DAFNE Dipartimento di Scienze Agrarie e Forestali

UNIVERSITÀ DEGLI STUDI DELLA Tuscia

Il cambiamento climatico e la sostenibilità dei sistemi zootecnici

Umberto Bernabucci

bernab@unitus.it

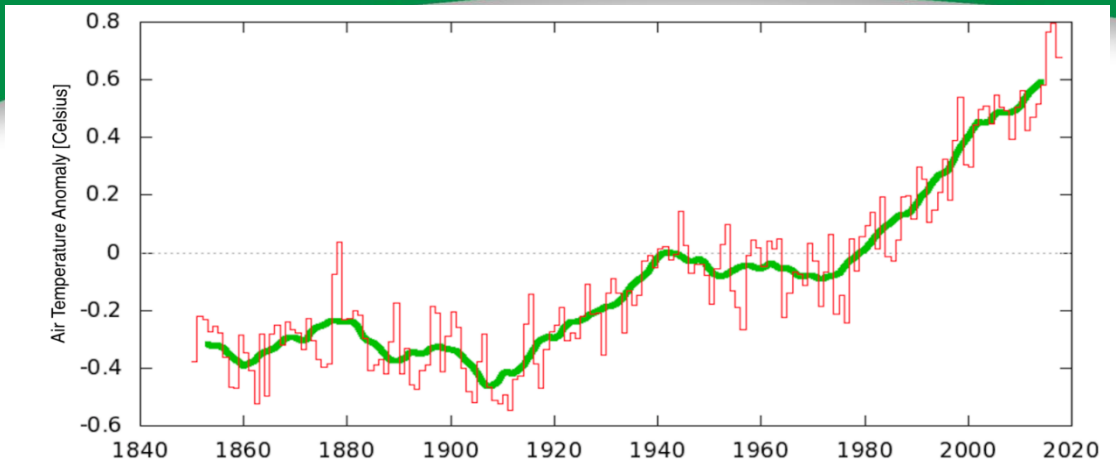
Convegno ASPA 2020
18.09.2020

Outlines

1. Climate change
2. Livestock production systems and sustainability
3. Concluding remarks

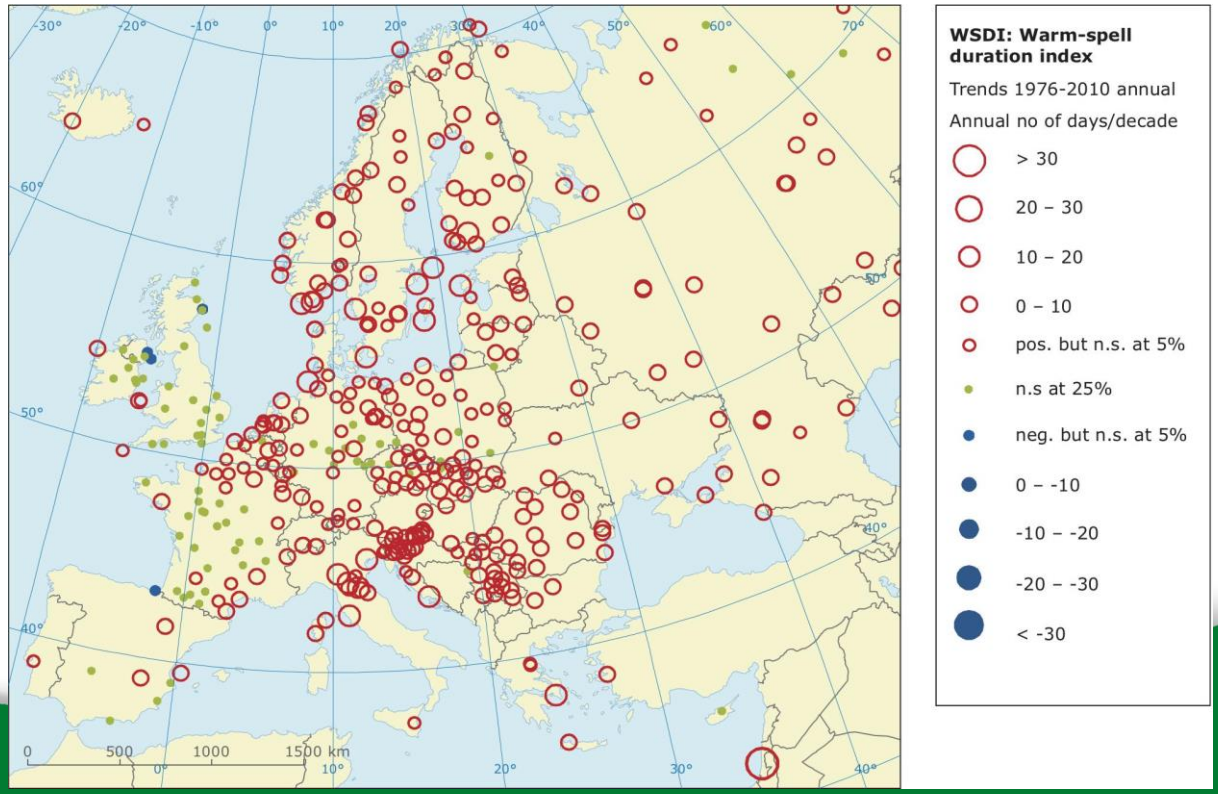
1. Climate Change

- *global warming*



Annual global mean air temperature anomaly (°C) at the surface (Jan-Dec)

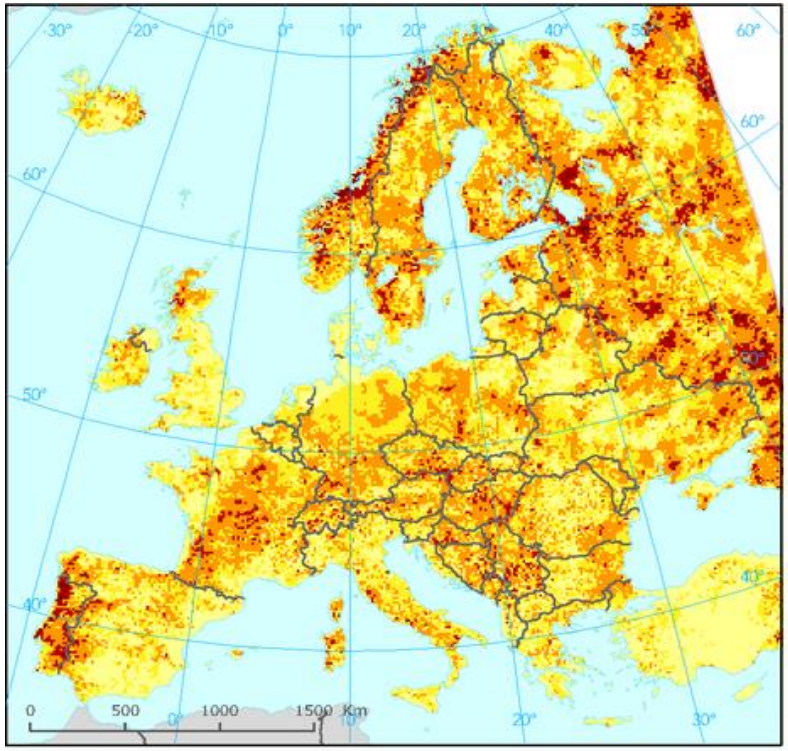
Trend of warm spell duration index 1976-2010. Circles represent the annual mean number of days for the decade.
Increase of hot days frequency.
(https://www.ecad.eu)



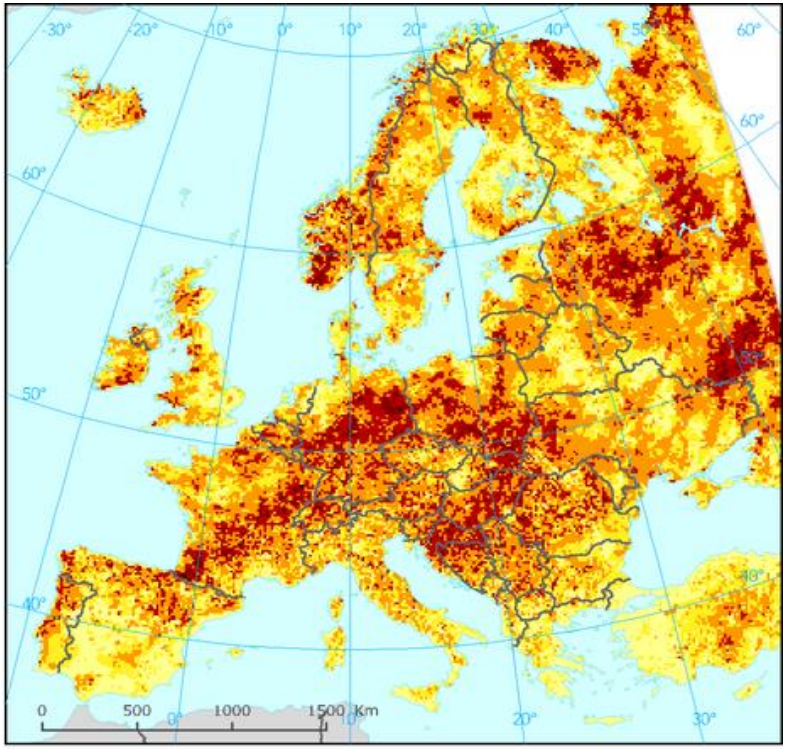
(Pasqui and Di Giuseppe, 2019)

