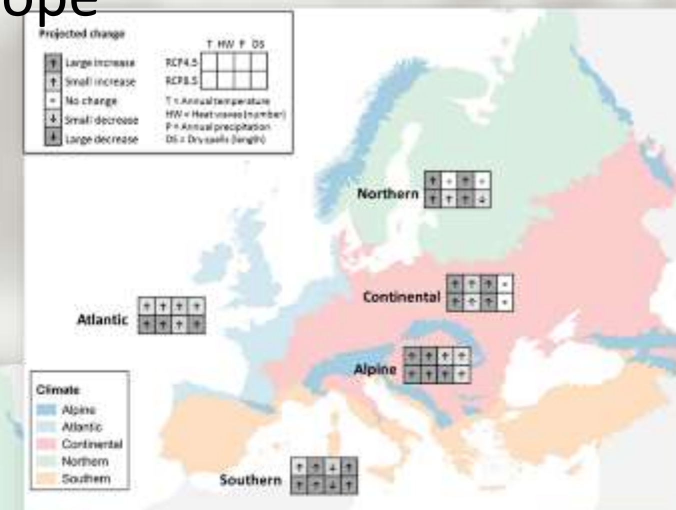


Fig.1- Climate change projections

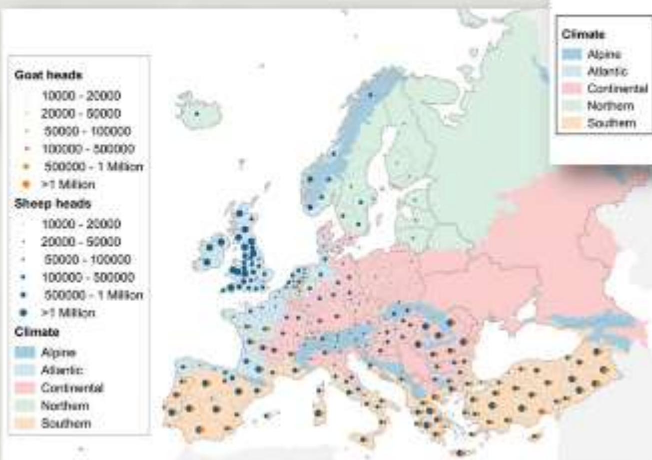


Fig.2 - Distribution of small ruminant livestock in Europe

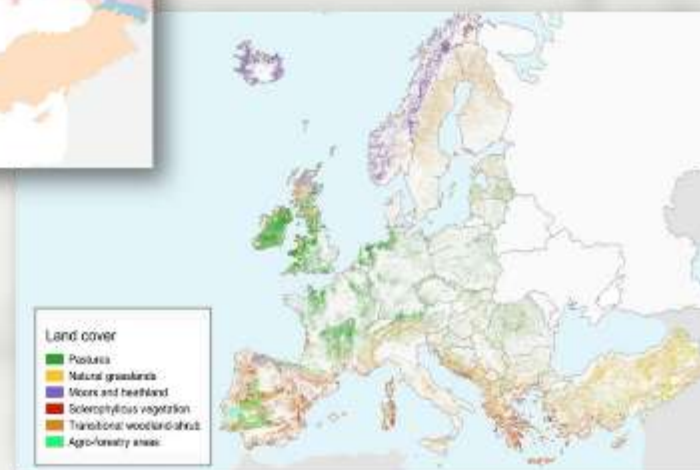


Fig.3 - Distribution of grasslands and scrublands in Europe

Regional implications:
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

Regional implications:
E) Southern (Mediterranean) region

Adaptation measures:

- Mediterranean systems traditionally had to adapt

Southern (Mediterranean) region

General adaptation strategies for forage production to face CC

- Diverse pastures:
  - to enhance resilience under variable climatic conditions
  - to adapt to potential shortages of global protein sources, or to face the expected decreased of protein content (increasing mixed legume-grass pastures).
- Reduced tillage for soil moisture conservation and increased long-term productivity (increase soil organic matter)

Southern (Mediterranean) region

General adaptation strategies for forage production to face CC

- Improved plant breeding (long-term):
  - improving adapted legume species:
    - reducing dependency on external protein-rich feeds
    - reducing use of synthetic fertilisers
  - developing varieties that can survive long drought periods and recover rapidly following autumn rains
    - mix mediterranean and temperate tall fescue, cocksfoot and lucerne

E) Southern (Mediterranean) region

Adaptation measures: Flexible grazing and alternative feed resources:

- Crop residues: Post-harvest cereals, olive leaves
- Mediterranean region is also projected to experience substantial crop yield losses, especially for rain-fed systems

E) Southern (Mediterranean) region

Adaptation measures: Flexible grazing and alternative feed resources:

- Underutilized feedstuffs from agro-industry by-products

Reference	Basal diet	Alternative feed sources	Supplement type	Animal	Breed
Abbeddou et al 2011	Barley straw/concentrate	**Olive cake and leaves, tomato pomace**		Dairy ewes	Awassi
Arco-Pérez et al 2017	Alfalfa hay/concentrate	**Olive cake, Tomato surplus**	Silage	Dairy goats	Murciano-granadina
Cabbidu et al 2004	Grass hay/concentrate	**Olive cake**	Silage	Dairy ewes	Sarda
Chiofalo et al 2004	Alfalfa hay/concentrate	**Olive cake**		dairy ewe	Comisana
Di Francia et al 2004	Oat hay/concentrate	**Tomato pomace**	Silage	dairy ewe	Comisana
Fegeros et al 1995	Alfalfa hay/concentrate	**Citrus pulp**	Dried	Dairy ewe	Karagouniko
Hadjipanayiotou	Barley straw/concentrate	**Olive cake**	Silage	Dairy ewes & goats	Chios, Damascus
Molina-Alcaide et al 2010	Alfalfa hay/concentrate	**Olive cake**	Feed blocks	Dairy goats	Murciano-granadina
Nudda et al 2006	Alfalfa hay/concentrate	**Linseed cake**	Extruded	Dairy goats	AlpinexSarda
Razzaghi et al 2015	Alfalfa hay/concentrate	**Pomegranate seed pulp, tomato pomace**		Dairy goats	Saanen
Romero-Huelva et al 2013	Alfalfa hay/concentrate	**Tomato fruits, citrus pulp, brewer's grain and yeast**		Dairy goats	Murciano-granadina
Romero-Huelva et al 2013	Alfalfa hay/concentrate	**Tomato and cucumber fruit wastes**	Feed blocks	Dairy goats	Murciano-granadina
Romero-Huelva et al 2017	Alfalfa hay/concentrate	**Tomato fruits, citrus pulp, brewer's grain and yeast**		Dairy goats	Murciano-granadina
Sedighi-Vesagh t al 2014	Alfalfa hay/concentrate	**Pistachio by-products**		Dairy goats	Saanen
Volanis et al 2004	Oat hay/concentrate	**Orange fruit waste**	Silage	Dairy ewe	Sfakian
Ben Salem and Znaidi 2008	Wheat straw/concentrate	**Tomato pulp, olive cake**	Feed blocks	Lambs	Barbarine
Bueno et al 2002	Grass hay/concentrate	**Citrus pulp**		Kids	Saanen
Caparra et al 2005	Oat hay/concentrate	**Citrus pulp**	Dried	Lambs	Merino
Denek and Can 2006	Wheat straw/wheat grain	**Tomato pomace**	Silage	Rams	Awassi
Eliyahu et al 2015	Wheat hay/concentrate	**Pomegranate pulp, grape pulp, avocado pulp**	Silage	Lambs	Assaf
Lanza et al 2001	Wheat straw/barley+maize	**Citrus pulp**		Lambs	Barbaresca
Pirmohammadi et al 2006		**Apple pomace**	Silage, dried	Rams	Gezel
Scerra et al 2001	Oat hay/concentrate	**Citrus pulp**	Silage	Lambs	Merinizzata

E) Southern (Mediterranean) region

Adaptation measures: Alternative feed resources:

- Underutilized feedstuffs from agro-industry by-products
  - Olive cake
  - Citrus pulp
  - Tomato by-products
  - Other vegetables and fruits

E) Southern (Mediterranean) region

Adaptation measures: Alternative feed sources

- Fodder trees (Acacia sp, carob tree)
- Shrubs: Cactus cladodes, saltbush (atriplex)

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:

- -adequate stock density
- -barn orientation and dimensions: east to west, width
- -features in barns: ventilation, spraying, evaporative cooling

-Outdoors:

- -providing physical protection with trees or artificial shelter

E) Southern (Mediterranean) region

Adaptation measures to cope with heat stress:

- Feeding practices:
  - -shifting meals to late afternoon or evening
  - -increasing number of meals
- Nutritional management:
  - -low fibre diets (decrease forage:concentrate)
  - -high energy density (DMI reduction)
  - -supplements: fat-rich feeds, whole flaxseed (linseed), buffers

E) Southern (Mediterranean) region

Adaptation measures to cope with heat stress:

- Animal breeding:
  - breeds from tropical and arid areas, are more resilient due to their low body mass and metabolism, which allows them to minimise water and maintenance requirements
  - artificial selection to increase milk yield has been shown to reduce heat tolerance
  - goats with loose skin, long legs, floppy ears tend to be most heat tolerant
  - Hair and fat-tailed sheep tend to tolerate heat better than wooled and thin-tailed sheep
  - Light coloured reflect solar light,
    but less skin protection against solar radiation

E) Southern (Mediterranean) region

Adaptation measures to cope with heat stress:

- Reproduction techniques:
    - artificial insemination can reduce the infertility risks associated with heat stress in males
    - improved oestrus detection and fixed time AI can be used for overcoming the reduced expression of oestrus in heat stressed animals
    - oestrus induction techniques in non-cyclic animals, to increase fertility

Development of methods/models to predict impact of change

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

Task 3.1
Literature review of CC and small ruminants

Forage availability

Task 3.2
Meta-models for CC impact on pasture

Animal performance

Task 3.3
Meta-models for CC impact at animal level

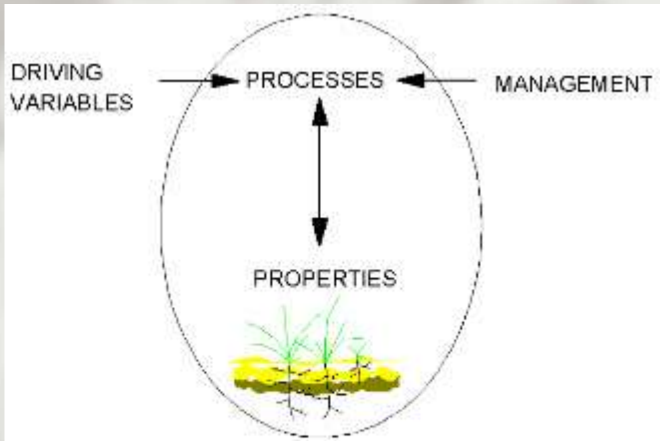
WP4 Task 4.3
Integrated in whole-farm model/run scenarios

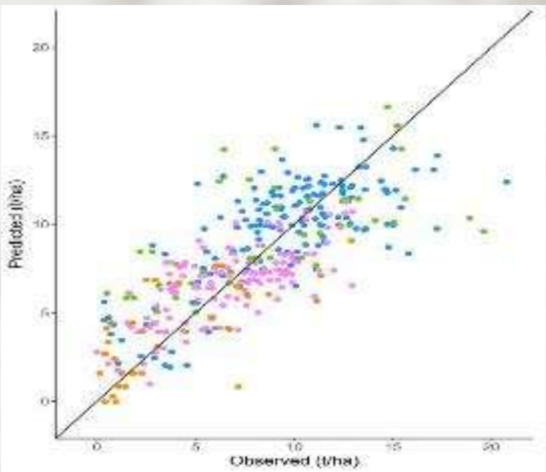
WP 5 - Strategies for adaptability and sustainability

Impacts of climate change on sheep and goat systems

Types of models:

- **Mechanistic models (process-based)**: aim to describe mathematically the relationships between the variables and components of the system. Constrained by the level of understanding existent about the behaviour of the system
- **Empirical/statistical models (regression models):** based on a hypothesized relationship between the variables in the data set, where the relationship seeks to best describe the data. Involves the use of extensive data records and measurements





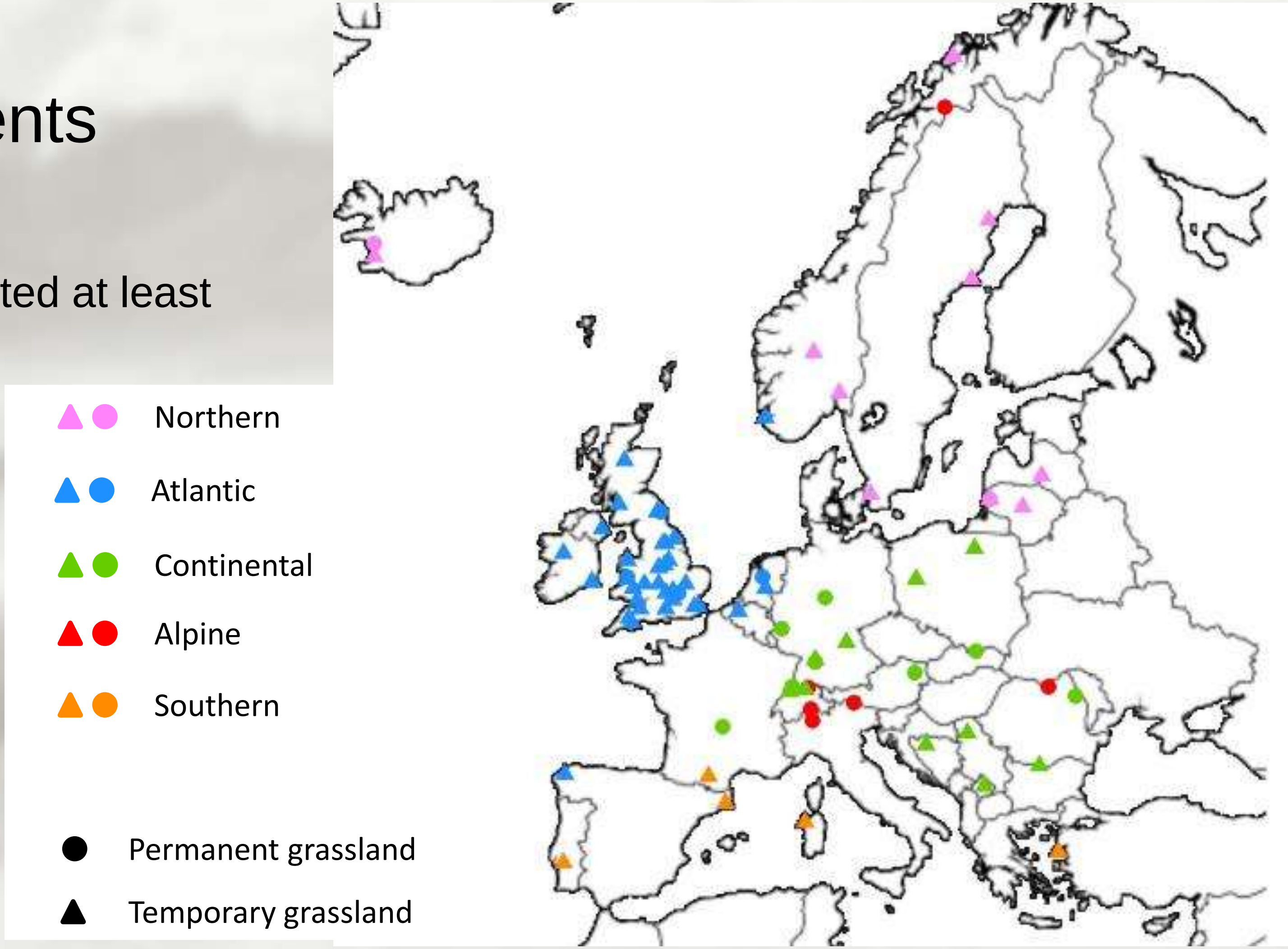
Development of models on pasture productivity and quality:

Regresion model

29 experiments

89 sites

All experiments lasted at least three years



Development of models on pasture productivity and quality:

Regresion model

Stepwise linear regression

$$\mathbf{Yield} = \alpha_0 + \alpha_1(\mathrm{Region}) + \alpha_2 R_{JFM} + \alpha_3 R_{AMJ} + \alpha_4 R_{JA} + \alpha_5 T_{FM} + \alpha_6 T_{AMJ} + \alpha_7 T_{JA} + \alpha_8 R_{JFM}^{\ 2} + \alpha_9 R_{AMJ}^{\ 2} + \alpha_{10} R_{JA}^{\ 2} + \alpha_{11} T_{JA}^{\ 2} + \alpha_{12}\mathrm{Altitude} + \alpha_{13}\mathrm{N\_input} + \alpha_{14}\mathrm{Cuts} + \alpha_{15}\mathrm{Cuts}^2 + \alpha_{16}\mathrm{N\_input}^2 + \alpha_{17}\mathrm{N\_input}{*}R_{JFM} + \alpha_{18}\mathrm{N\_input}{*}T_{JA}$$

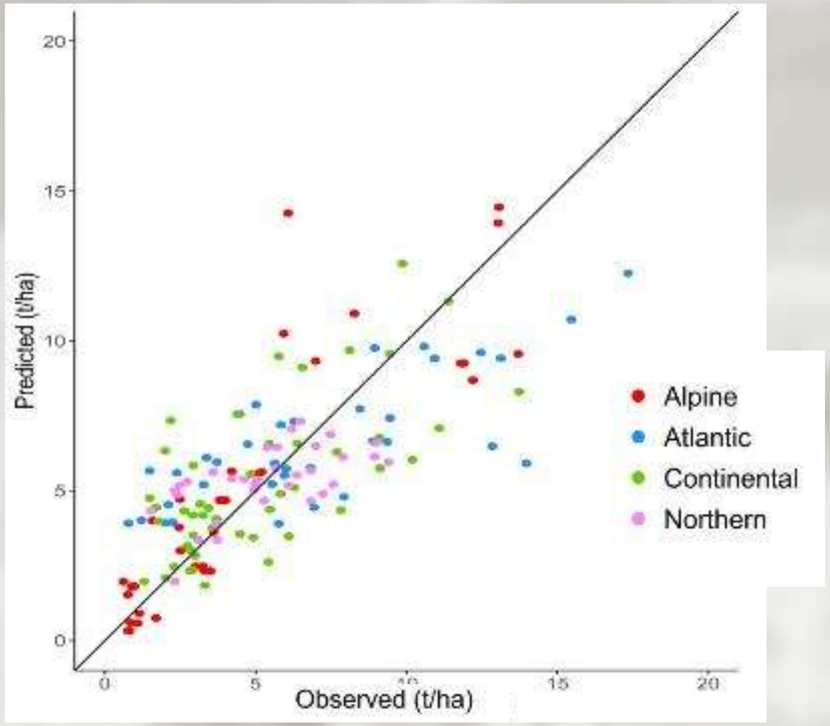
Inputs:

