

Small Study Group Activity
H2020-TWINN-2015-Serbia for Excell

Climate change-induced abiotic stress affects agriculture

Jorge Alvar-Beltrán¹, Sabina Thaler², Leonardo Verdi¹ and Milena Daničić³

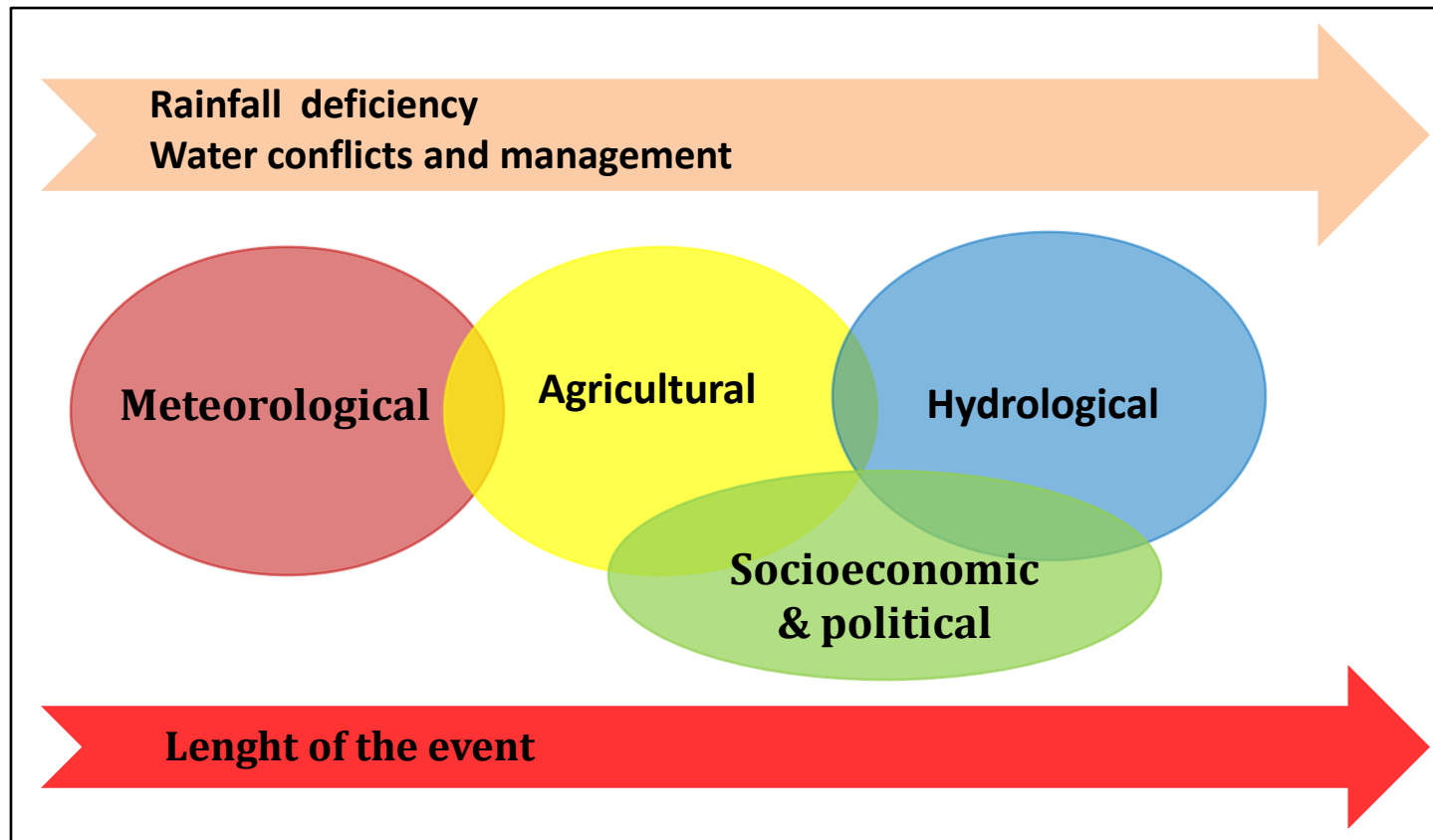
¹*University of Florence, Department of Agrifood Production and Environmental Sciences, Italy.*

²*University of Vienna (BOKU), Department of Natural Resources and Life Sciences, Austria.*

