Co-funded by the
Erasmus+ Programme
of the European Union

L'élevage dans les régions aride et semi-aride face aux défis du changement climatique

Mardi 12 Mars 2019

Response of sheep & goats to water and salinity stress in the context of climate change in Tunisia

Hichem BEN SALEM, INRAT-IRESA

bensalem.hichem@iresa.agrinet.tn

Co-funded by the
Erasmus+ Programme
of the European Union

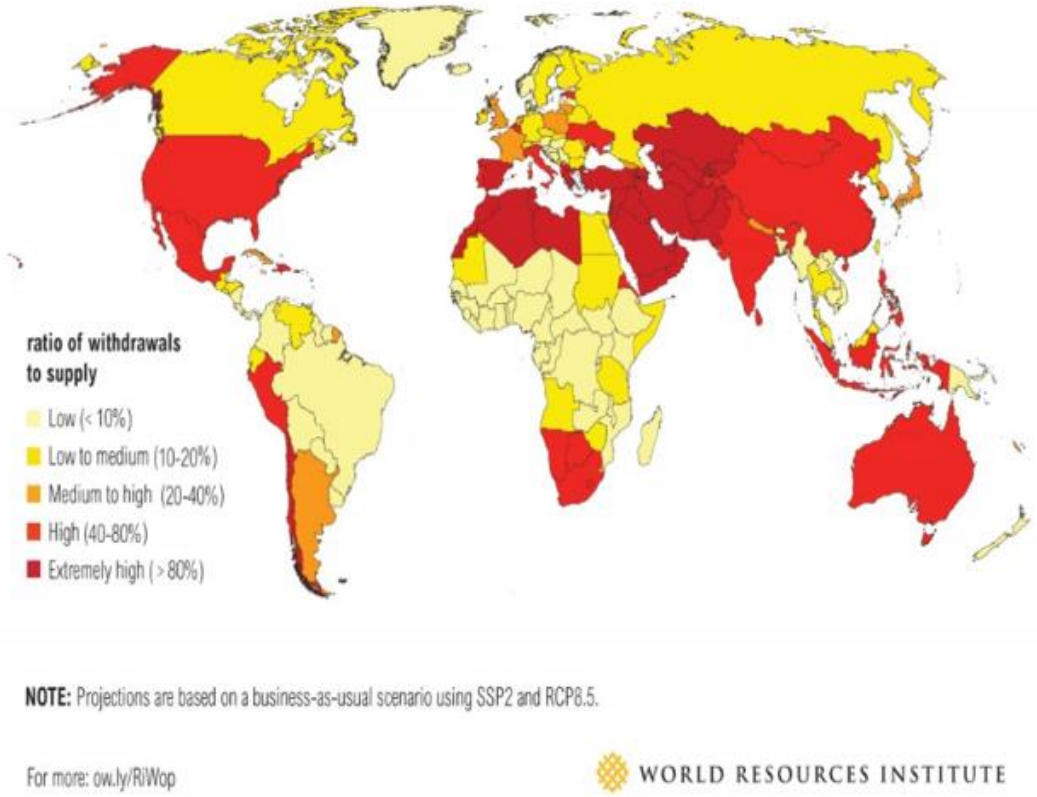
Outline

1. Outlook and setting the scene
2. Water importance & footprint
3. Adaptation mechanism and response to water restriction
4. Adaptation mechanism and response to water salinity
5. Concluding remarks