Heat waves frequency in Europe

1961-1990



2071-2100

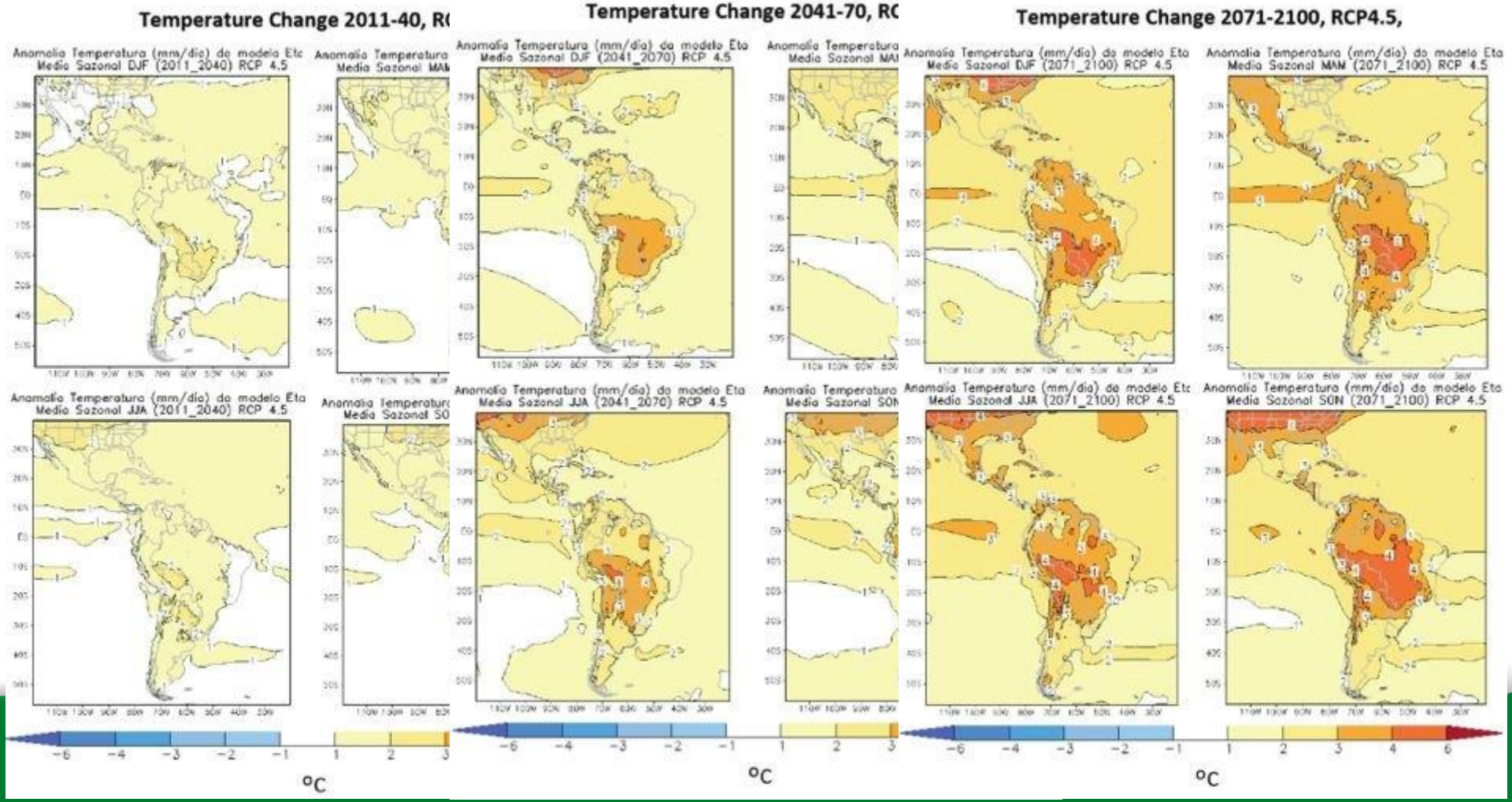


Heat wave frequency for the periods 1961–1990 (left) and 2071–2100 (right)
Based on the IPCC-SRES A2 emission scenario and the DMI climate model

< 1 | 1 | 2–3 | 4–5 | 6–7 | 8–9 | ≥ 10 | Outside report coverage

European Environment Agency

Temperature anomalies: South America (Marengo et al., 2014)



Bioclimatic index

Other than only temperature to estimate heat stress in farm animals a specific thermal index is adopted.

The THI (temperature-humidity index) is the index most used and is a combination between temperature and humidity effect.

Kibler (1964), Johnson (1980):

$THI = T_{db} + 0.36T_{dp} + 41.2^{\circ}\ C$

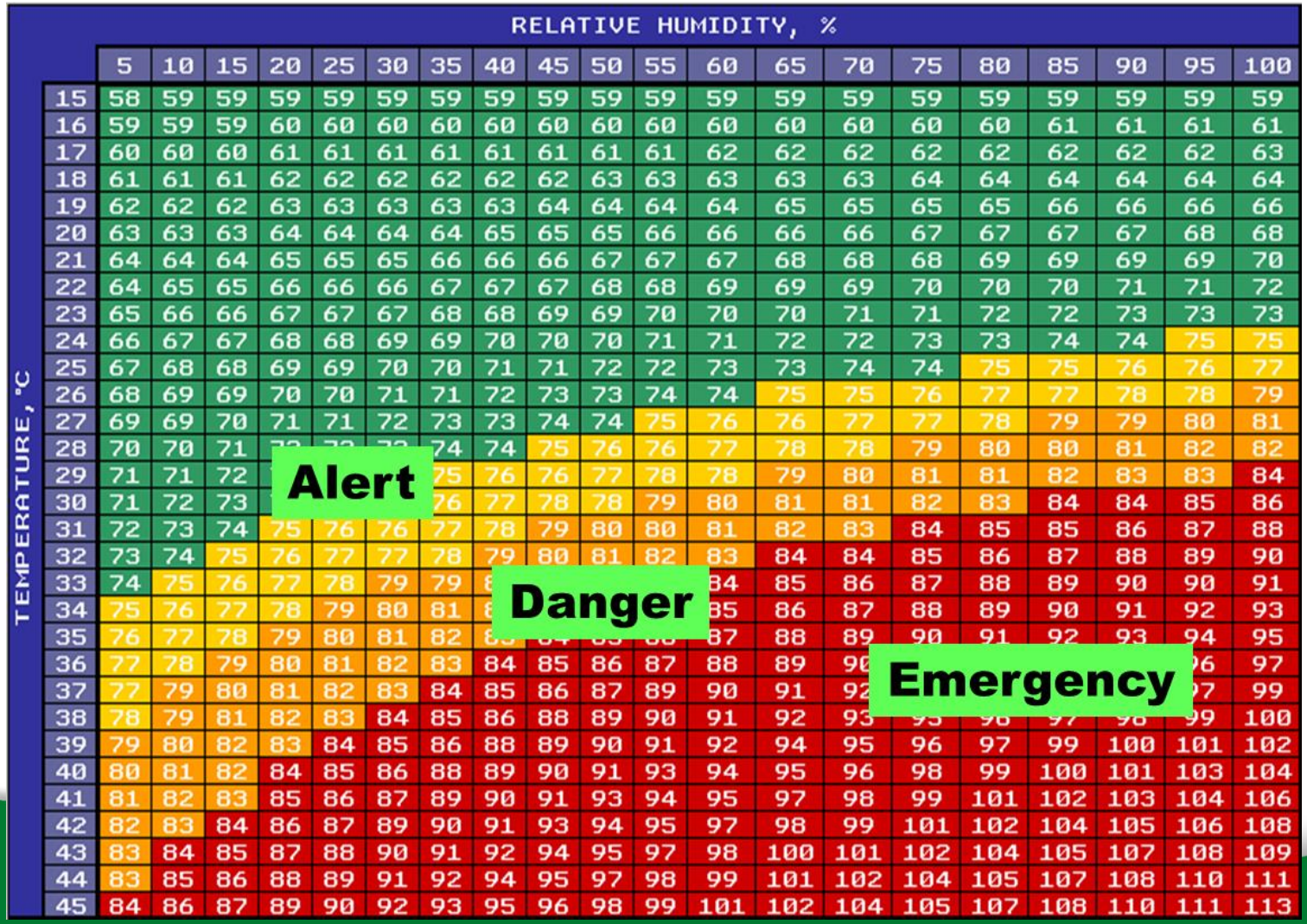
Kelly and Bond (1971):

$THI = (1.8 * T_{db}+32)-(0.55-0.55*RH/100)*[(1.8*T_{db}+32)-58)]$

Tdb = dry bulb temperature (° C)