³*University of Novi Sad, Faculty of Agriculture, Novi Sad*

Drought stress

Fig.1: *Interrelation between the different types of droughts*

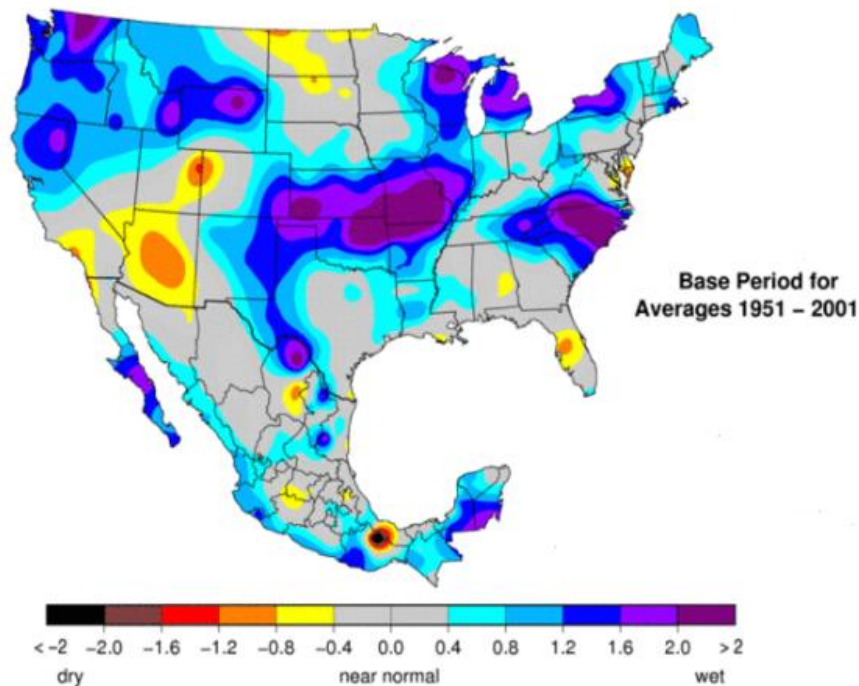


Source: *Modified from National Drought Mitigation Centre, University of Nebraska-USA*

Drought monitoring

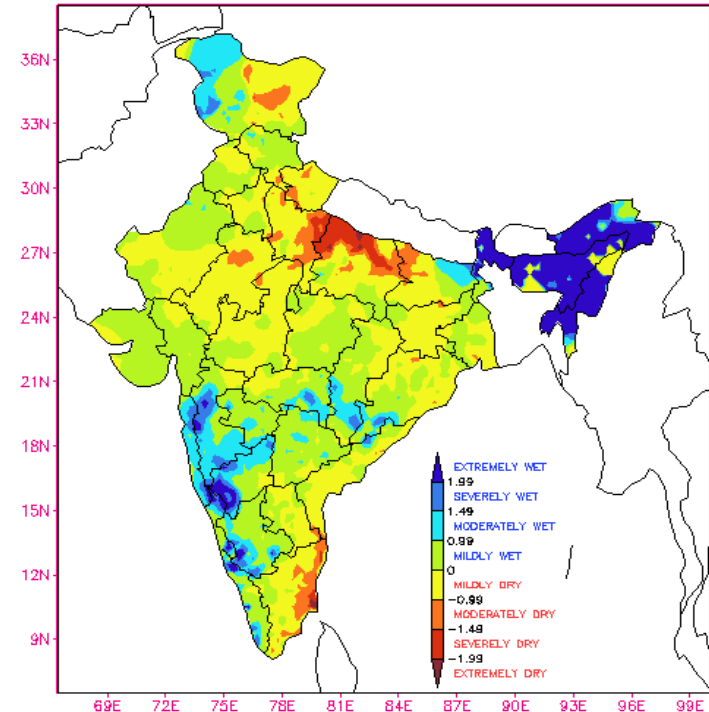
Standardized Precipitation Index (SPI)

Fig.2: SPI, USA April 2017



Source: USA Drought Monitor Department

Fig.3: SPI, India Jan-Feb. 2017



Source: India Meteorological Department

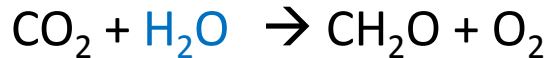


Water effects on crops

Water function

Assimilation:

- water is required for photosynthesis



-approx. 200l ha⁻¹day⁻¹ in summer in The Netherlands

Turgor & medium:

- water pressure is required to keep the plant rigid

- water is an adequate solvent for nutrients

- medium for biochemical processes

-approx. 800l ha⁻¹day⁻¹ in summer in The Netherlands

Fig.4: Assimilation

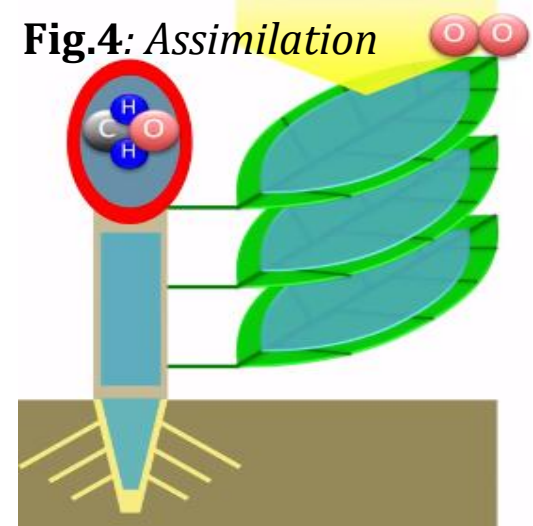
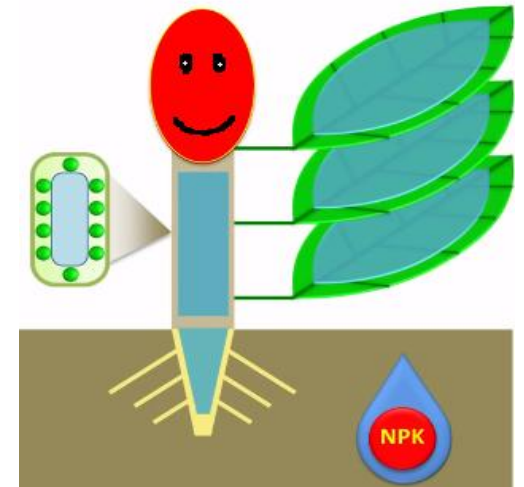