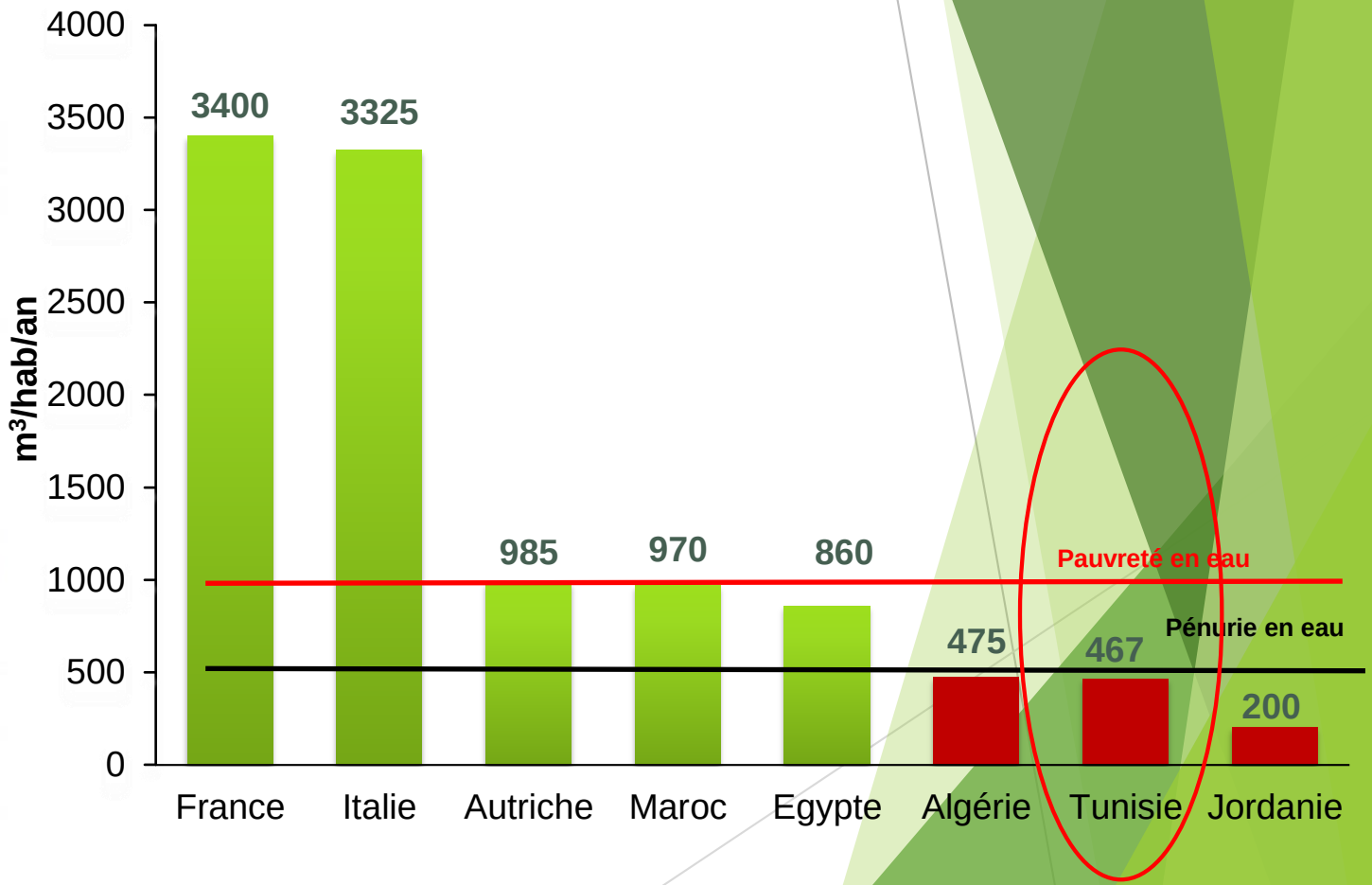
Co-funded by the
Erasmus+ Programme
of the European Union