Tdp = dew-point temperature (° C)

Weather safety Index (THI) chart



TEMPERATURE, °C	RELATIVE HUMIDITY, %																			
	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
15	58	59	59	59	59	59	59	59	59	59	59	59	59	59	59	59	59	59	59	59
16	59	59	59	60	60	60	60	60	60	60	60	60	60	60	60	60	61	61	61	61
17	60	60	60	61	61	61	61	61	61	61	61	62	62	62	62	62	62	62	62	63
18	61	61	61	62	62	62	62	62	62	63	63	63	63	63	64	64	64	64	64	64
19	62	62	62	63	63	63	63	63	64	64	64	64	65	65	65	65	66	66	66	66
20	63	63	63	64	64	64	64	65	65	65	66	66	66	66	67	67	67	67	68	68
21	64	64	64	65	65	65	66	66	66	67	67	67	68	68	68	69	69	69	69	70
22	64	65	65	66	66	66	67	67	67	68	68	69	69	69	70	70	70	71	71	72
23	65	66	66	67	67	67	68	68	69	69	70	70	70	71	71	72	72	73	73	73
24	66	67	67	68	68	69	69	70	70	70	71	71	72	72	73	73	74	74	75	75
25	67	68	68	69	69	70	70	71	71	72	72	73	73	74	74	75	75	76	76	77
26	68	69	69	70	70	71	71	72	73	73	74	74	75	75	76	77	77	78	78	79
27	69	69	70	71	71	72	73	73	74	74	75	76	76	77	77	78	79	79	80	81
28	70	70	71	[illegible]			74	74	75	76	76	77	78	78	79	80	80	81	82	82
29	71	71	72				75	76	76	77	78	78	79	80	81	81	82	83	83	84
30	71	72	73				76	77	78	78	79	80	81	81	82	83	84	84	85	86
31	72	73	74	75	76	76	77	78	79	80	80	81	82	83	84	85	85	86	87	88
32	73	74	75	76	77	77	78	79	80	81	82	83	84	84	85	86	87	88	89	90
33	74	75	76	77	78	79	79	[illegible]				84	85	86	87	88	89	90	90	91
34	75	76	77	78	79	80	81	[illegible]				85	86	87	88	89	90	91	92	93
35	76	77	78	79	80	81	82	[illegible]				87	88	89	90	91	92	93	94	95
36	77	78	79	80	81	82	83	84	85	86	87	88	89	90	[illegible]				96	97
37	77	79	80	81	82	83	84	85	86	87	89	90	91	92	[illegible]				97	99
38	78	79	81	82	83	84	85	86	88	89	90	91	92	93	[illegible]				99	100
39	79	80	82	83	84	85	86	88	89	90	91	92	94	95	96	97	99	100	101	102
40	80	81	82	84	85	86	88	89	90	91	93	94	95	96	98	99	100	101	103	104
41	81	82	83	85	86	87	89	90	91	93	94	95	97	98	99	101	102	103	104	106
42	82	83	84	86	87	89	90	91	93	94	95	97	98	99	101	102	104	105	106	108
43	83	84	85	87	88	90	91	92	94	95	97	98	100	101	102	104	105	107	108	109
44	83	85	86	88	89	91	92	94	95	97	98	99	101	102	104	105	107	108	110	111
45	84	86	87	89	90	92	93	95	96	98	99	101	102	104	105	107	108	110	111	113

Alert

Danger

Emergency

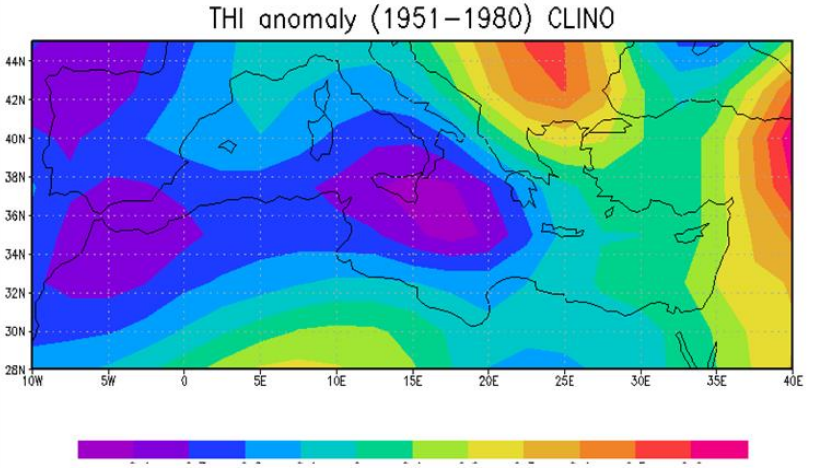
Int J Biometeorol (2011) 55:253–263
DOI 10.1007/s00484-010-0331-3

ORIGINAL PAPER

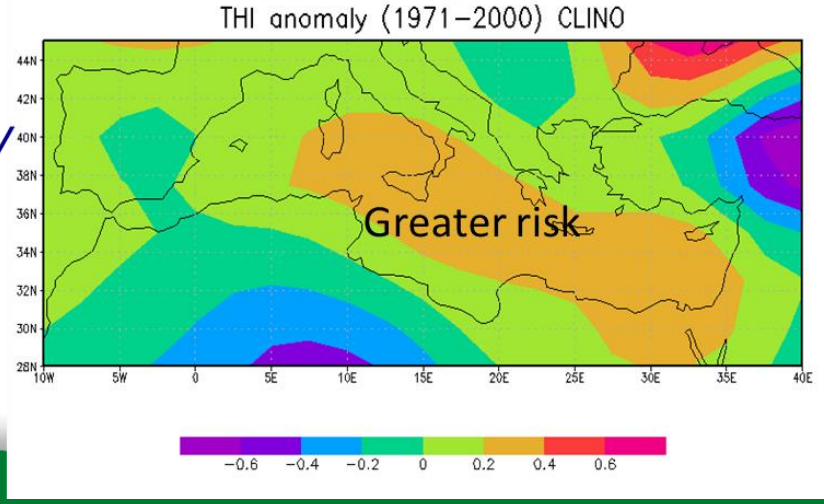
Dynamics of the temperature-humidity index in the Mediterranean basin

Maria Segnalini · Alessandro Nardone · Umberto Bernabucci · Andrea Vitali · Bruno Ronchi · Nicola Lacetera

Mediterranean basin: THI changes



THI anomaly compared to the reference period



1. *High degree of heterogeneity*
2. *Strong North-South gradient*
3. *Overall warming in summer*

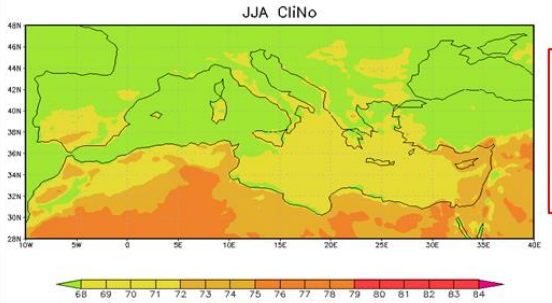
THI scenario: Mediterranean basis – Maps of summer THI dynamics

Int J Biometeorol (2013) 57:451–458
DOI 10.1007/s00484-012-0571-5

ORIGINAL PAPER

Temperature humidity index scenarios in the Mediterranean basin

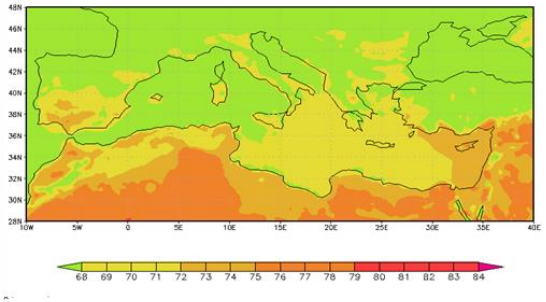
M. Segnalini &U. Bernabucci &A. Vitali &A. Nardone & N. Lacetera