Fig.5: Turgor & medium



Source: Wageningen University

Water effects on crops

Water function

Transpiration:

- most of crops water requirement comes from transpiration processes
- during photosynthesis water is loss to the air via the stomata....
- hence, cooling and preventing the plant from overheating....
- while, keeping the optimal temperature range for biochemical processes
- approx. 25000-75000l ha⁻¹ day⁻¹ in summer in the Netherlands
(total amount for cooling and nutrient transport)*

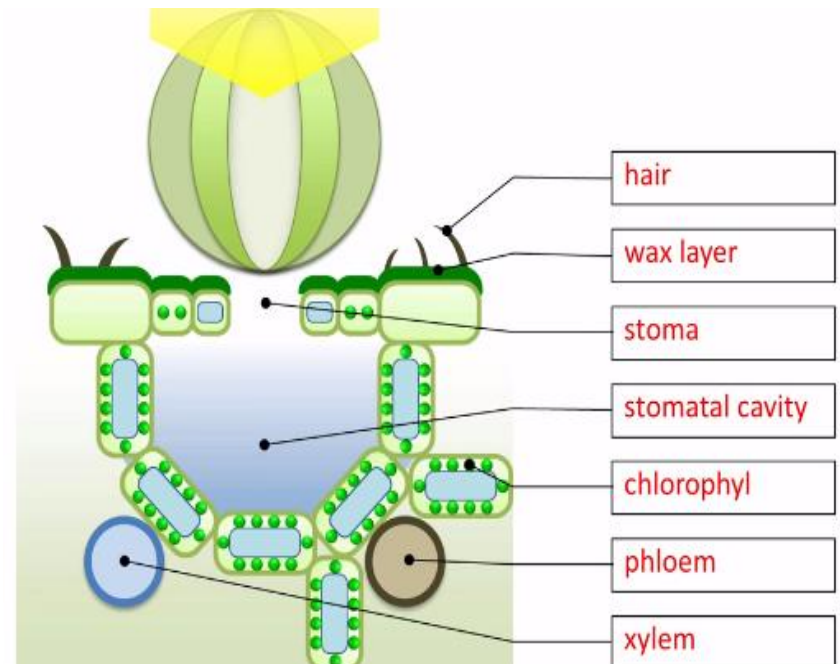
Water effects on crops

Water demand

Stomata regulation & evapo-transpiration

- stomatal cavity is saturated with water....
- as the resistance of the xylem for water transport is lower than stomatal's resistance
- low air humidity = high evaporative demand (e.g. during windy and cold days)
- longer hairs within the boundary layer can hamper water movement

Fig.6: *Stomata regulation*



Source: Wageningen University

Water effects on crops

Water supply

Water balance

- crops water demand is determined by evapo-transpiration
- soil is the most important medium for water supply
- major input of water for a crop is precipitation, but additional can be applied through irrigation
- the type of precipitation, intensity and frequency, as well the type of soil determines the amount of water reaching the groundwater....
- therefore, low percolation occurs during rain showers in clayey soils, where evaporation and surface run-off is highest

Water effects on crops

Water use

Drought tolerance

- dry spells during the growing season = canopy closure
- drought reduces net assimilation, therefore the different development stages of the plant and dry matter distribution
- water restrictions are mitigated with surface flooding & irrigation systems

Water logging

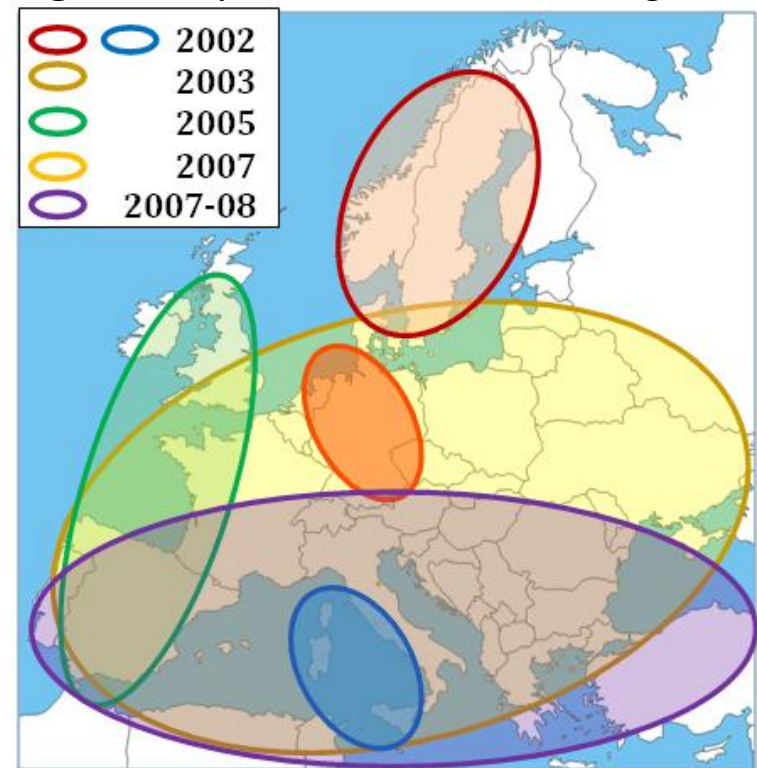
- occurs in areas with heavy showers and soils with low infiltration rates....
- but, it can also happen when the sub-soil has a non permeable layer...
- resulting in the flooding of the rooting zone, hence reducing the plant's oxygen availability while hampering nutrient uptake