Tunisia is getting drier

❖ Water stress



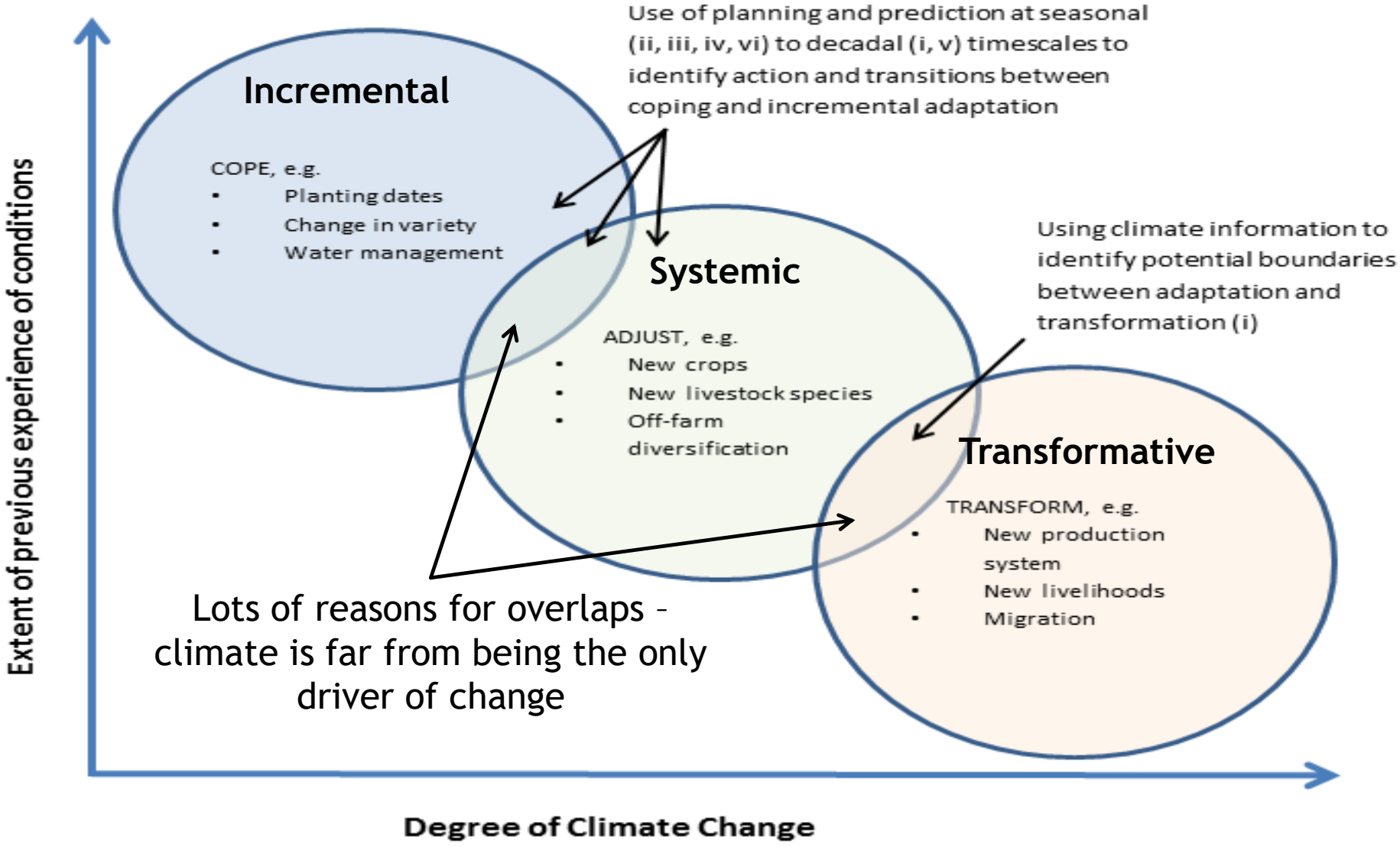
(World Resources Institute, 2017)



(BPEH, 2018)

Using climate science to determine when transitions will be required

Co-funded by the Erasmus+ Programme of the European Union



Co-funded by the
Erasmus+ Programme
of the European Union

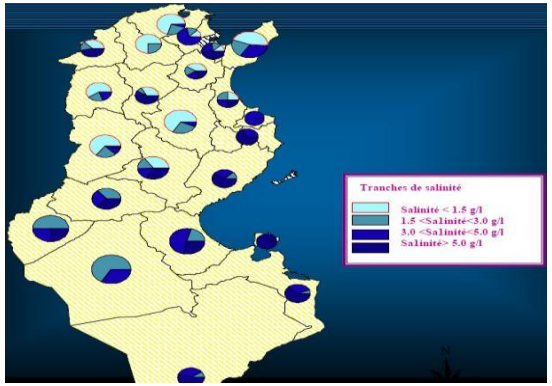
Tunisia, climate variability & change with extreme events have become a reality

- Recurrent drought periods (15 years drought, 10 normal, 10 good years)
- Tunisia is now classified as water shortage suffering country (370 m3/inhabitant/year)
- Extreme climate events (47-50°C / floods)
- Recent floods in the governorate of Nabeul (World record 297 mm in five hours – Septembre 21, 2018)

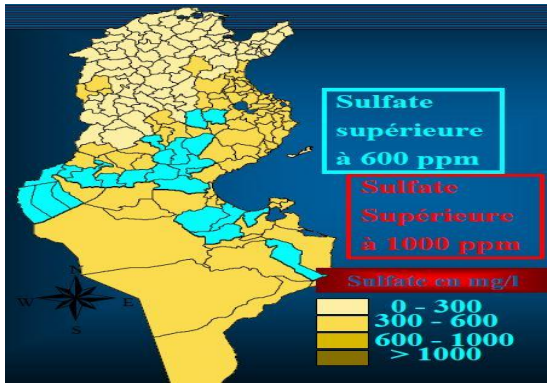
Co-funded by the
Erasmus+ Programme
of the European Union

Tunisia, Natural mineralisation-Human activities-Climate change

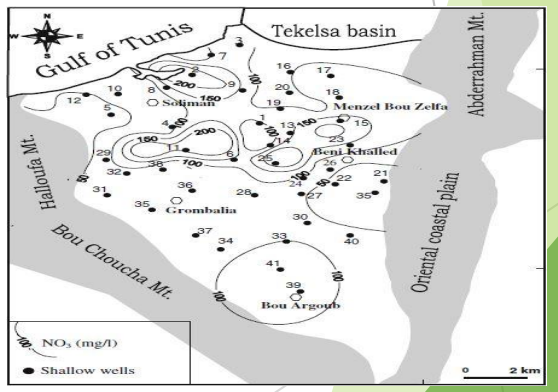
Increasing mineral contamination of water