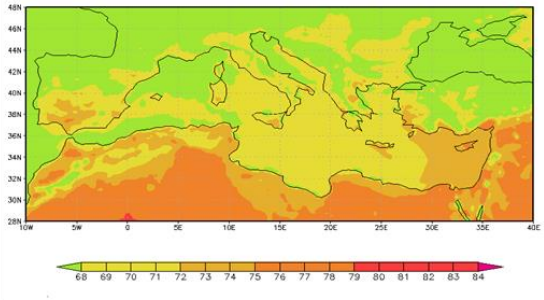
CLINO
Reference period
1971-2000

It will be one of the hot-spots of the World

2011 to 2020

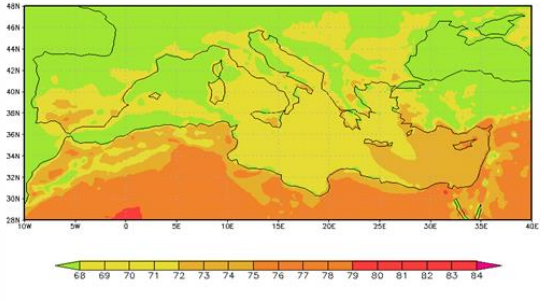


2021 to 2030

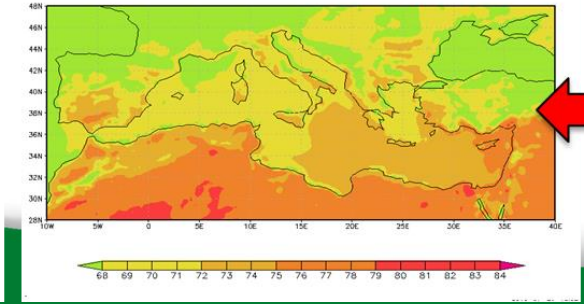


Tendency in the gradual increase of THI from 2011 to 2050

2031 to 2040

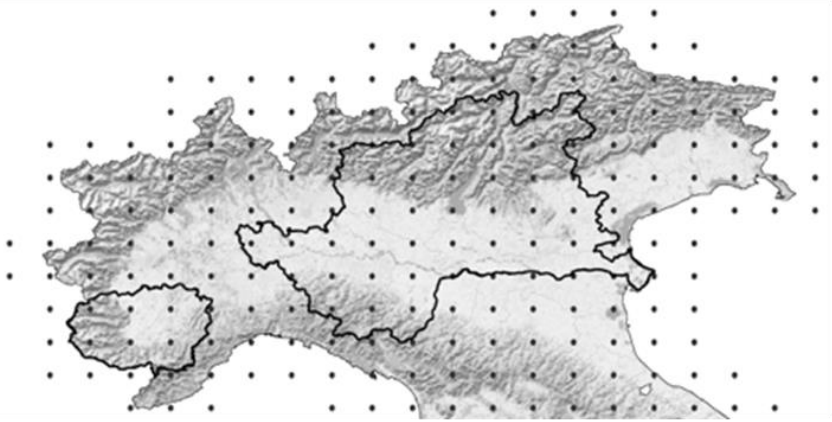


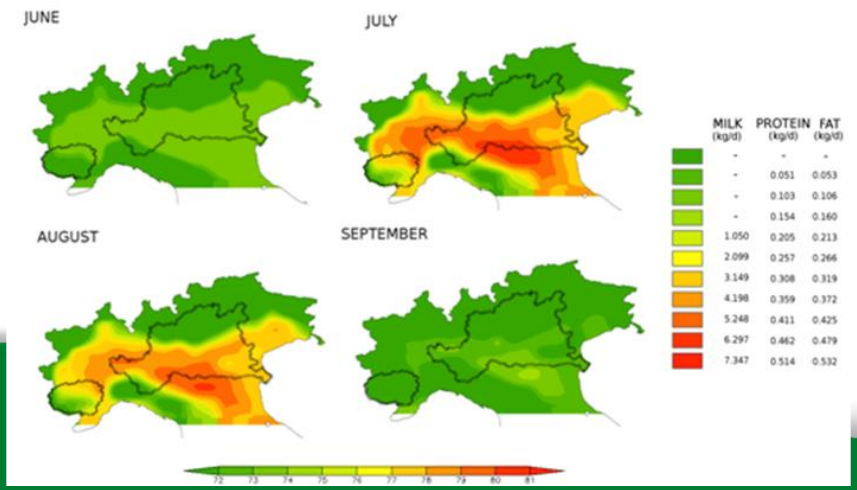
2041 to 2050

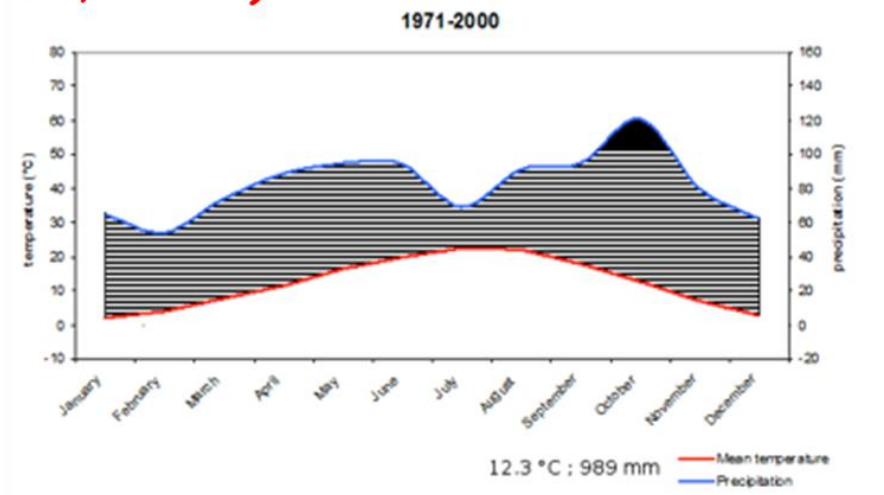


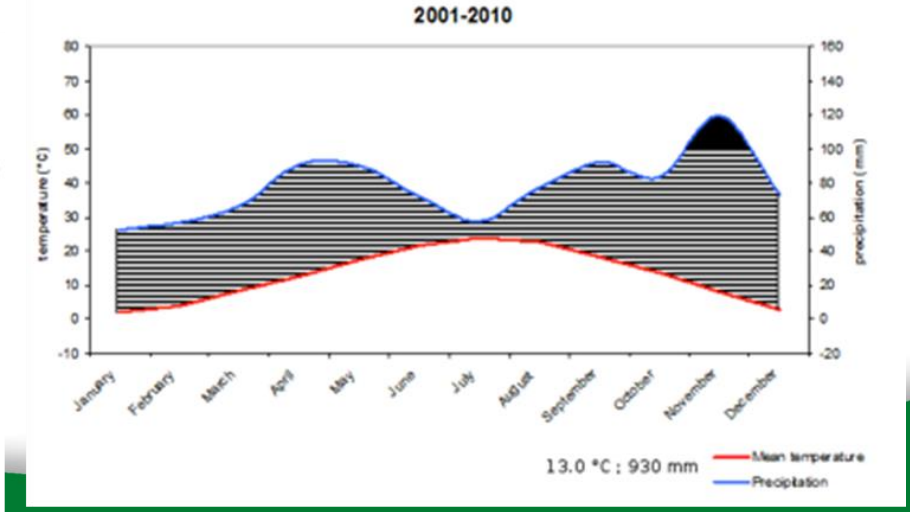
Spain, southern France and Italy: THI in 2041-2050 is expected to increase up to 3-4 units

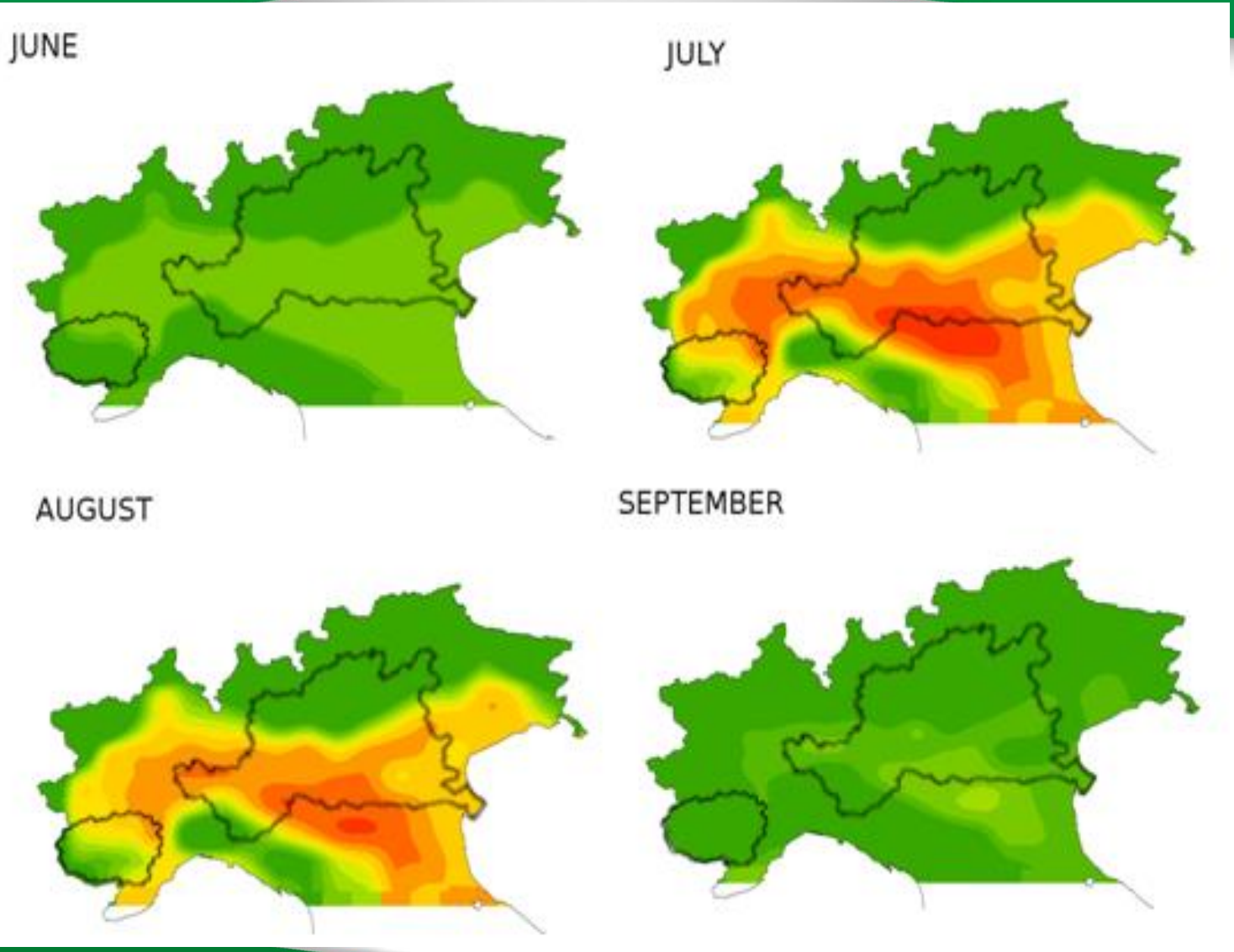
Climate caracterization of Grana Padano production aera (Vitali et al., 2019)