- Monthly mean temperature
- Monthly total precipitation
- Altitude
- N fertiliser
- Mowing frequency
- Legume content

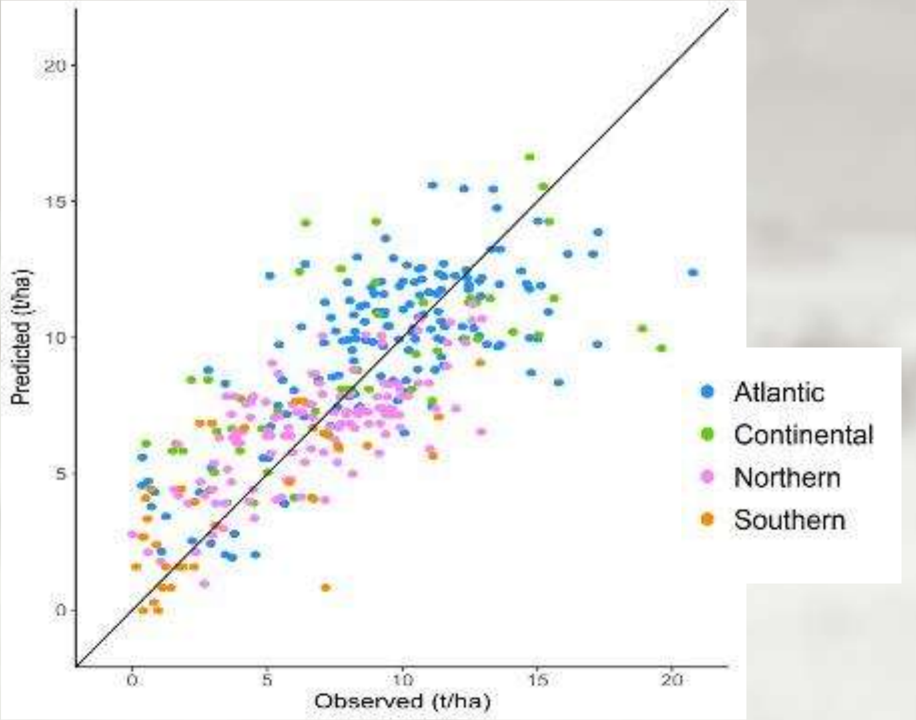
Development of models on pasture productivity and quality:

Regresion model: Checking model fit on observed yield data

Predicting current yield



Permanent grasslands
Correlation: 0.77 ± 0.014
RMSE: 2.23 ± 0.03



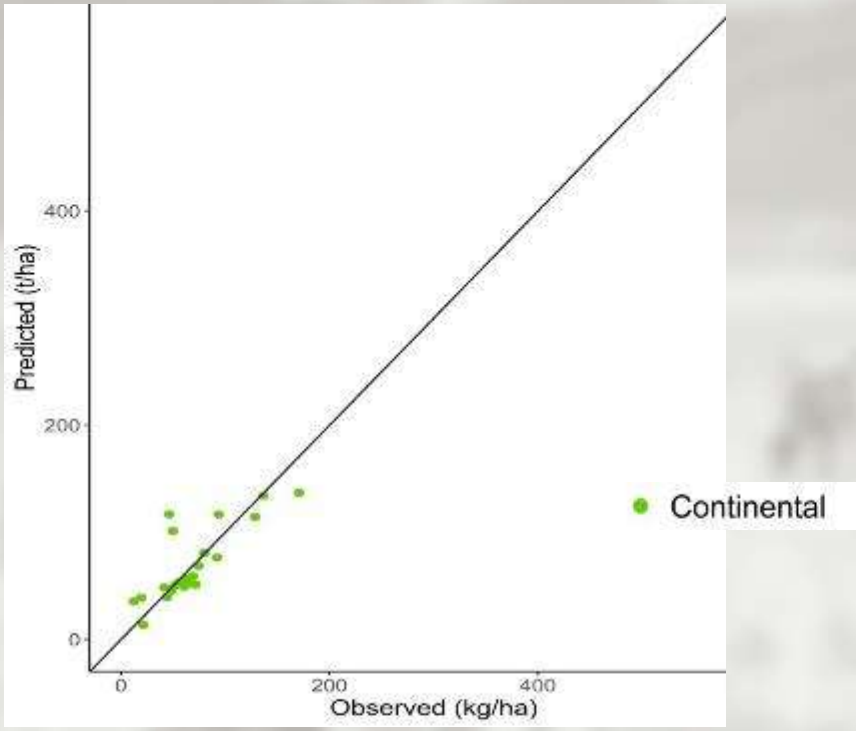
Temporary grasslands
Correlation: 0.76 ± 0.006
RMSE: 2.75 ± 0.07

bc3
BASQUE CENTRE FOR CLIMATE CHANGE
Klima Aldaketa Ikergai

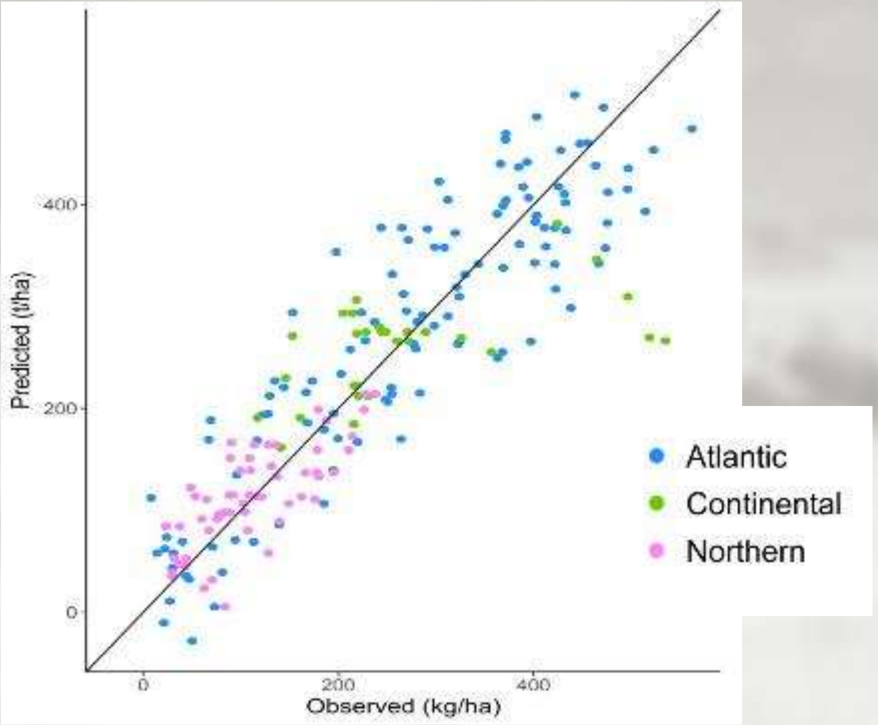
Development of models on pasture productivity and quality:

Regresion model:Checking model fit on observed yield data

Predicting current protein content



Permanent grasslands
Correlation: 0.80 ± 0.043
RMSE: 25.2 ± 4.7



Temporary grasslands
Correlation: 0.89 ± 0.005
RMSE: 64.9 ± 1.7

Development of models on pasture productivity and quality:

Mechanistic model: Century

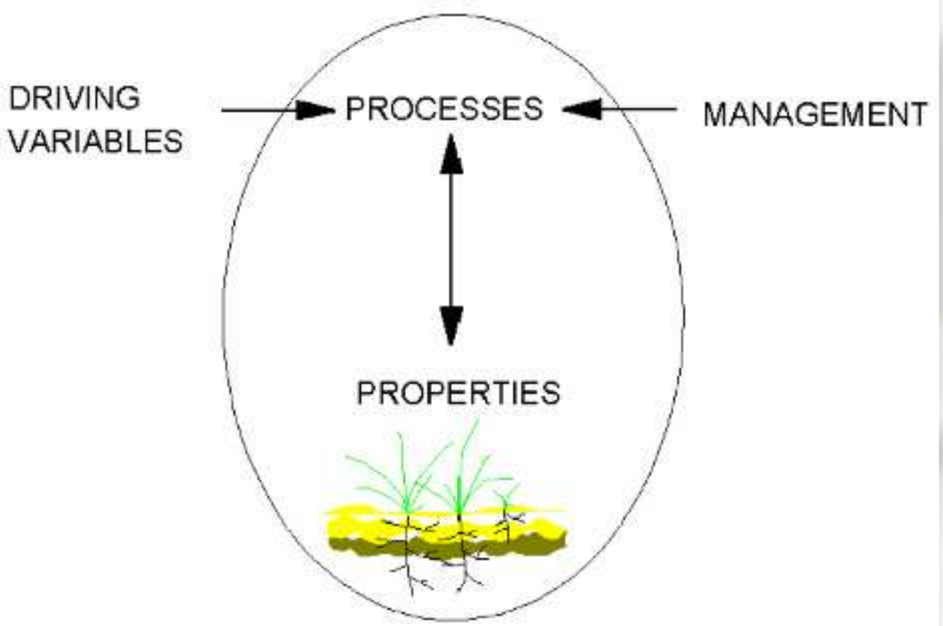
Ecosystem analysis tool

Models C and N fluxes throughout plant-soil system

Monthly time-step

Site specific

Large number of inputs



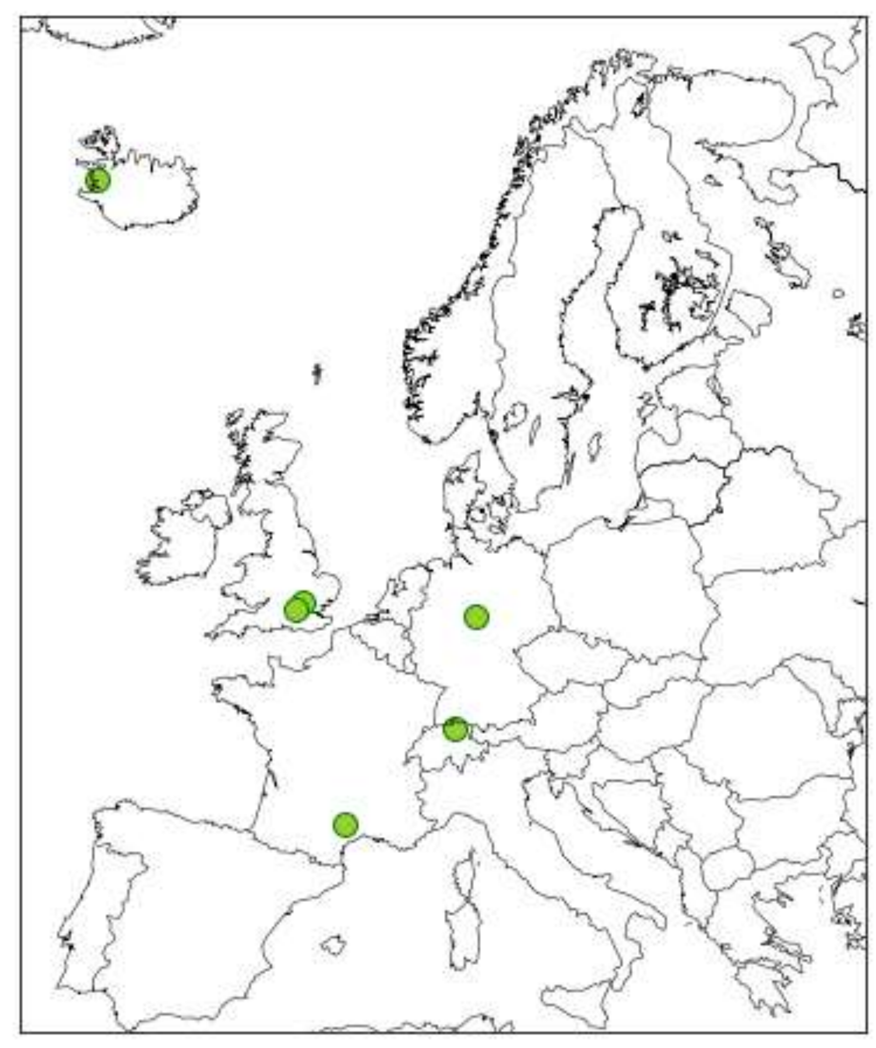
- Main inputs: monthly temperature and precipitation, soil properties, plant properties, CO_2 change, management, site history

Development of models on pasture productivity and quality:

Mechanistic model: Century

One site per region (two for Atlantic region)

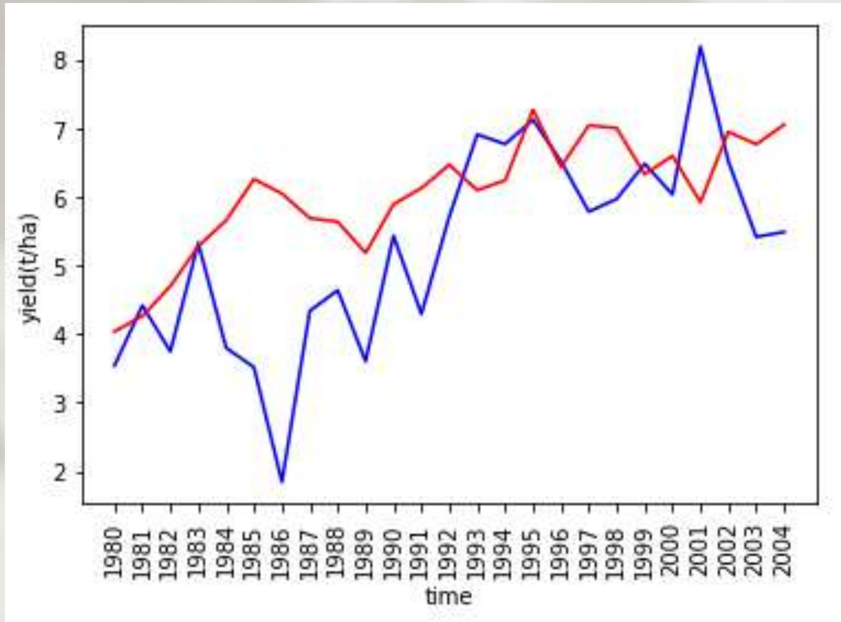
All permanent grasslands (except one Atlantic site)

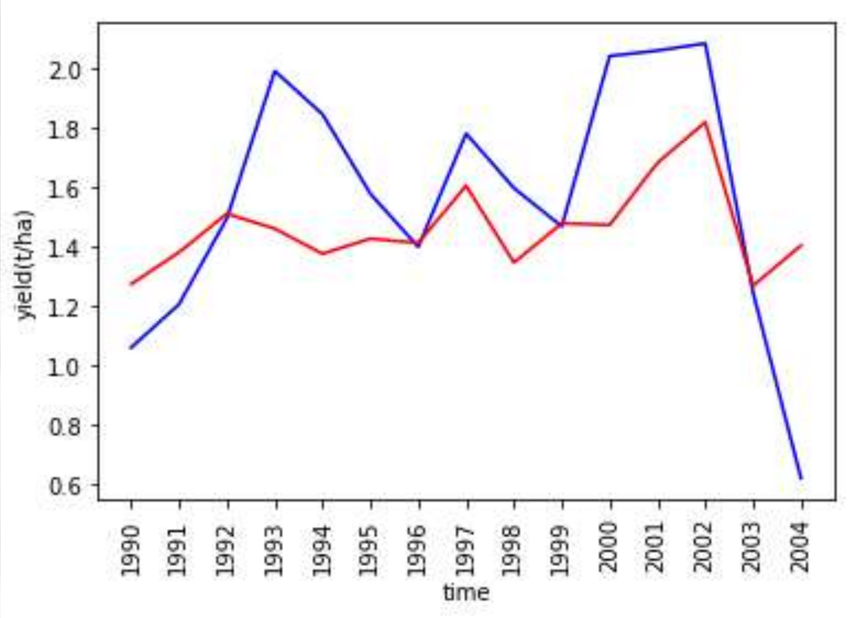


Development of models on pasture productivity and quality:

Mechanistic model: Century

Southern France rangeland





Observed

Predicted

Fertilised, intensive grazing

Unfertilised, moderate grazing

Development of models on pasture productivity and quality:

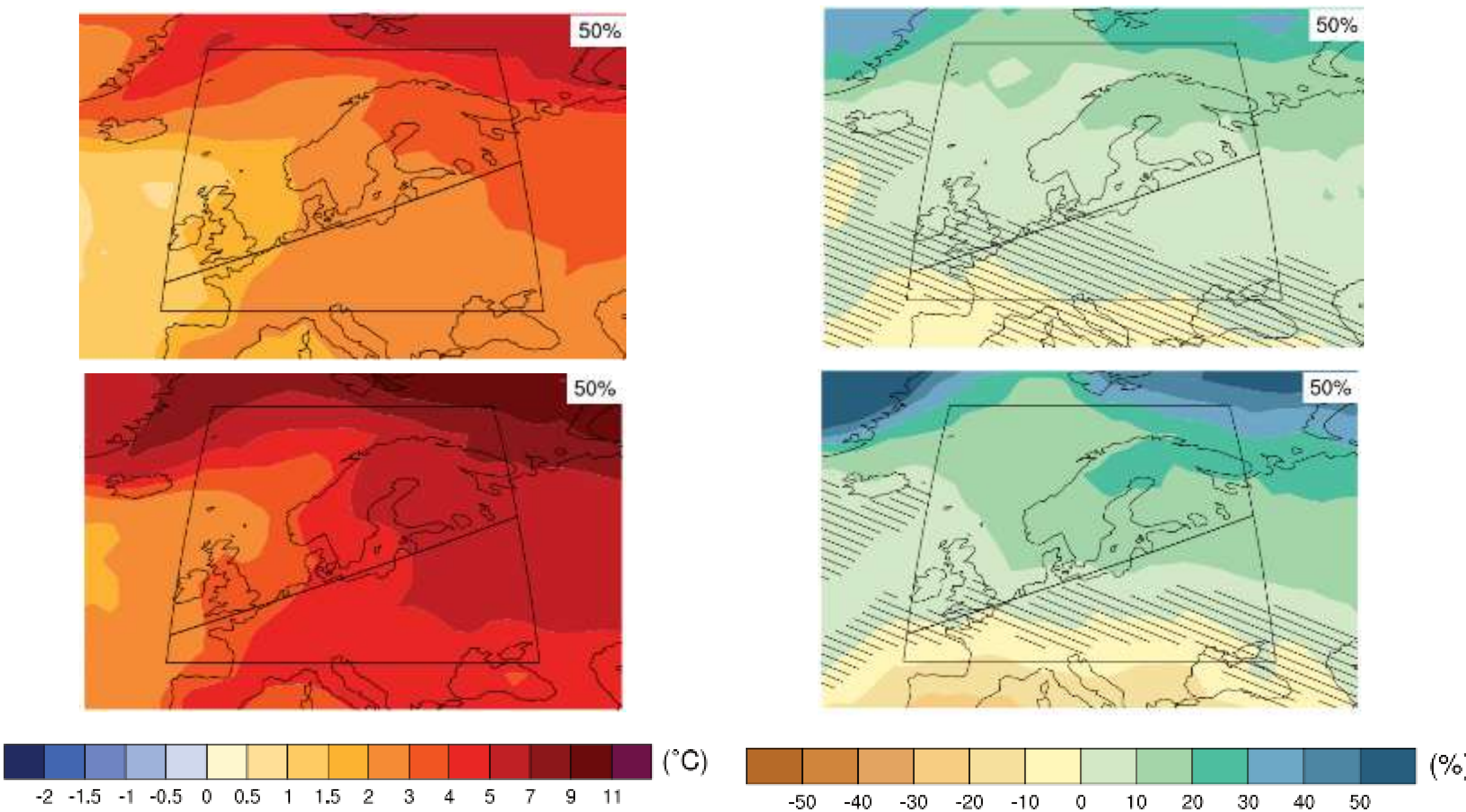
Predicting climate change impact: Two CC scenarios