40% and 20% of groundwater have a salinity above **3** and **5 g/l**



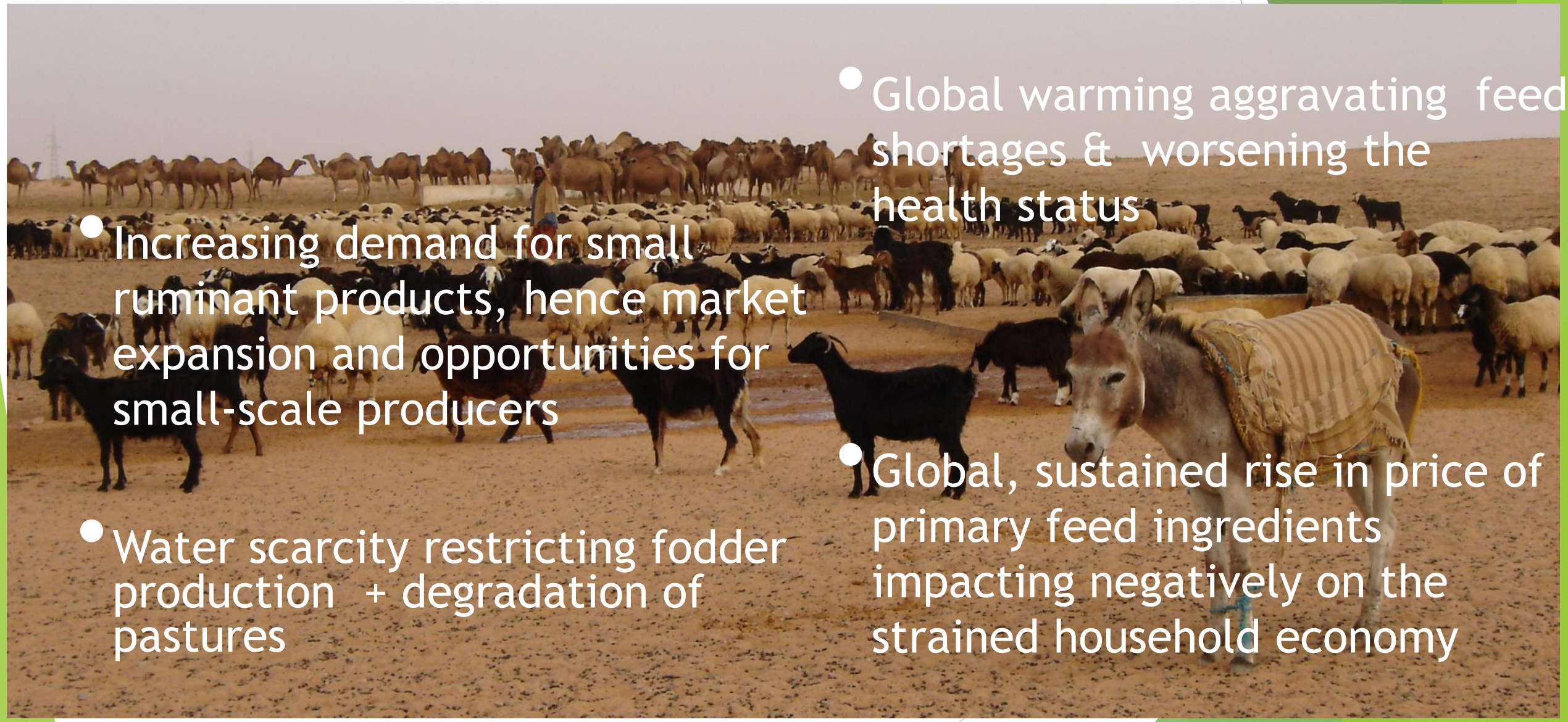
TDS content is highly correlated to **ion sulfate**



Up to **400 mg Nitrate /l in the groundwater of** Nabeul-Hammamet.