	MILK (kg/d)	PROTEIN (kg/d)	FAT (kg/d)
	-	-	-
	-	0.051	0.053
	-	0.103	0.106
	-	0.154	0.160
	1.050	0.205	0.213
	2.099	0.257	0.266
	3.149	0.308	0.319
	4.198	0.359	0.372
	5.248	0.411	0.425
	6.297	0.462	0.479
	7.347	0.514	0.532

Vitali et al., 2019

In Summary

1. Increase in temperature (and THI), increase in the frequency of heat waves and alteration of rainfall frequency and intensity is expected in the future.

2. The increasing concern with the thermal comfort of agricultural animals is justifiable not only for countries occupying tropical zones, but also for nations in **temperate zones** where high ambient temperatures are becoming an issue.

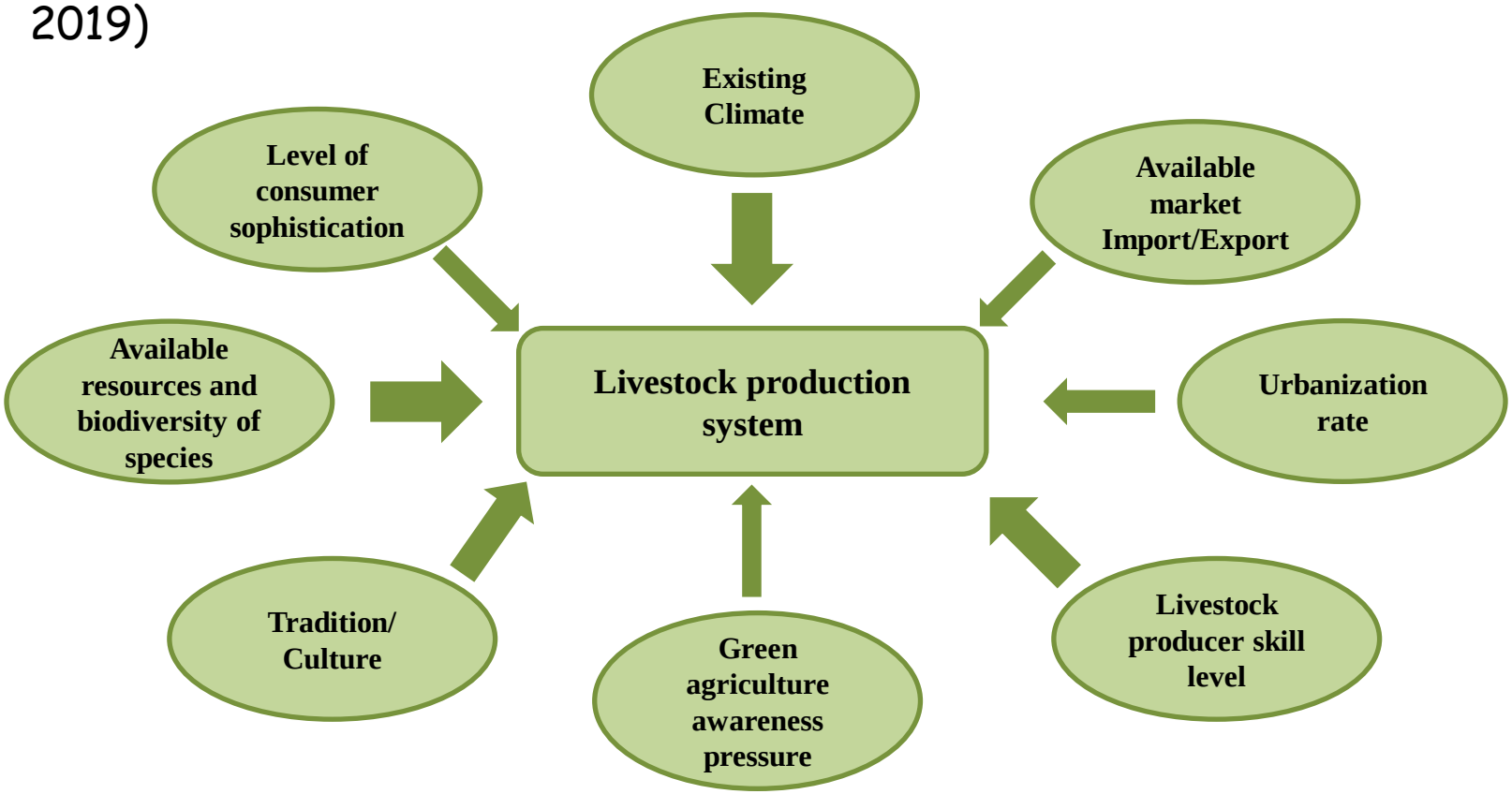
2. Livestock production systems and sustainability

What do we mean when we talk about livestock production and what is the definition of livestock?

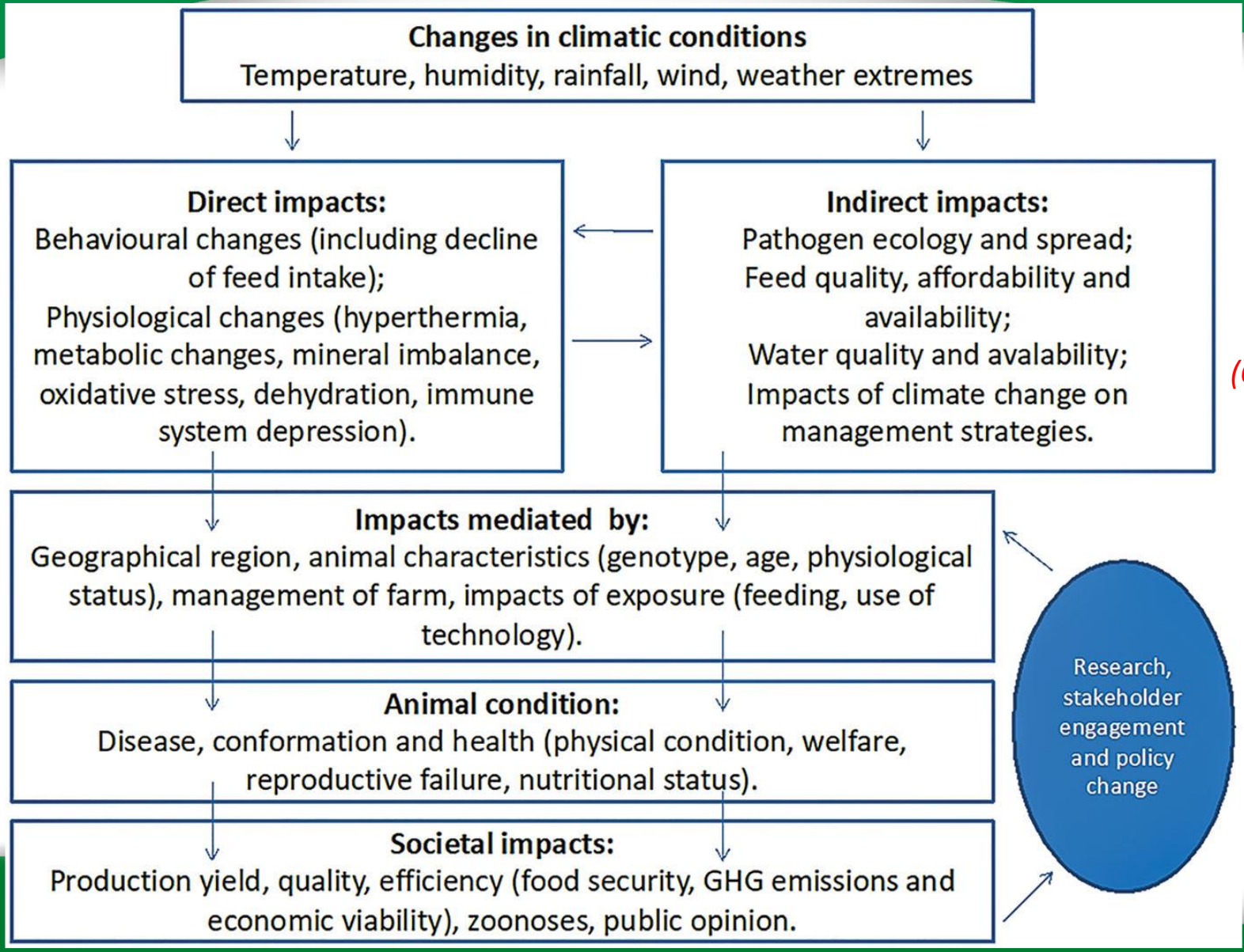
It is defined as domesticated animals raised in an agricultural production system with the aim of producing food, fibre and labour.