Average annual predictions for 2081 - 2100, relative to 1986 - 2005

Temperature | Precipitation

Midrange scenario (RCP4.5)

Extreme scenario (RCP8.5)

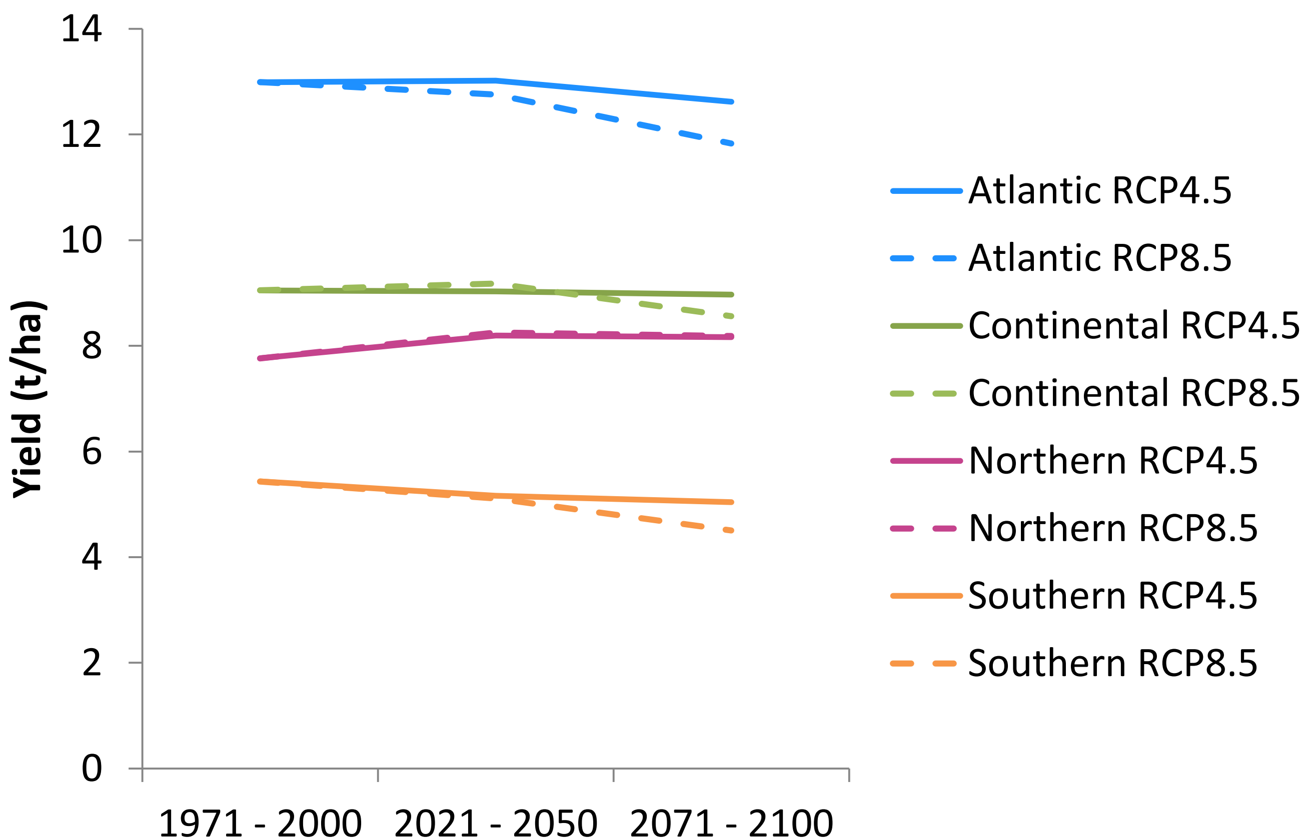


bc3 BASQUE CENTRE FOR CLIMATE CHANGE Klima Aldaketa Ikergai

Development of models on pasture productivity and quality:

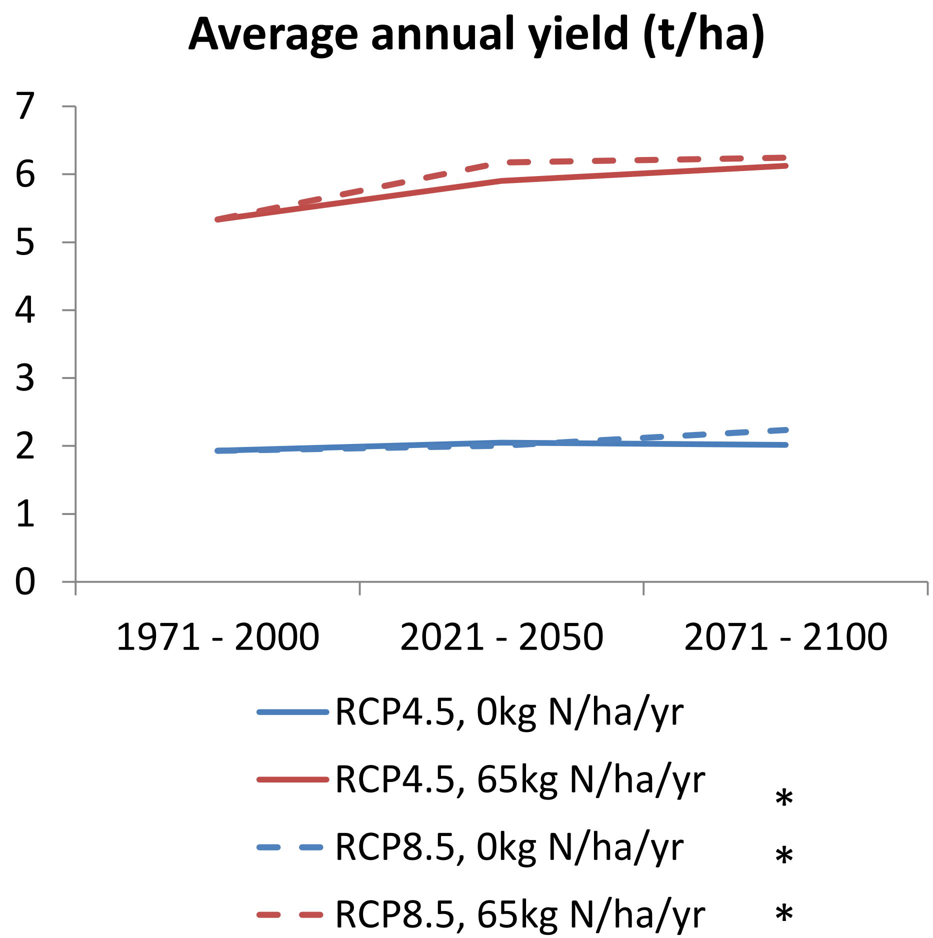
Predicting climate change impact:

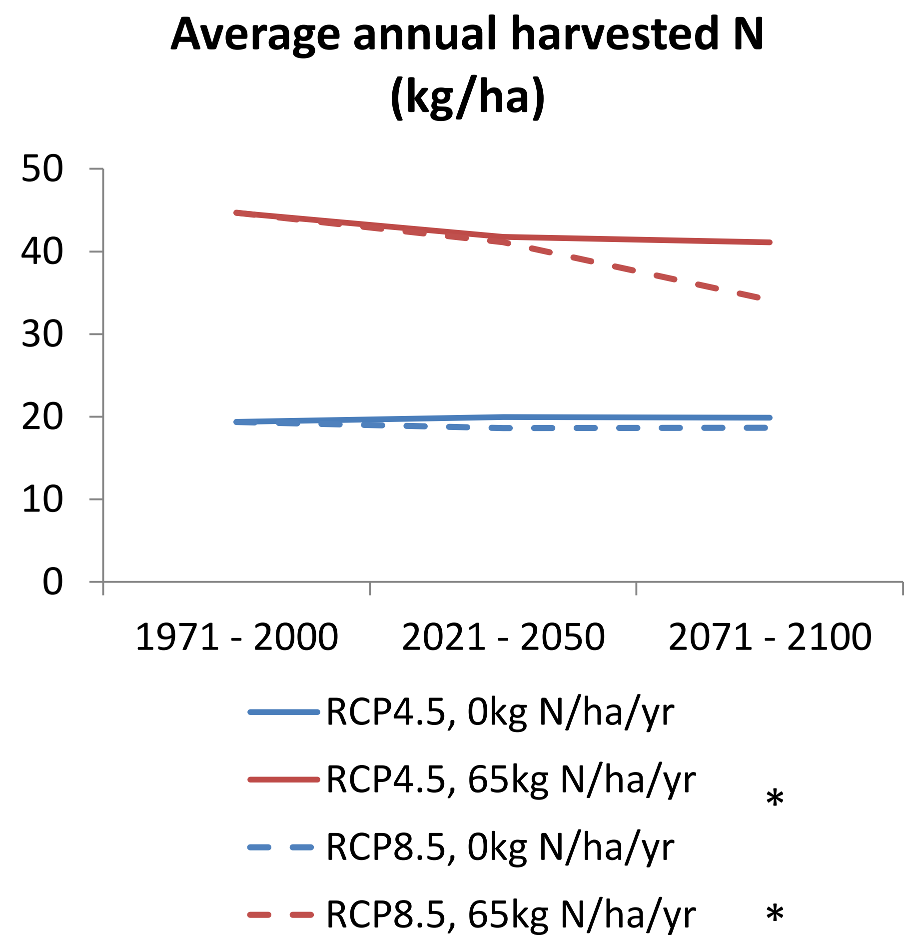
Temporary grasslands



Development of models on pasture productivity and quality:

Predicting climate change impact:

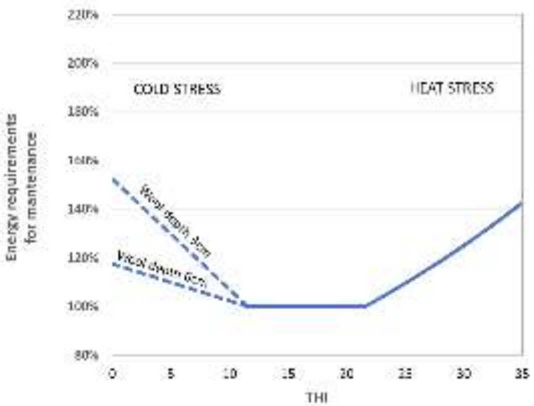


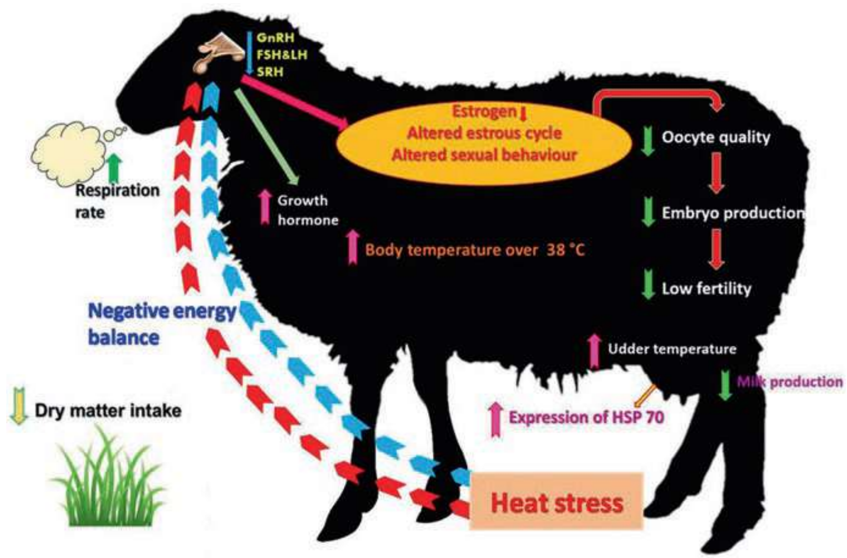


* Significant change in yield between 1971-2000 and 2071-2100 ($p<0.05$)

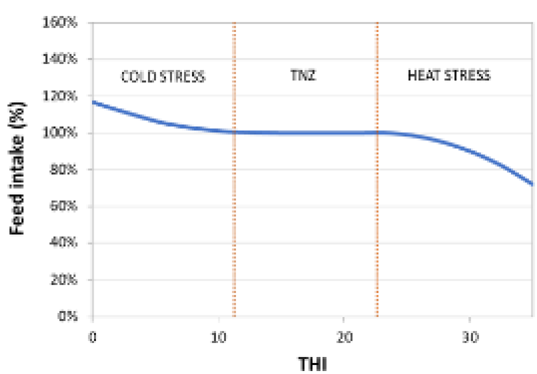
Development of models on animal performance:

Semi-mechanistic model:



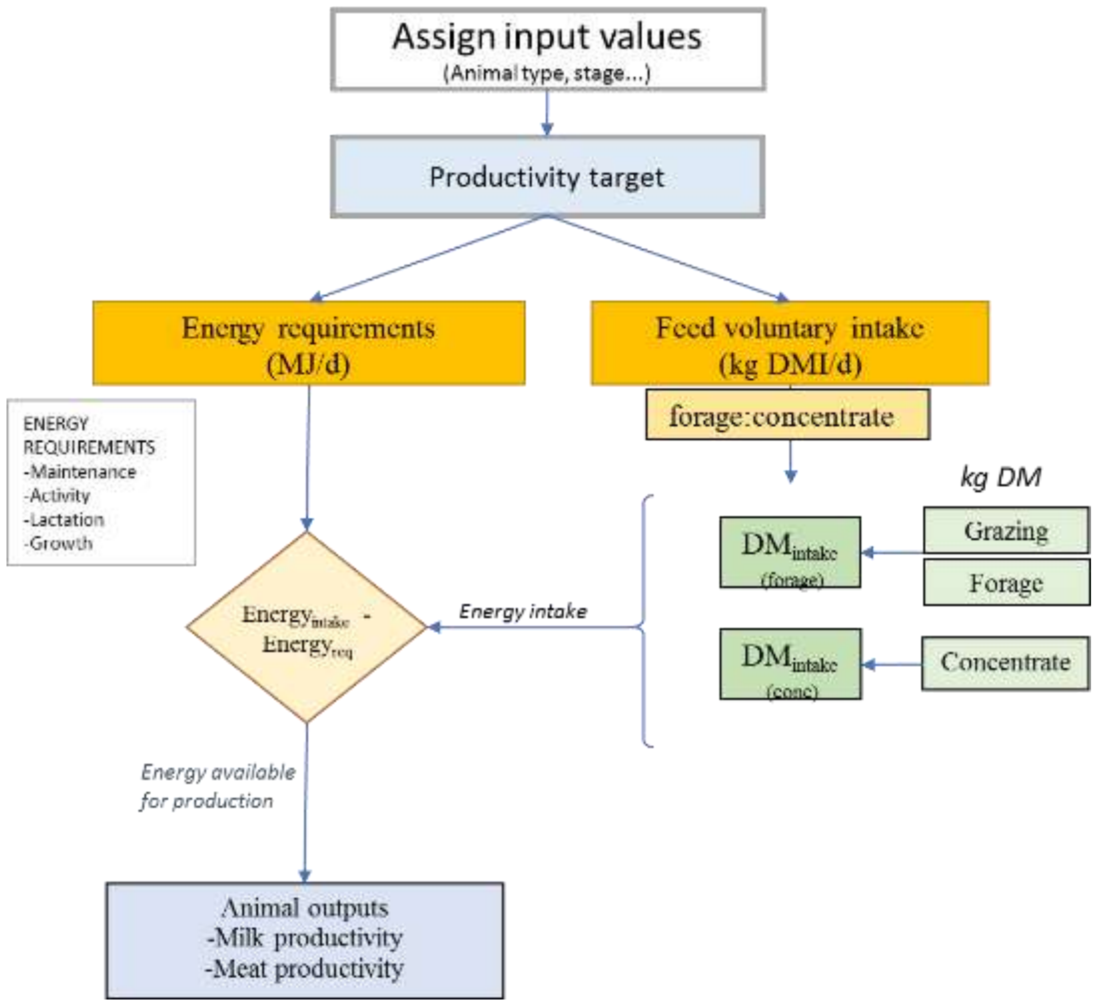


Sejian et al., 2017



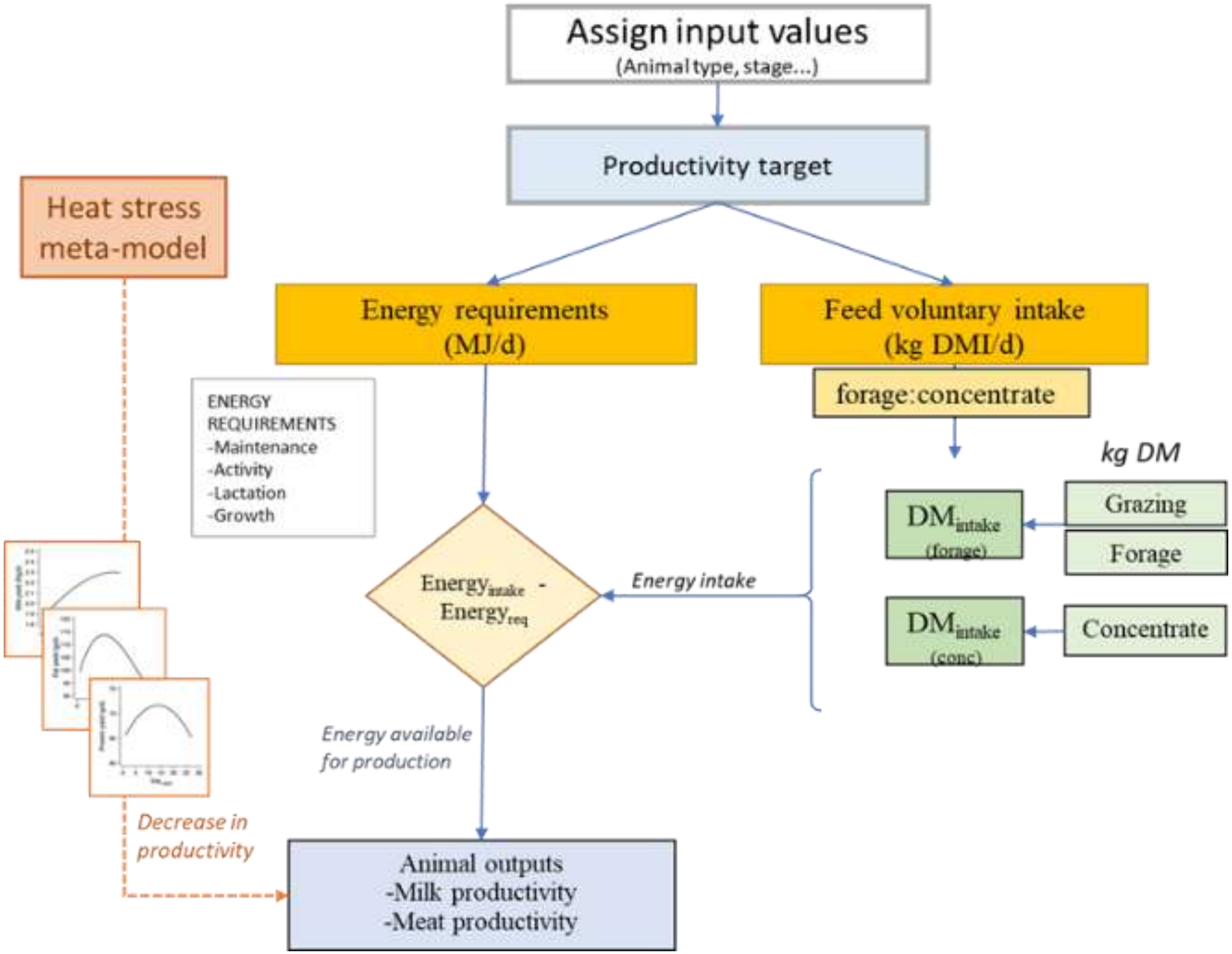
Development of models on animal performance:

Whole farm model:



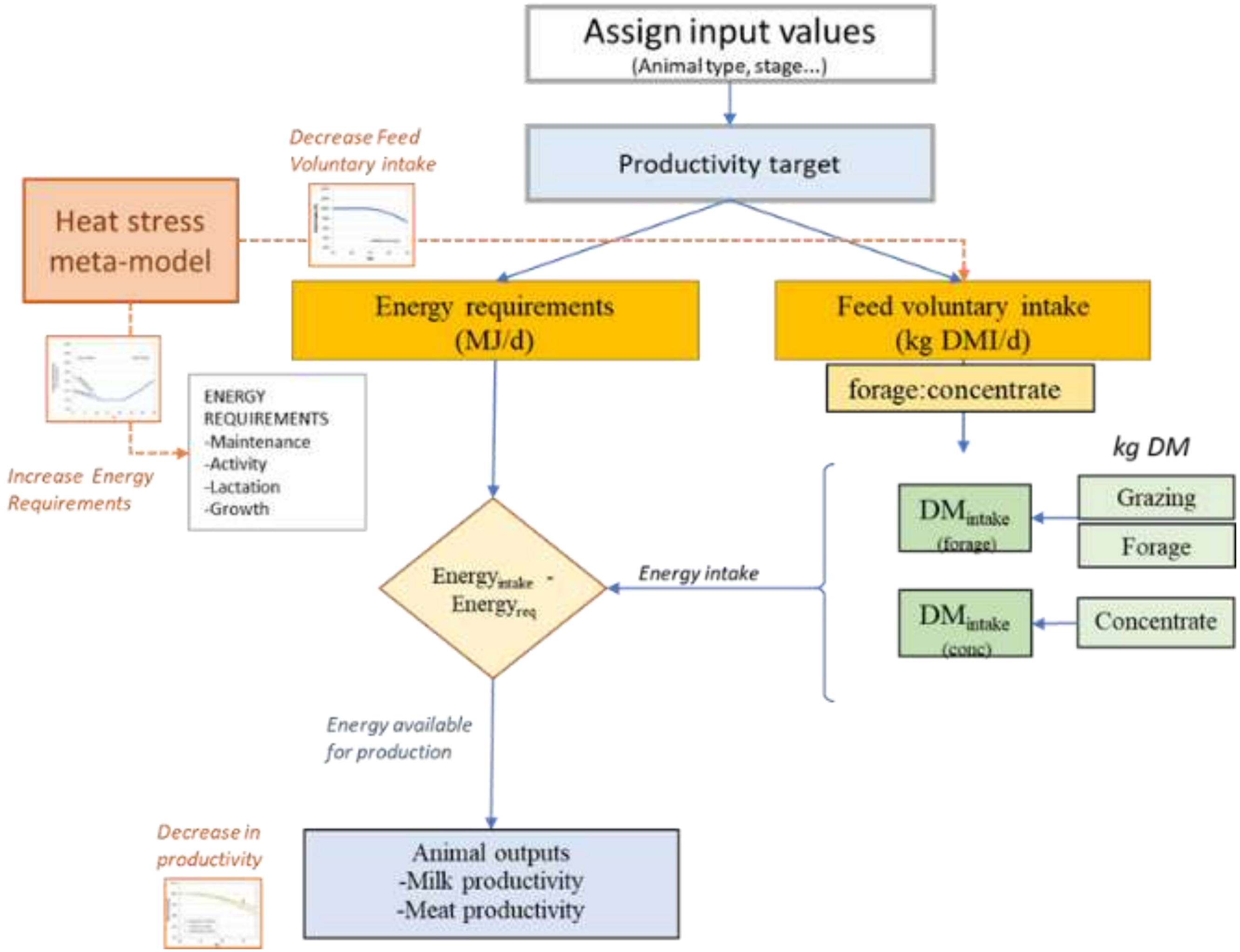
Development of models on animal performance:

Whole farm model: Integration of empirical models



Development of models on animal performance:

Whole farm model: Integration of semi-mechanistic model



Testing the modelling approach (lamb growth)

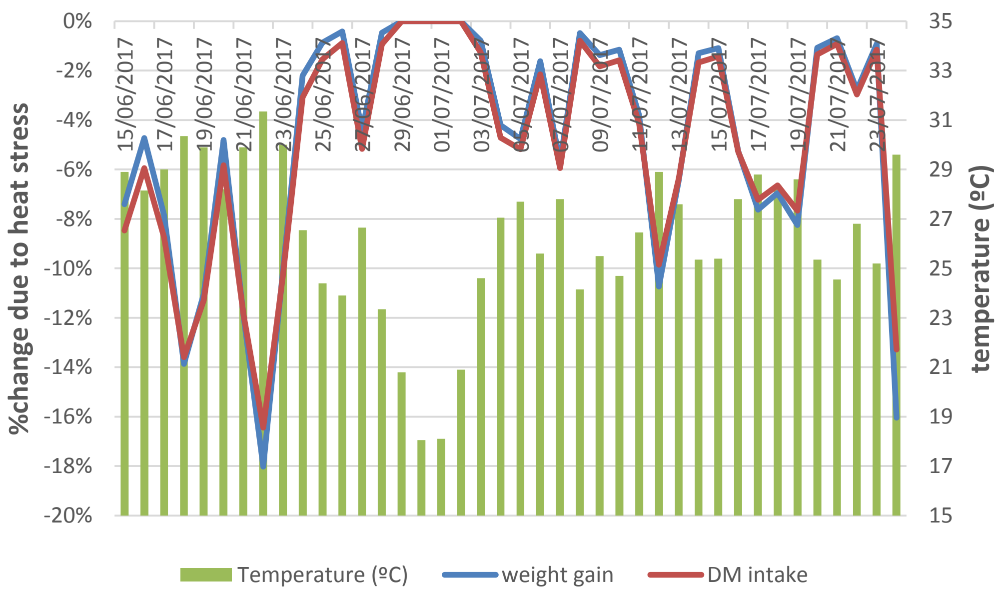
- Breed: rasa Aragonesa
- Location: Zaragoza (Spain) (June-July 2017)
- Effect of heat on Lamb growth (born in May)
- Period of study: from weaning (13.9 kg LW) to slaughter (22 kg LW)
- Number of ewes: 550, 650 lambs sold/yr (40% born in May)

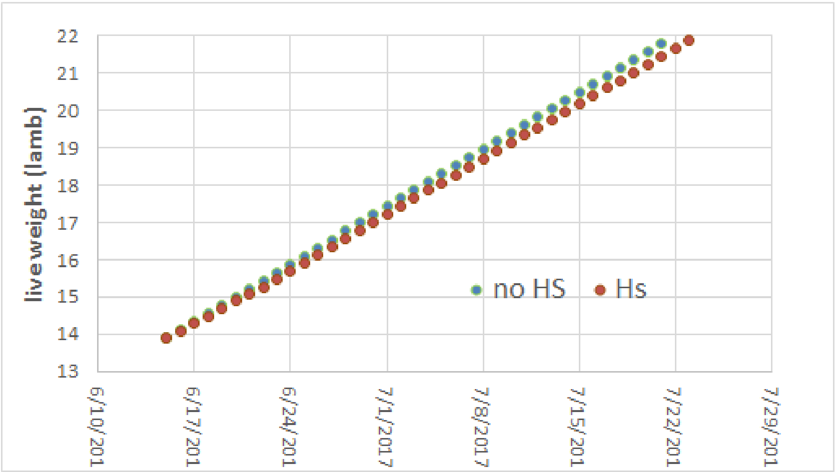
Diet composition (wean to slaughter)