In dry areas, livestock is a key to food security

Co-funded by the Erasmus+ Programme of the European Union



- Increasing demand for small ruminant products, hence market expansion and opportunities for small-scale producers
- Water scarcity restricting fodder production + degradation of pastures
- Global warming aggravating feed shortages & worsening the health status
- Global, sustained rise in price of primary feed ingredients impacting negatively on the strained household economy

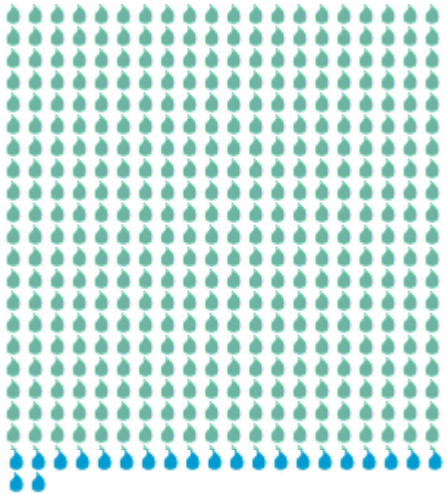
Co-funded by the
Erasmus+ Programme
of the European Union

Water footprint of sheep farming

WF of sheep production in Humid region (Fernena)

6975 litre water / kg body weight

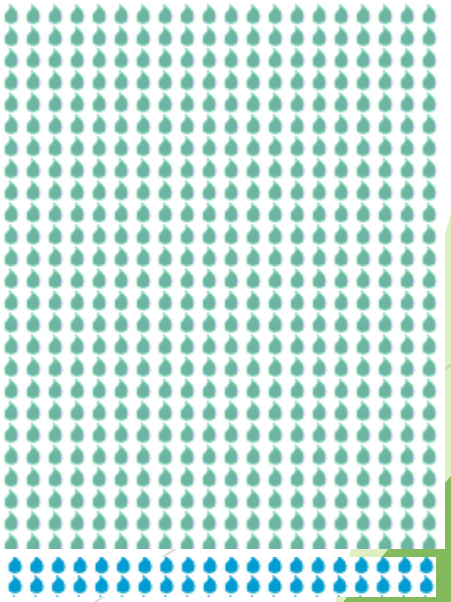
97.3% green, 2.7% blue, 17.3% virtual



WF of sheep production in semi-arid region (Sidi Bouzid)

9068 litre water / kg body weight

94.6 % green, 5.4 % blue, 65.5% virtual



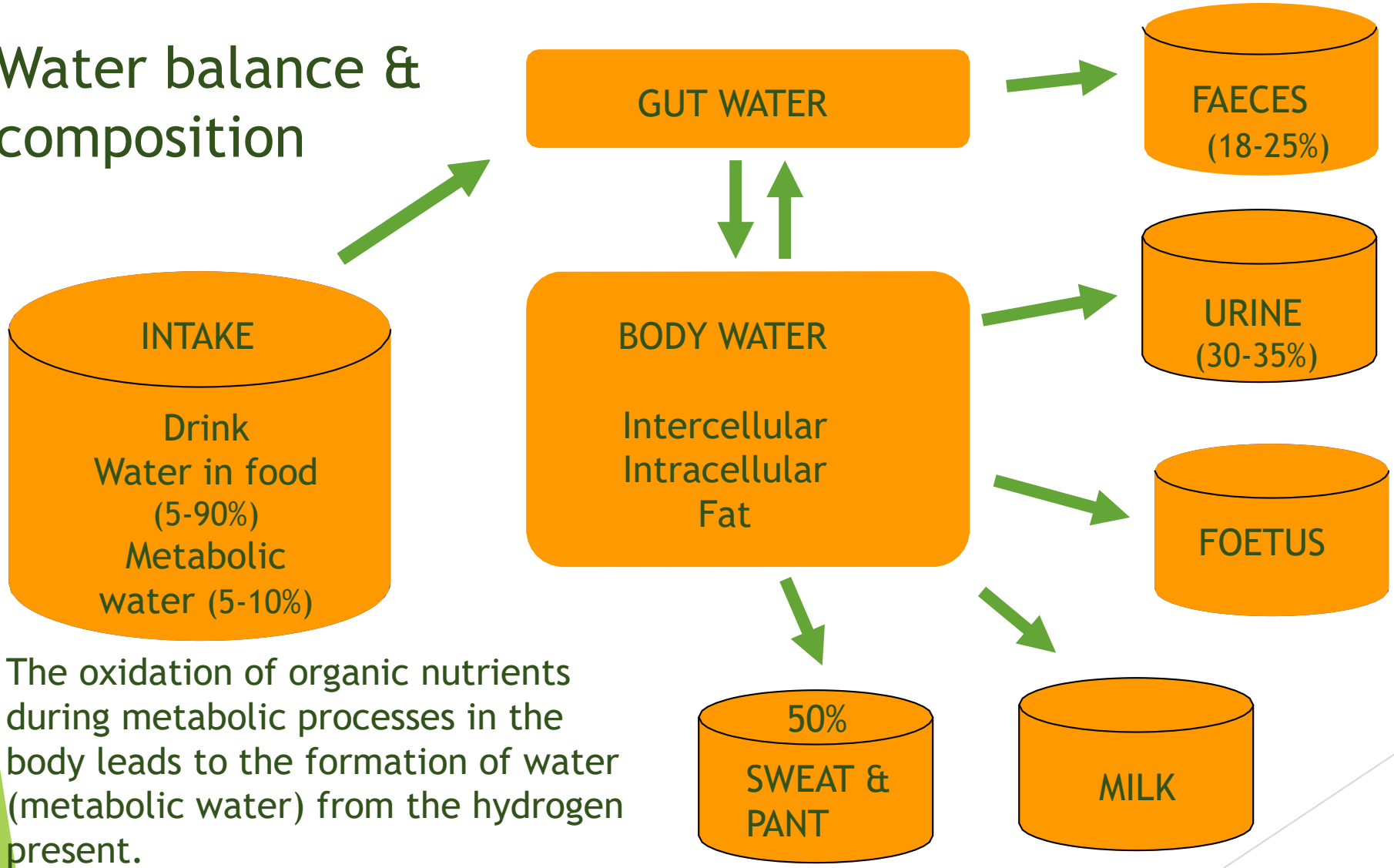
Ibidhi & Ben Salem (2019)