Sometimes, reference is only made to ruminants such as cattle, sheep and goats but this definition should include all livestock which fits the original description, including poultry, pigs etc.

The most important factors influencing a specific livestock production approach can be summarised as follows (Rust, 2019)

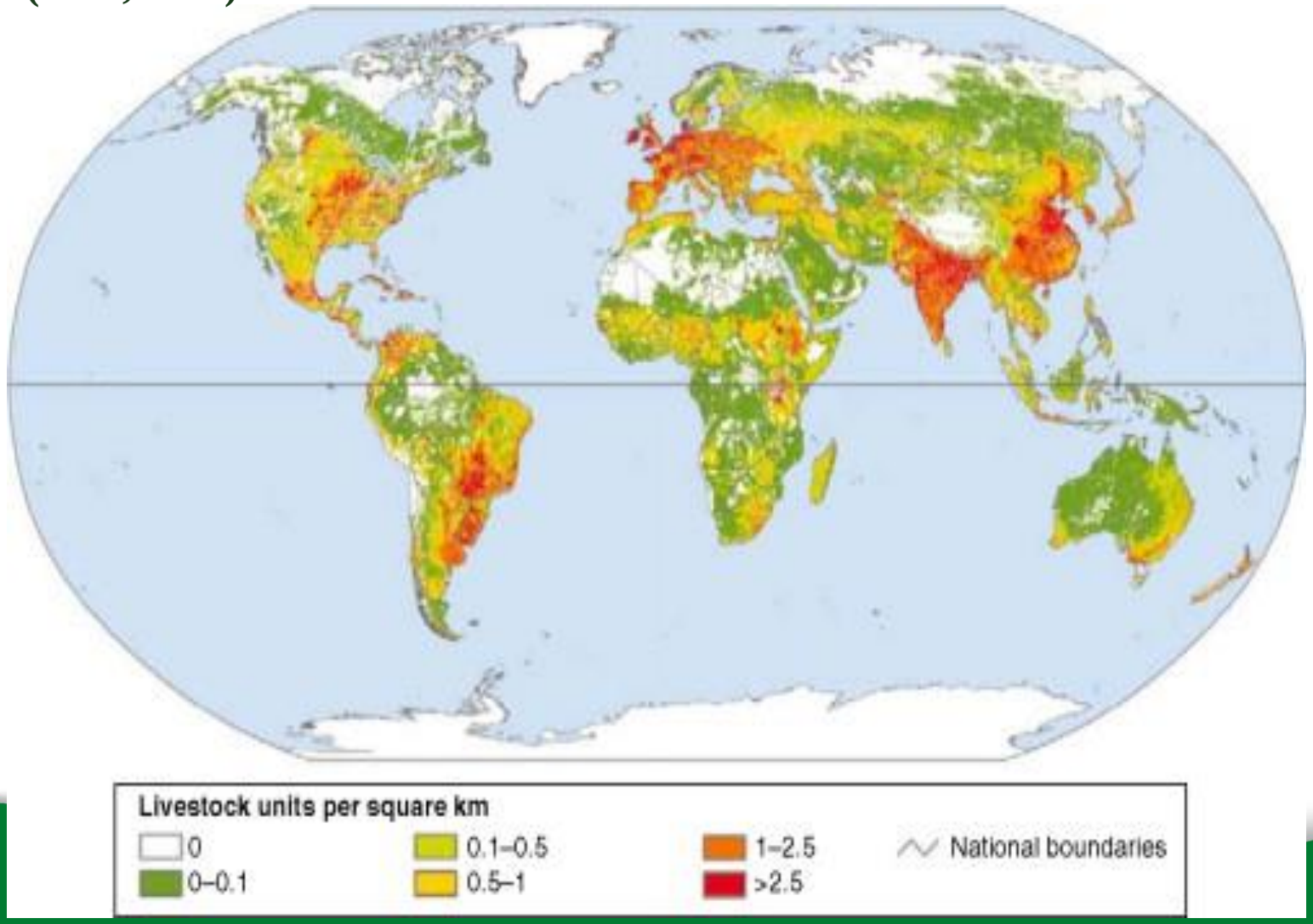


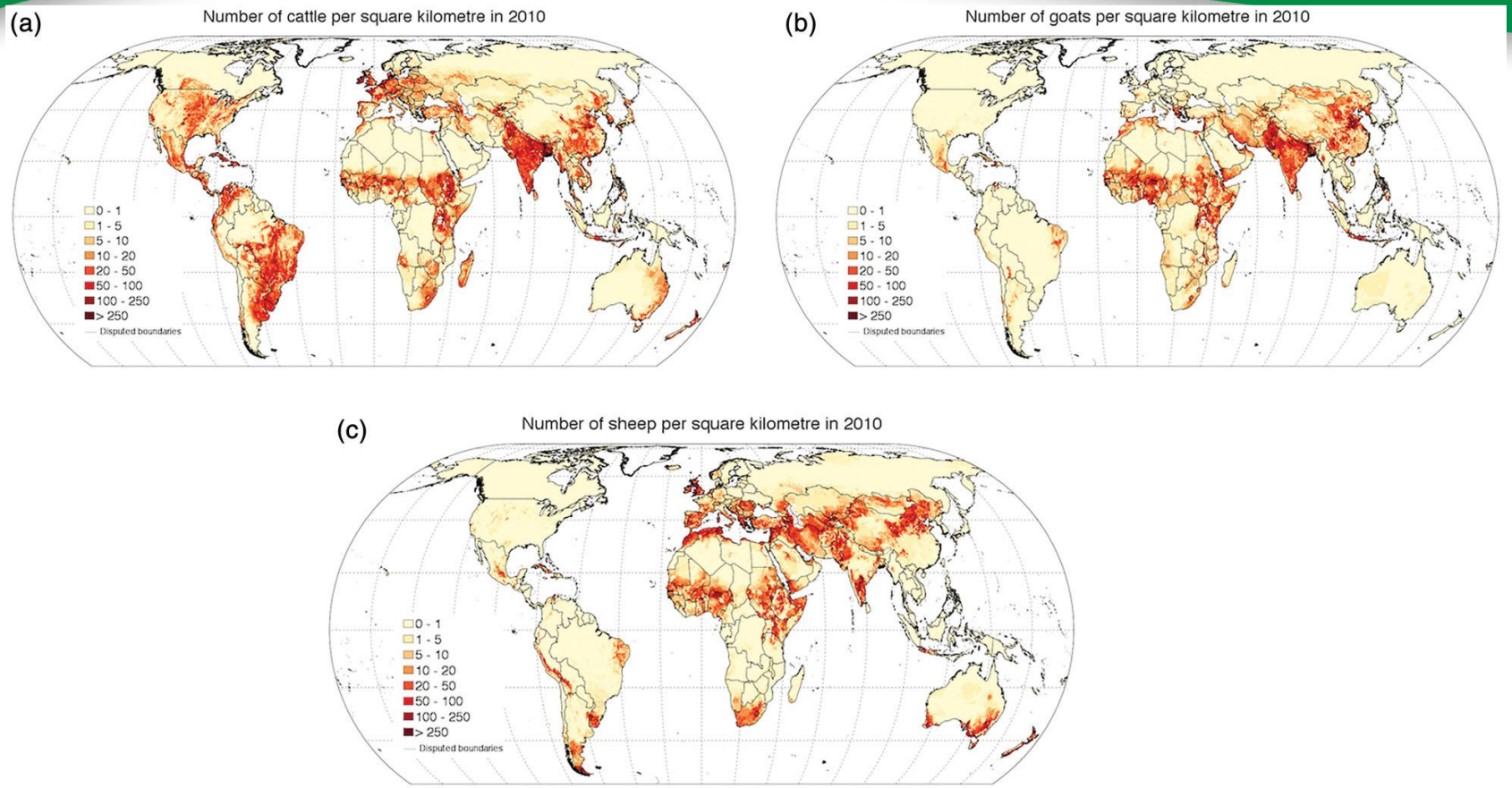
Main drivers of a specific livestock production system (*weight of arrow indicate importance*)