EU policy framework

Droughts and heatwaves

- climate change will increase water shortages throughout Europe
- more severe impacts are expected to occur in south and southeastern Europe....
- however, the n° of people and area affected has folded, while the costs have quadrupled
- as a result, there is a greater need for risk reduction measures, preparedness and land management plans....
- hence, a thorough drought policy-framework

Fig.6: *Europe's main recent droughts*



Source: Modified from Tallaksen, 2007

EU policy framework

Droughts and heatwaves

- EU has a wide range of interacting policy instruments, directive and communications aiming to adapt critical sectors to natural hazards
- for instance, Common Agriculture Policy (CAP), EU Climate Adaptation Policy, EU Water Framework Directive, EC Communication 'Blueprint to Safeguard Europe's Water Resources', among others
- overall, EU policy approach for agriculture is through effective adaptation measures....
- with short and mid-term solutions: adapt time of farm operations, select climate resilient crops, improve the effectiveness of pest and disease control and promote water conservation strategies



Heat stress

- is the rise in temperature beyond a threshold level for a period of time sufficient to cause irreversible damage to plant growth and development
- is a complex function of intensity (temperature in degrees), duration, and rate of increase in temperature
- particular during vegetative and reproductive stages heat stress causes severe yield reductions
- temperature stress is mainly connected with water stress





Threshold high temperature for some crop plants



Crop plants	Threshold temperature (°C)	Growth stage	References
Wheat	26	Post-anthesis	Stone and Nicolas (1994)
Corn	38	Grain filling	Thompson (1986)
Cotton	45	Reproductive	Rehman et al. (2004)
Pearl millet	35	Seeding	Ashraf and Hafeez (2004)
Tomato	30	Emergence	Camejo et al. (2005)
Brassica	29	Flowering	Morrison and Stewart (2002)
Cool season pulses	25	Flowering	Siddique et al. (1999)
Groundnut	34	Pollen production	Vara Prasad et al. (2000)
Cowpea	41	Flowering	Patel and Hall (1990)
Rice	34	Grain yield	Morita et al. (2004)



Major effects of high temperature on plants



The Mitigation of Heat Stress

Mitigation of stress by crop management:

- Management methods at sowing
- Choice of sowing date
- Cultivars, irrigation and other management methods

The Mitigation of Heat Stress by Plant Resistance:

- The Nature of Resistance to Heat
- Methods of Breeding for Resistance to Heat



Serbia for Excell

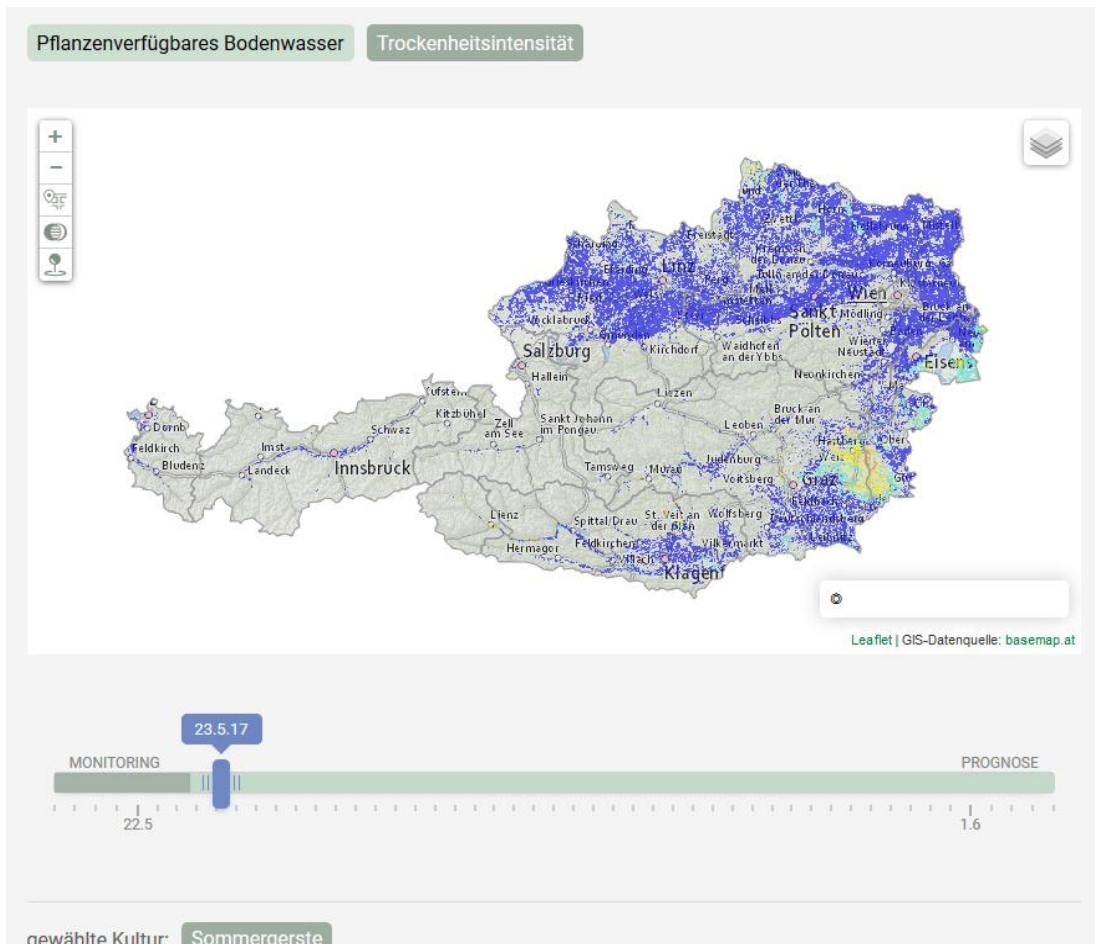


Drought monitoring system for Austrian agriculture

<https://warndienst.lko.at/gruenland+2500+++6576>

for

- spring barley
- grain maize
- winter wheat
- sugar beet
- grass land



NaCl and heavy metal impact on crops



Introduction...

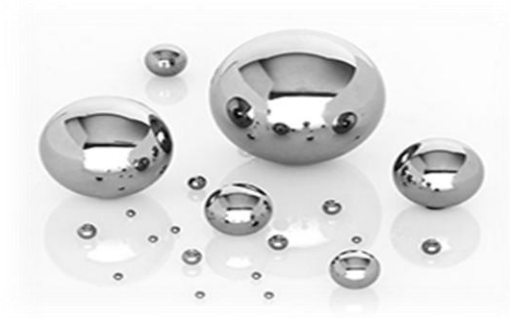
Climate changes affect agricultural production worldwide.

Most prominent problems due to climate change and inconvenient agricultural practice are soil salinization and heavy metal accumulation (HM).

Majority of Europe- cultivated crops are adversely affected by saline conditions.

Most of salt stress is caused by NaCl.

Excess salt levels affect around 3.8 million ha in Europe.



HMs...

One of the implications of human- induced disturbance of natural cycles is **heavy metal accumulation (HMs)**.

HMs are group of nonbiodegradable inorganic chemical constituents with atomic mass over 20 and density higher than 5 g cm^{-3} .

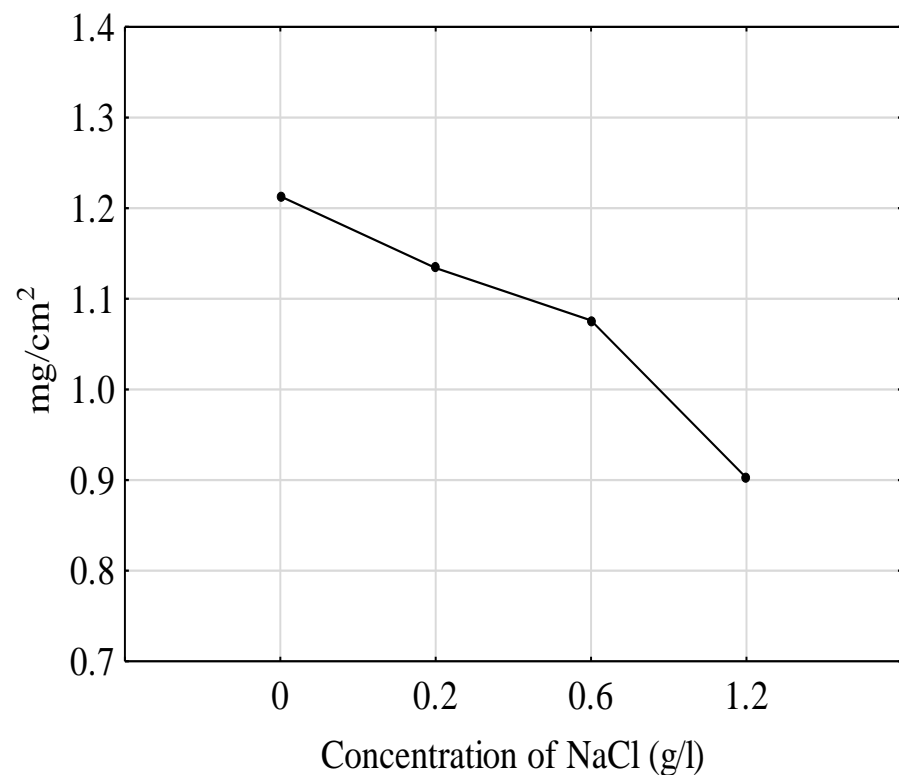
Presence of HMs in excess amounts may lead to reduction and inhibition of growth and physiological processes in crops.

137.000 km² of Europe soil is contaminated with HMs.



Main NaCl and Hm effects on crops...

1) Plant growth



Daničić et al., 2016.-The influence of NaCl on dry mass/leaf area ratio of safflower