Co-funded by the
Erasmus+ Programme
of the European Union

Importance of water to livestock

What do we know?

Water balance & composition



The oxidation of organic nutrients during metabolic processes in the body leads to the formation of water (metabolic water) from the hydrogen present.

Co-funded by the
Erasmus+ Programme
of the European Union

Water requirements of Livestock

Main factors

- Animal species
- Age – related to body size
- Physiological status of the animal
- Animal health
- Environmental conditions (Temp., Humidity, …)
- Activity rhythms
- Distance between feed and water source
- Type and amount of feed (green or dry)
- Water quality

Co-funded by the
Erasmus+ Programme
of the European Union

3 How animals cope with dehydration?

Behavioral and physiological adaptations

- The capacity of kidney to **concentrate urine** and its ability to **reduce water loss** during dehydration is directly related with the relative kidney medullary thickness (RTM). The greater the RTM, the greater the ability of the kidney to reabsorb water.

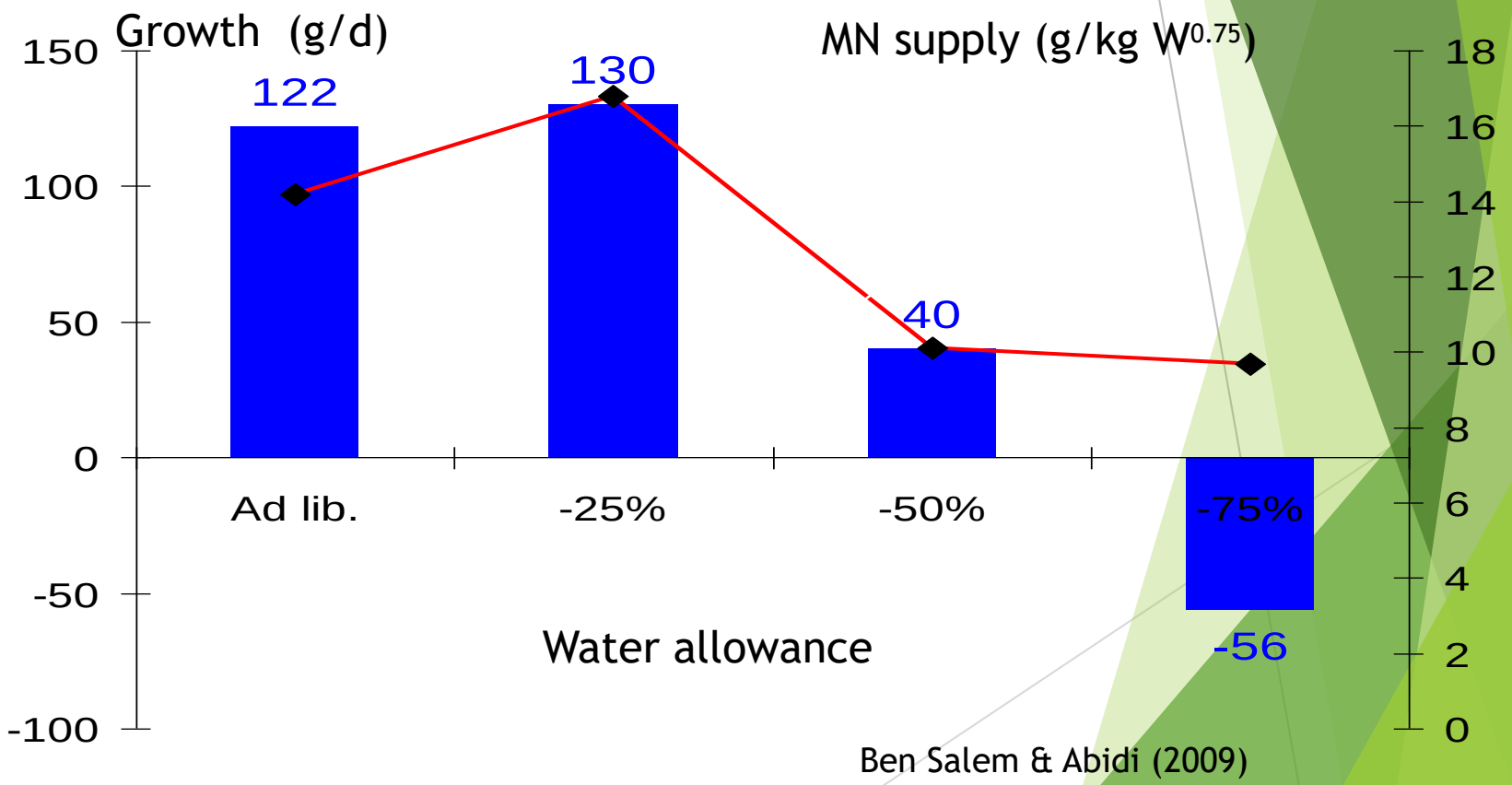
    - Sustained water restriction resulted in the activation of water saving mechanisms. Plasma vasopressin concentration increases with the extend length of dehydration. This will reduce the renal secretion which contributes to the water saving mechanism.