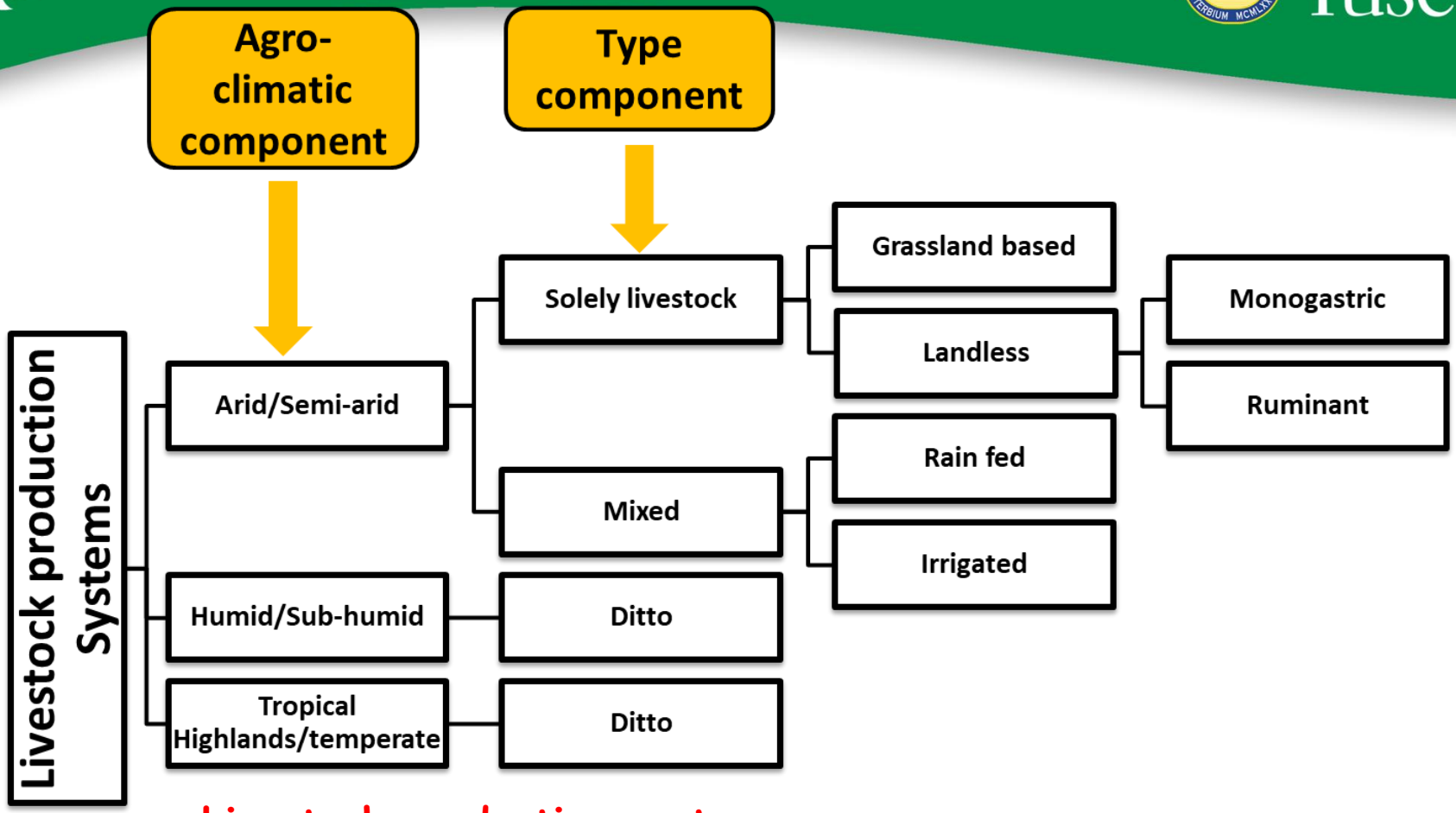
Impacts of climate change on livestock *(Özkan et al. 2016).*

Global density of livestock (units per square kilometre) (FAO, 2006)





(a) Overview of the livestock of the world: data set for dairy and beef cattle
(b) Overview of the livestock of the world: data set for goat
(c) Overview of the livestock of the world: data set for sheep IT



Livestock production systems according to the classification devised by Seré and Steinfeld (1996). This classification system consists of two main criteria namely Agro-climatic and Type (Rust, 2019).

Farming systems

Principal categories :

Serè and Steinfeld, 1996; Steinfeld et al., 2006, 2006b (modified)

1. **Grazing/pastoral systems:** these include 3.35 billion hectares of arid pastures which are not cultivable. This system provides 24% of the production of beef and 30% of the production of sheep and goat meat *(Steinfeld et al., 2006).* Ruminants are the most represented species reared.

2. **Combined/mixed agro-zootechnical systems** (rainfed/irrigated): these are the most important systems of animal production for that which regards the number of animals, total production and the number of consumers supplied. These systems include nearly 2.5 billion hectares which represent the principle sources of meat (46%) and milk (90%). All species are represented.

3. **Industrial/landless systems** (monogastrics/ruminats): these systems provide the production of roughly 71% of the chicken and 55% of the pork produced worldwide. Monogastrics are the most represented species.

4. **Stratified systems** (a combination of the above)

Three questions regarding **climate change**

1st. Which livestock systems will be more affected by climate changes?

2nd. Which modifications are needed in the livestock systems to cope with the effects for maintaining sustainability?

3rd. Which livestock production factors will be the most vulnerable under climate changes?

Nardone et al. 2010

The answer to the 1st question

To answer the 1st question we can divide the livestock systems into 3 main levels regarding **climate dependence**

Climate dependence/vulnerability of livestock systems

CLIMATE	SYSTEMS		
Totally dependent	Grazing/Pastoral		
Partially dependent	Mixed	Rainfed Irrigated	
Potentially independent	Industrialized/Landless		

Dependence: how much the animal performances and health are affected by the climatic conditions

Nardone et al., 2010

Climate dependence/vulnerability of livestock systems

Totally dependent

Grazing/Pastoral systems: are systems where the animals are free or forced to graze, and don't have any protection from direct climatic effects. Animals can avoid solar radiation only by taking shelter in the shade of the trees, where and if there are any.

Partially dependent / Independent

Mixed and Industrialized systems: Animals are reared in barns where temperature, humidity, solar radiation, wind and so on, are totally or at a very high level under structural and managerial control.

Nardone et al., 2010

The answer to the 2nd question
on modification of systems

Pastoral systems: species, feeding and production

	Dairy cattle	Beef	Pigs	Small ruminants	Others
Pasture	↓	↓ ↑	↓	↓	↓
Fight Climate Change	↔	↔	↔	↔	↔
Animal health	↓	↓	↓	↓	↓ →
Stock	↓	↓ →		↓ →	↑ →
Production	↓	↓ →		↓ →	↑ →
Biodiversity	↓	↓ →	↓	↓	↔
Sustainability	↓	↓	↓	↓	↑ →

Africa; North, Central, South America; Southern Asia

↓ Reduction

↑ Increase

→ No change

Silvopastoral systems

Silvopastoral systems (SPS) are agroforestry arrangements that purposely combine fodder plants, such as grasses and leguminous herbs, with shrubs and trees or palms for animal nutrition and complementary uses *(Murgueitio et al. 2011; Chará et al. 2019).*

They allow the intensification of cattle production based on natural processes and are recognized as an integrated approach to sustainable land use. SPS promote beneficial ecological interactions that manifest themselves as increased yield per unit area, improved resource use efficiency and enhanced provision of environmental services

Silvopastoral systems provide technological, economic, environmental, and cultural options for supporting livelihoods and commercial activities through sustainable livestock farming. All these are coincident with the objectives of the Global Agenda and with its support of the SDGs.

Meat and milk production per hectare in years 0 and 9 (Chará et al. 2019)

	Milk (Mg ECM/ha)				Meat (kg LW/ha)		
Case	Baseline	Year 9	% Diff.		Baseline	Year 9	%Diff.
1					126	1187	842
2	7.2	11.5	60				
3	11.3	13.4	19				
4	14.0	24.4	74				
5					85	1034	1116
6	0.4	9.2	2200				
7	2.9	12.0	314				
8					341	2670	683
9					48	274	471
10					86	150	74

SPS benefits

when compared to treeless pastures are:

i) increased production of higher quality forages, which reduces the need of supplementation from external sources *(Mojardino et al. 2010, Barahona et al. 2014)*;
ii) increased (up to 4-fold) cattle production per ha *(Thornton and Herrero 2010)*;
iii) higher storage of carbon in both aboveground and belowground compartments of the system (Nair et al. 2010, Montagnini et al. 2013);
iv) improvement of soil properties due to greater uptake of nutrients from deeper soil layers, enhanced availability of nutrients from leaf-litter and increased nitrogen input by N2-fixing trees (Nair et al. 2007, Vallejo et al. 2010, Cubillos et al. 2016);
v) enhanced resilience of the soil to degradation, nutrient loss, and climate change, *(Ibrahim et al. 2010, Harvey et al. 2013, Murgueitio et al. 2013)*;
vi) improved water holding and infiltration capacity of the soil which contributes to the regulation of the hydrological cycle by reducing runoff intensity (Jose 2009, Rios et al. 2007);
vii) habitats of higher biodiversity *(Nair et al. 2010, Sáenz et al. 2007, Giraldo et al. 2011, Montoya-Molina et al. 2016)*;
viii) improved animal welfare (Broom et al. 2013).