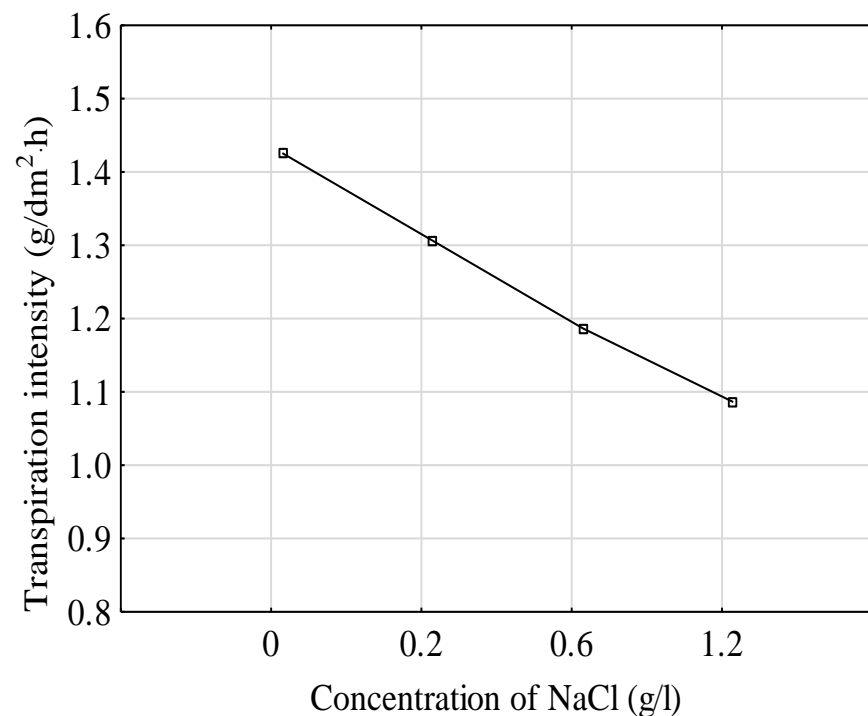
Genotype	Treatment	Fresh w. (g plant ⁻¹)	Dry w. (g plant ⁻¹)	Dry matter (%)
1	K	0.13	8.10	6.61
	Ni	0.05	5.44	11.05
	Cd	0.03	3.53	12.36
5	K	0.09	6.84	8.01
	Ni	0.07	7.06	10.53
	Cd	0.03	4.76	16.13
7	K	0.21	19.60	9.53
	Ni	0.10	12.22	11.69
	Cd	0.09	14.11	11.43
8	K	0.13	15.21	11.69
	Ni	0.06	7.08	11.55
	Cd	0.02	2.81	14.96
9	K	0.10	9.55	9.34
	Ni	0.03	4.56	13.09
	Cd	0.04	4.36	11.00

Gani et al., 2009.- Fresh and dry weight and dry mass percentage in leaves of spring (1) and winter (5) oilseed rape, *Sinapsis alba* (7) and *Sinapsis nigra* (8) i *Brassica rapa* (9) cultivated in presence of Ni and Cd. K is control treatment



Main NaCl and Hm effects on crops...

2) Water relations in plants



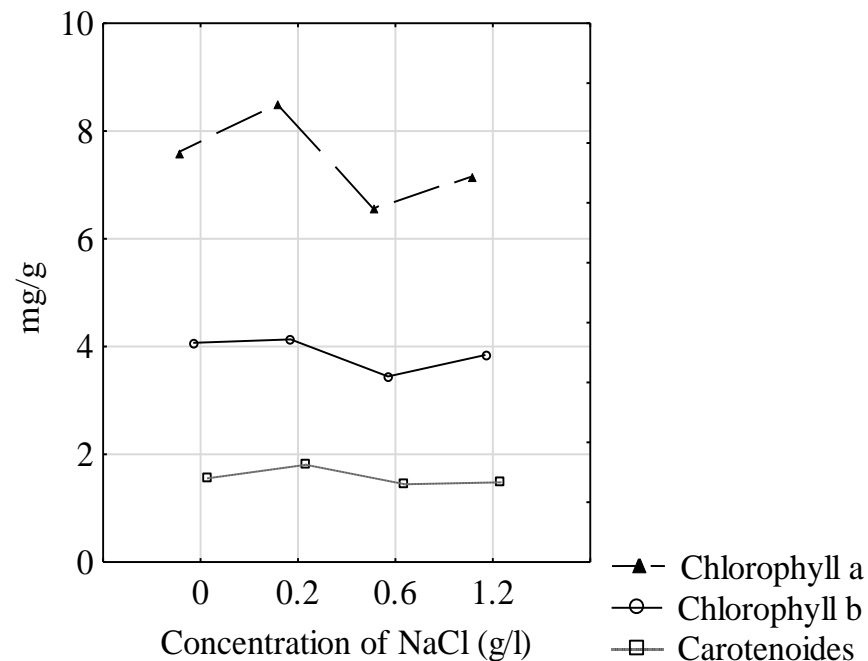
Daničić et al., 2016.- The influence of NaCl on the transpiration intensity of safflower

Genotype	Treatment	IT g dm ⁻² h ⁻¹
1	K	0.076
	Ni	0.099
5	K	0.080
	Ni	0.102
7	K	0.078
	Ni	0.157
8	K	0.078
	Ni	0.122
9	K	0.074
	Ni	0.081

Gani et al., 2009.- Transpiration intensity (IT) of spring (1) and winter (5) oilseed rape, *Sinapsis alba* (7) and *Sinapsis nigra* (8) and *Brassica rapa* (9) cultivated in presence of Ni. K is control treatment

Main NaCl and Hm effects on crops...