Co-funded by the
Erasmus+ Programme
of the European Union

Response to W restriction - Growing lambs

Diet - Oat hay + 0.5 kg Conc.

Water allow.	DMI (g/Kg $W^{0.75}$)
Ad lib	89.2
- 25%	84.8
- 50%	71.6
-75%	59.5
Signif.	***
Contrast	L



Ben Salem & Abidi (2009)

Co-funded by the
Erasmus+ Programme
of the European Union

Response to W restriction - Growing lambs

Three breeds subjected to 75% W restriction

Diet – Oat hay + 0.5 kg Conc.

	Barbarine		Queue Fine de l'Ouest		Noire deThibar		Significance		
Water regimen	Ad lib	Rest	Ad lib	Rest	Ad lib	Rest	Breed	Water	B x W
DMI (g/kg$^{0.75}$)	89.6	60.3	88.8	58.2	90.4	71.8	ns	***	ns
Growth (g/day)	99.2	0.51	111.9	- 6.0	105.1	-8.9	ns	***	ns

Ben Salem et al. (2015)

Co-funded by the
Erasmus+ Programme
of the European Union

Response to water restriction - Lactation

Responses of Barbarine lactating ewes to water deprivation and salinity (11%)

	N-Daily	N-48 h Alternate	S-Daily	S-48 h Alternate	N *vs* S	Daily *vs* Alternate
24 h-Colostrum (ml)	378	367	331	306	ns	ns
Milk (g/day)						
Day 30	1180	1260	1226	1133	ns	ns
Day 60	746	773	898	876	ns	ns
Water intake (l/d) Day 60	2.9 ^{a}	2.2 ^{b}	5.4 ^{c}	3.0 ^{a}	***	***
DM intake (g/d) Day 60	1494	1546.2	1517.1	1429	ns	ns

Yousfi & Ben Salem (unpublished)

Diet – Barley straw + Barley silage + Conc.

Co-funded by the
Erasmus+ Programme
of the European Union

4 *How animals cope with water salinity?*

- Sheep and goats **excrete more urine** and **increase the filtration rate** to reduce the high salt load resulting from their high consumption of saline water.
    - Exposure to saline water results in an induction of enzymes in the ilium, liver and kidney. The main enzyme is NaK ATPase that increases the pumping of sodium out of cells and potassium return to the intracellular space. The induction of this enzyme is a powerful adaptive mechanism.

Co-funded by the
Erasmus+ Programme
of the European Union

Importance of water to livestock
Water salinity - What do we know?