Mixed rainfed systems: species, feeding and production

The possibility to cope with the effects of climate change will vary according to the available technologies and extension services where the systems are located.

	Dairy cattle	Beef	Pigs	Poultry	Small ruminants	Others
Forages	↓ →	↓ →			↓	
On farm grain	↓	↓	↓		↓	
Market grain	↑	↑	↑	↑	↑	
Fight Climate Change	↓	↔	↔	↓ →	↔	↔
Animal health	↓	↓	↓	↓	↓	↓ →
Stock	↓	↔	↓	↓	↓	↑ →
Production	↓ →	↓ →	↓ →	↔	↓ →	↑ →
Biodiversity	↓	↓	↓	↓	↓ →	↔

Africa;
South America;
South Asia;
South Australia

↓ Reduction

↑ Increase

→ No change

Mixed irrigated systems: species, feeding and production

	Dairy cattle	Beef	Pigs	Poultry	Small ruminants	Others
Forages						
On farm grain						
Market grain						
Fight Climate Change						
Animal health						
Stock						
Production						
Biodiversity						

Modifications are possible according to the possibilities in irrigating and in adaptation of barn/houses

Central Europe;
North America;
Northern India;
North-East China

Industrialized systems: species, feeding and production

	Dairy cattle	Beef	Pigs	Poultry	Small ruminants
On farm grain	↑	↑	↑	↑	↑
Market grain	↑	↑	↑	↑	↑
Stock	↑	↑	↑	↑	↑
Production - *Milk* - *Meat*	↑	↑	↑	↑	↑

↓ Reduction

↑ Increase

→ No change

The answer to the 3rd question on factors more vulnerable

Climate change

risks of poor quality water

>salinisation (harder water)

>content of chemical contaminants (organic/inorganic)

>concentration of heavy metals

>concentration of biological contaminants

		i.e. impairments
>nitrites	→	-cardiovascular system -respiratory system
>heavy metal	→	-escretory, skeletal and nervous system -production (hygienically and sanitary Q.)
>altered pH	→	-metabolism -fertility -digestion

Global warming forces us to produce animal products that need less water

Protein content in % per Kg of product		g of product to obtain 1 unit of protein (= 34 g)	
		g of product	Kg water consumption
Beef	21	162	4577
Chicken	19	179	1342
Milk	3	1000	1500

	Sweat water/year (Km^3/year)
Total	110.300
Loss	97.800
Avalaible for man activity:	12.500
-agricult.	2880
-industrial	975
-towns	300
-other	275

Beef cattle require 3.4 times more water than poultry or milk to produce 1 unit of animal proteins

Nardone et al. 2010

Summary of three answers

Regarding adaptation to climate change (CC)

- All livestock systems are affected by CC, (>pastoral, >rainfed mixed, <>irrigated mixed, <industrialized),
- Pastoral systems and ± mixed rainfed systems will face difficulties adapting to CC,
- Industrialized and ± mixed irrigated systems can cope with CC.
- Money and energy will be needed.

Regarding animal population

- Pigs and poultry will remarkably increase in number,
- Species and breeds tolerant to heat stress will increase in population, especially goats,
- Camels could be rediscovered.

Summary of three answers

Regarding production

- Pork, poultry and egg production will remarkably increase,
- Production dependent on crops and pastures will undergo inconveniences,
- Growth in production of meat from ruminants and cow milk will be restricted.

Regarding productive factors

- Water can be a very limiting factor for livestock.

3. Concluding remarks

Concluding remarks

- The grazing and mixed rainfed systems, which count on the availability of pastures and on farm crops, will be most damaged by climate change.

- Consequences would be considerable, since these two systems raise almost 70% of all the ruminants in the world and (Worldwide) they produce almost 2/3 (two/thirds) of the milk and more than 70% of meat from ruminants.

- An aspect which makes the situation even more critical is that more than 50% of this production is raised in developing countries where the need of animal products will increase.

Concluding remarks

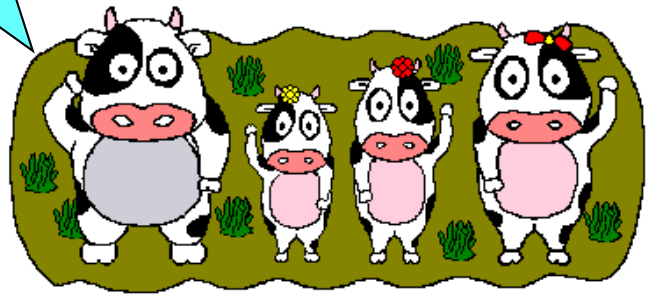
- Because of the foreseeable reduction in areas suitable for livestock and the limited availability of water, the number of heads of species reared in industrialized systems will increase. Therefore, we will have more pigs and poultry.

- In addition, because of the main difficulties in grazing and rainfed systems, we can predict an increase in production also of milk and beef in industrialized systems, even if this increase will be more moderate than poultry and pork.

The role of research

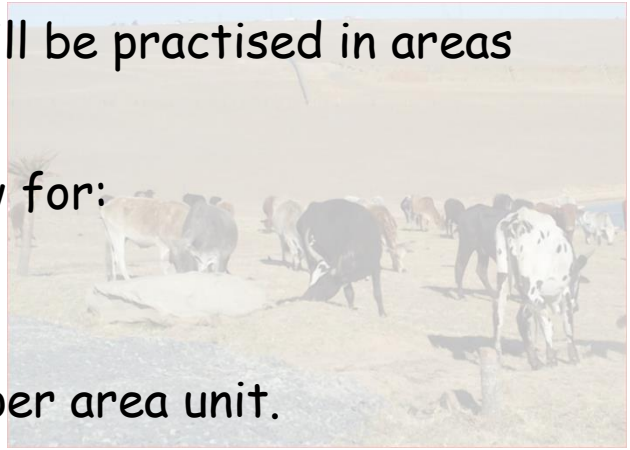
- Close collaboration between animal scientists and agronomists, meteorologists, engineers, economists and others
- Effort in selecting animals concentrating on robustness and adaptability to heat stress
- Avoid risk of inbreeding and loss of genetic variability
- Develop new technologies in controlling microclima with low energy expenditure
- Develop new indices to evaluate climatic effects on animals
- Develop ad hoc weather forecast-reports for animal species or production
- Improve technology of water conservation
- Select crops for harsh environment

Thanks for attention



How will extensive systems have to adapt/change under a predicted climate change scenario?

- Decrease in the total extent of extensive livestock production systems (ELPS) in both developing and developed countries.
- Spatial movement (extensive livestock production will be practised in areas and regions where it was impossible before).
- Camps/paddocks will have to be re-designed to allow for:
  - *More shaded areas (trees or artificial).*
  - *More and strategically placed water points.*
- Farming units will increase in size with less animals per area unit.
- Conservative stocking rates, pasture conservation and rainwater harvesting.
- Indigenous/adaptive breeds will dominate but should not be to the detriment of production levels.



How will extensive systems have to adapt/change under a predicted climate change scenario?

- Production efficiency will become paramount:
  - *Survivability (disease, heat and drought tolerance); Reproduction efficiency/fertility; Feed conversion rates.*
- Marker assisted selection will become more relevant for the genetic improvement of extensive production animals.
- Diversification of species will be needed (mixture of small and large stock).
- Small stock species (goat in particular) will begin to dominate over large stock species.
- The production cost will increase to some extent with subsequent increase in product price and potential consumer resistance.
- A relatively high skill set level will be required of extensive livestock farmers in order to deal with the adaptation/mitigation aspects of climate change.

How will intensive systems have to adapt/change under a predicted climate change scenario?

- Monogastric species will be seen as more "environmentally friendly"
- Intensive livestock production will move closer to the urban areas
- Housing systems will change: self-sufficient energy supply, air filtration, recycling of water and sophisticated cooling systems
- Ruminant and monogastric diets will become more refined, keeping in mind the life cycle environmental production cost of the components used
- Drought tolerant grains will form part of ruminant and monogastric diets as opposed to less drought tolerant varieties
- Manure management of intensive systems will become industrial processes in order to minimize environmental impact and to generate re-usable energy.

How will intensive systems have to adapt/change under a predicted climate change scenario?

- Genetic selection will be leaning towards more efficient subjects under intensive conditions
- Marker assisted selection will become essential for the genetic improvement of intensive production animals
- There will be a shift from extensive to intensive production systems in developing countries
- The production cost of intensive livestock farming will increase considerably with subsequent increase in product price and potential consumer resistance
- A "very high" skill set level will be required of intensive livestock farmers in order to deal with the adaptation/mitigation aspects of climate change.