3) Photosynthesis and chlorophyll content



Daničić et al., 2016.- The influence of NaCl on content of photosynthetic pigments in dry leaf mass of safflower

Genotype	Treatment	chl. a	chl. b	carot.	chl. a+b
1	K	14.69	4.90	3.23	19.58
	Ni	6.69	2.32	1.64	9.02
	Cd	1.77	0.67	0.53	2.44
5	K	15.30	5.11	3.29	20.42
	Ni	11.86	4.11	2.94	15.97
	Cd	1.69	0.78	0.51	2.47
7	K	17.02	8.61	4.32	25.62
	Ni	6.95	3.02	1.63	9.97
	Cd	2.14	0.88	0.59	3.03
8	K	17.75	5.74	3.91	23.49
	Ni	9.80	3.50	2.46	13.30
	Cd	0.84	0.30	0.25	1.14
9	K	17.50	5.58	3.85	23.07
	Ni	9.30	3.19	2.32	12.48
	Cd	2.85	1.04	0.78	3.89

Gani et al., 2009.- Content of pigments of spring (1) and winter (5) oilseed rape, *Sinapsis alba* (7) and *Sinapsis nigra* (8) and *Brassica rapa* (9) cultivated in presence of Ni and Cd. K is control treatment

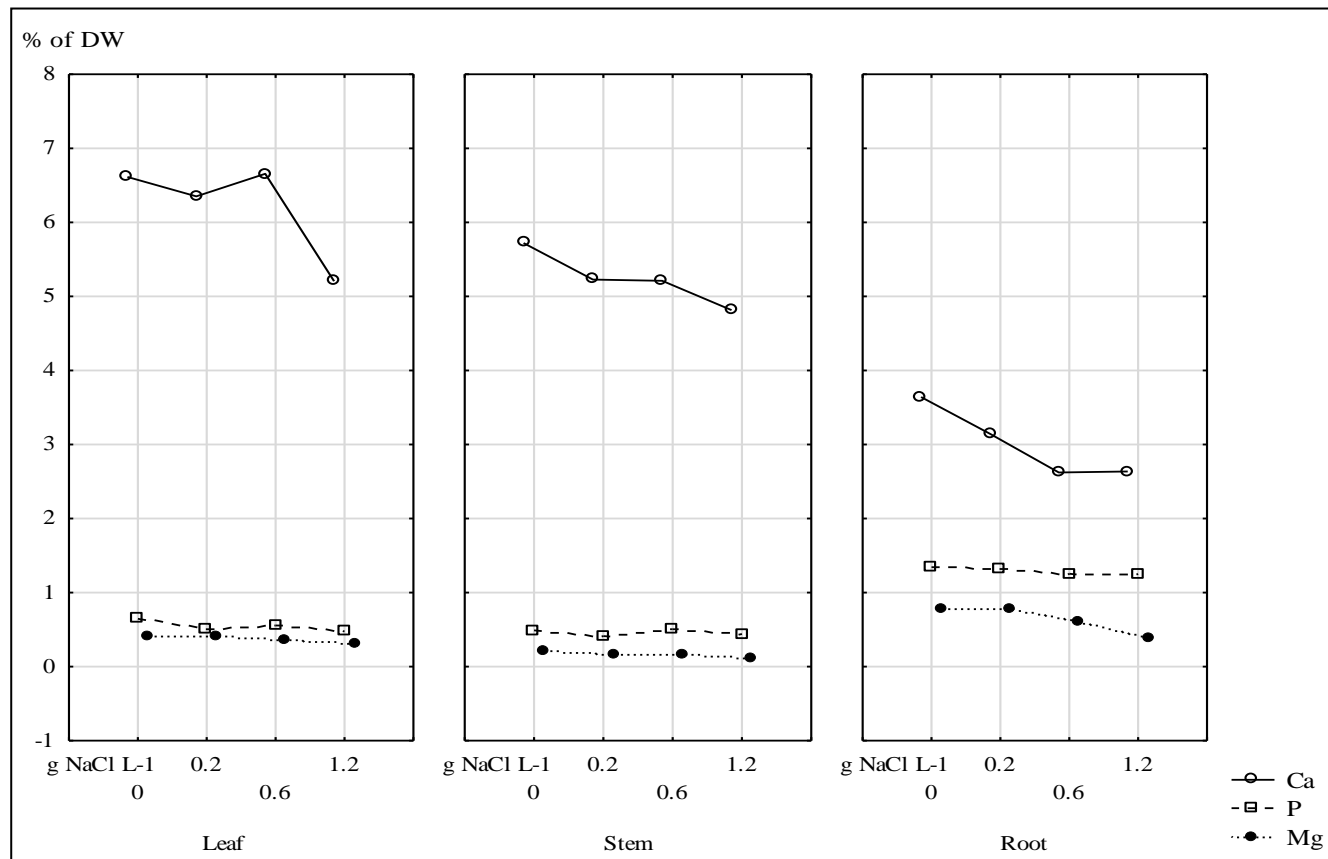


Serbia for Excell

Main NaCl and Hm effects on crops...



4) Mineral nutrition



Daničić et al., 2016. (unpublished results)- The influence of NaCl on concentration of some macronutrients in tissues of safflower

Mitigation strategies of plants...

Plants respond with physiological and biochemical changes which aim the maintenance of basic metabolic processes:

- a) Activation of enzymes such as **superoxide dismutase (SOD)**, **peroxidase and catalase (CAT)**.
- b) Synthesis of proteins and aminoacids such as **free proline**.
- c) Synthesis of phenolic substances such as **ascorbic acid (vit. C)**.
- d) **Application of silicon (Si)** - under abiotic stress conditions, Si application results in alleviation of stress and enhancement of plant growth.

Conclusion...

The impact of **global climate change** on crop production has emerged as a major research priority during the past decade.