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

Effect of heat on Lamb growth & DM Intake

<u>Lamb growth reduction and DM intake (%)</u>





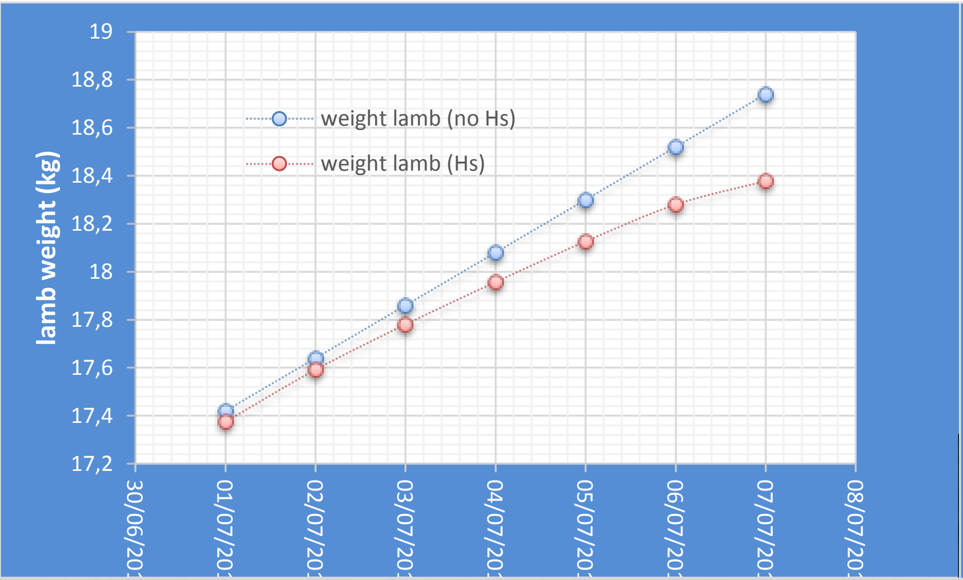
<u>2 extra days with heat stress</u>
450 g DM extra/lamb
228 kg extra concentrates

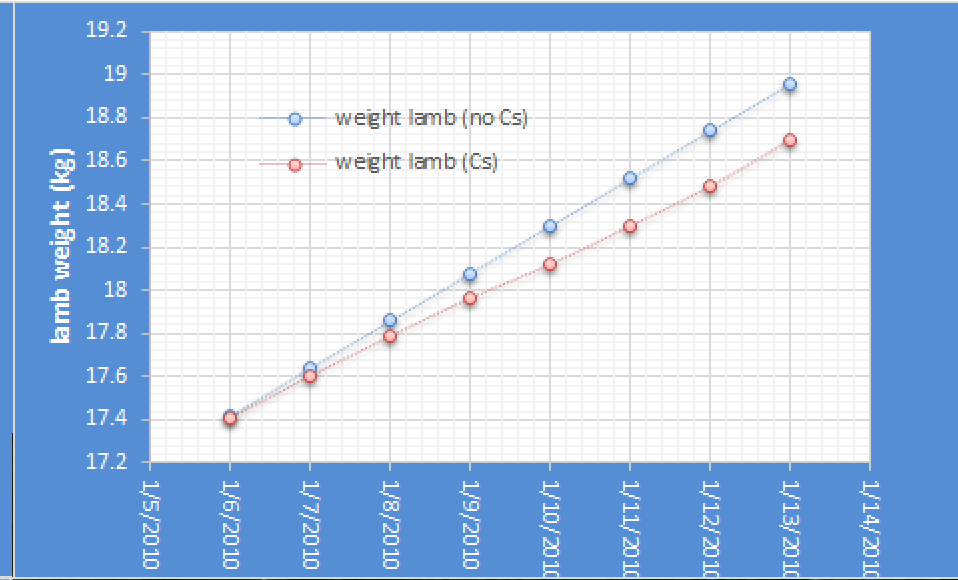
iSAGE Innovation for Sustainable Sheep and Goat Production in Europe

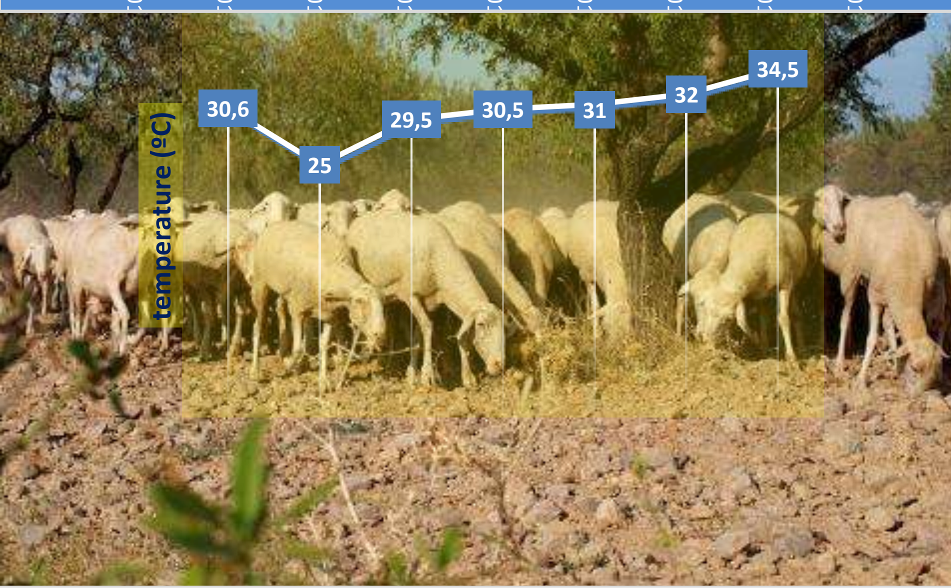
Extremes (heat and cold wave)

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

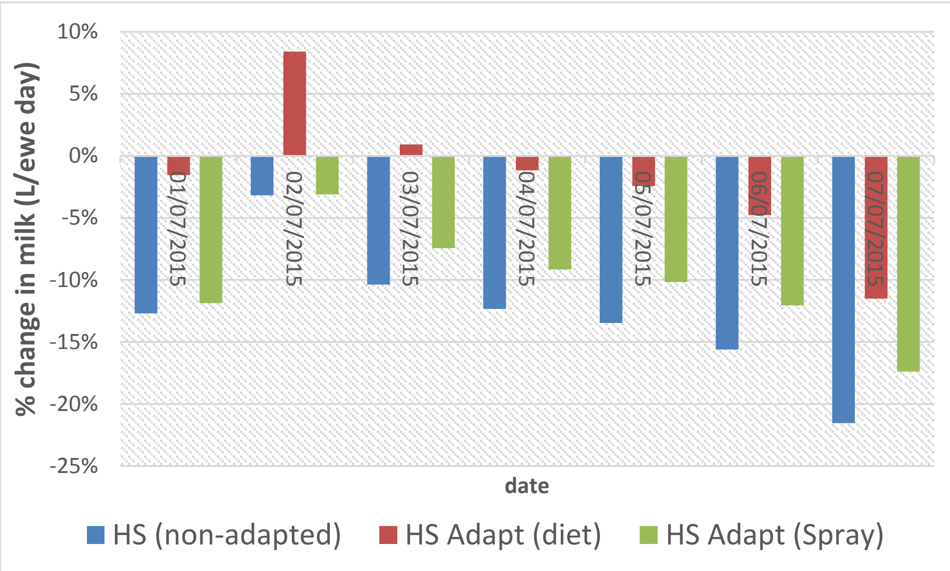
4 scenarios

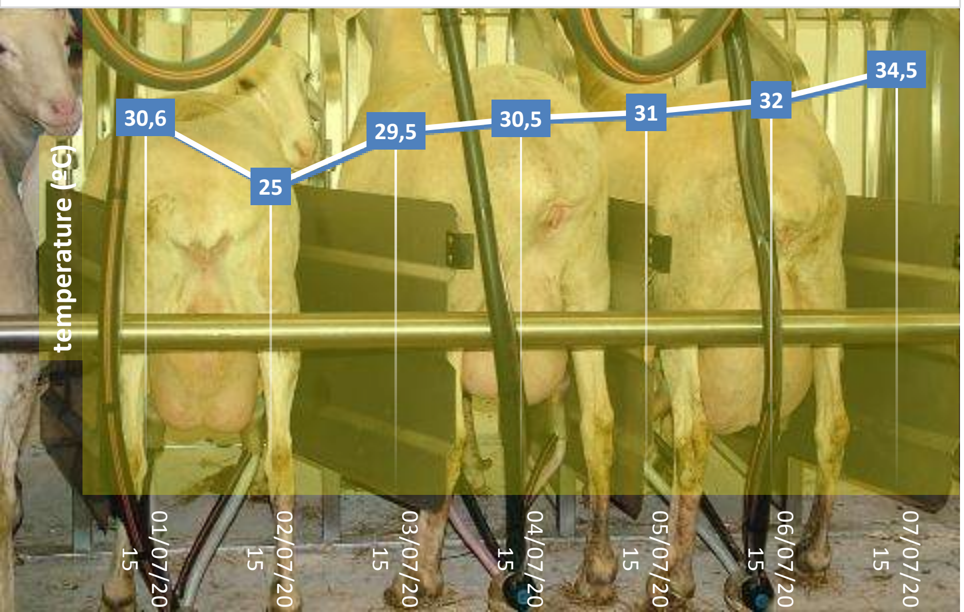
- No HS
- HS (non-adapted)
- HS (adapted-diet)
- HS (Adapted-spraying)

iSAGE

Innovation for Sustainable Sheep and Goat Production in Europe

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

Thank you!

iSAGE Training Course

21–22 October, Meknès, Morocco

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