Symptoms of salt poisoning

- Rapid breathing
- Blindness
- Ataxia
- High temperature
- Abdominal pain
- Diarrhea
- Excessive thirst
- Weakness
- Head pressing
- Death

Maximum desirable level of salinity in water (TDS, mg/l)

Class of animal	Sheep	Goat
Young	5,000	7,000
Dry adult	10,000	14,000
Lactating female	5,000	10,000

McGregor (2004)

Co-funded by the
Erasmus+ Programme
of the European Union

4 Response to water salinity - Fetal programming

Foetal programming (FP) describes the life-long effects of in utero environmental effects

- *The foetus is being programmed for its later-life functioning by the environment it is experiencing at the earliest stage*
- *FP programming may prepare the foetus for later-life events*
- *FP … predictive adaptive response*

Co-funded by the
Erasmus+ Programme
of the European Union

4 Response to water salinity - Fetal programming

Pregnant ewes change foraging behavior when exposed to saline water (11%)

	C-Ewes	S-Ewes	SE	Prob.
Grazing time (% total time, TT)	55.62	43.39	5.90	*
Walking time (%TT)	31.93	41.95	1.69	*
Resting time (%TT)	12.45	14.65	2.33	ns
Total intake (g/kg W0.75)	138.0	130.0	2.30	*
Mortality newborns (%)	6.4	11.4		*

Co-funded by the
Erasmus+ Programme
of the European Union

4 Response to water salinity - Growing lambs

Three breeds subjected to saline water (11 g/l)

Diet – Oat hay + 0.5 kg Conc.

	Barbarine		Queue Fine de l'Ouest		Noire deThibar		Significance		
Water regimen	NW	SW	NW	SW	NW	SW	Breed	Water	B x W
DMI ($g/kg^{0.75}$)	97.4	96.6	92.9	90.1	91.0	89.7	*	ns	ns
Growth (g/day)	69.8	77.1	73.7	68.3	63.9	67.1	ns	ns	ns

Bouzarraa & Ben Salem (unpublished)

Response to water salinity - Lactation

Co-funded by the Erasmus+ Programme of the European Union

Responses of Barbarine lactating ewes to water deprivation and salinity (11%)

	N-Daily	N-48 h Alternate	S-Daily	S-48 h Alternate	N *vs* S	Daily *vs* Alternate
24 h-Colostrum (ml)	378	367	331	306	ns	ns
Milk (g/day)						
Day 30	1180	1260	1226	1133	ns	ns
Day 60	746	773	898	876	ns	ns
Water intake (l/d) Day 60	2.9 ^{a}	2.2 ^{b}	5.4 ^{c}	3.0 ^{a}	***	***
DM intake (g/d) Day 60	1494	1546.2	1517.1	1429	ns	ns

Yousfi & Ben Salem (unpublished)

Diet – Barley straw + Barley silage + Conc.

Co-funded by the
Erasmus+ Programme
of the European Union

4 Response to water salinity and restriction

Foraging behavior of range goats

	Control	3% Salt	6% Salt	Restric.	Prob.
Moving (% TT)	21.4^{a}	27.6^{ab}	23.0^{a}	**30.7^{b}**	***
Resting (%TT)	4.1	5.6	8.1	4.9	ns
Woody species consumption (%TT)	42.1^{a}	39.9^{a}	**19.6^{b}**	**17.6^{b}**	***
Herbaceous species consumption (%TT)	32.4^{a}	26.9^{a}	**49.2^{b}**	**46.8^{b}**	***
Woody species intake (g DM/kg0.75)	78.7^{a}	92.8^{a}	**55.6^{b}**	**42.4^{b}**	***
Herbaceous species intake (g DM/kg0.75)	7.4^{a}	4.8^{a}	**38.3^{b}**	**22.6^{c}**	***
Total intake (g DM/kg0.75)	86.1	97.6	93.9	65.0	0.05

Cherif & Ben Salem (2015)

Co-funded by the
Erasmus+ Programme
of the European Union

Concluding remarks

Water restriction

- Sheep & goats respond by decreasing feed intake causing reduction of body weight (water and body mass loss)
- Responses to WR depend on physiological status
- Caution, lactation is the most water demanding physiological status. Water restriction would reduce blood flow to the mammary gland leading to decreased milk production

- **25% restriction** not harmful and even could have **positive impact**
- Severe **dehydration** has **detrimental effect** on productive and reproductive performances and animal health

Co-funded by the
Erasmus+ Programme
of the European Union

Concluding remarks

Water salinity

- Major homeostatic responses to **high salt load**: increased water intake and decreased feed intake
- With diets composed of dry feeds, S&G can **tolerate** the consumption of water containing **up to 11%**
- To adapt to salt-rich water, S&G consume more water and **change their foraging behavior** (more herbaceous and less shrubby vegetation)
- Exposing S&G early in life would improve their adaptation to high salt water later in their life

Thank you for your attention!

Resarch team

Ibrahim Yousfi, Imtiez Bouzarraa, Mohamed Cherif, Ridha Ibidhi, Salah Guarsallah, Sourour Abidi, Wiem Mehdi, Hichem Ben Salem