Understanding abiotic stress factors such as NaCl and heavy metal, in combination with high yield in plants is of a paramount importance to counter climate change related adverse effects on the productivity of crops.



NITROGEN STRESS ON CROP



NITROGEN STRESS ON CROP

Symtoms

- **Lack in chlorophyll and reduction of photosynthesis.** Normally, is the first symptoms that plant show in N deficiency.
- **Plant growth.** N shortage leaf area and, consequently, stems and roots growth. Results of previous situation is an imbalance between epigeal and hypogeal part of plants.
- **Flowers, seeds and fruits.** The N deficiency reduce carbohydrates and proteins content of fruits. Quality decrease and ripening is anticipate. Moreover, the lack of protein negatively affect seeds quality and germination potential.
- **Elongation of biological cycle of plants.** N excess extend the vegetative phase of plants that improve leaves production and reduce energy and nutrients for reproductive organs production. Stems lenght increase: risk of stems and branches breaking in trees and pland lodging in herbaceous crops. Cellular walls and lignification are reduced and plants are more susceptible to pest and low temperatures.
- **Water consumption.** The elongation of vegetative phase of plants induce and increasing of water consumption through the evapotranspiration.



NITROGEN STRESS ON CROP

Factors affecting N dynamics and impacts

Emissions



- Greenhouse gas with Global Warming Potential of 290-300 times more than CO_2
- Mainly produced in anaerobic conditions through denitrification and in a small part during nitrification

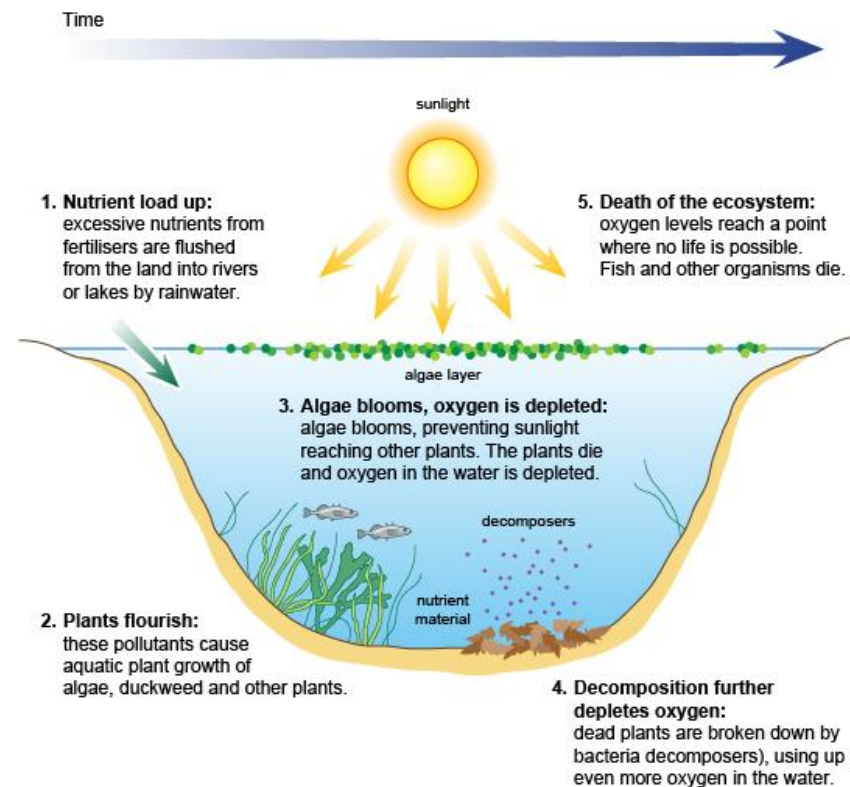


- Precursor of N_2O and main N loss through volatilization
- Strongly affected by soil texture that directly affect the water – oxygen ratio into the soil

NITROGEN STRESS ON CROP

Factors affecting N dynamics and impacts

Eutrophication



NITROGEN STRESS ON CROP

Factors affecting N dynamics and impacts

Water content of soil

Leaching: first factor that affects the translocation of N in the deep layers of the soil and can contribute to the contamination of groundwater. Nitrates are mainly affected by leaching with negative impacts on crop growth and yields. Great planning of fertilization and irrigation represent the best strategy to reduce this kind of N losses.

Denitrification: is a process that converts nitrate into molecular nitrogen (N_2) that is lost through volatilization. This phenomenon requires a wide range of factors as soil saturation, temperature, pH etc.), however water management strategy represents the first method to reduce denitrification risk.

Environmental conditions: further factors affect, directly and indirectly, N dynamics on soil. The main are temperature, soil texture, soil organic matter content, soil microorganism population and pH.

NITROGEN STRESS ON CROP

Mitigation Strategies

Application of the **good agronomic practices** represent the main strategy to reduce N imbalance into the soil and stress on crops:

- **High fertilization efficiency** (fertilizers spreading during highest nutrients demand of crops, maintaining of a great water/oxygen ratio into the soil and the application of spreading strategies aimed at the reduction of N losses through volatilization as incorporation or injection)
- **High efficiency irrigation** (maintaining of a great water/oxygen ratio into the soil and application of strategies for water managing to reduce leaching and denitrification)
- **Crop rotation and soil erosion control** (maintaining of physical, chemical and biological soil fertility)
- **Weather monitoring** (temperatures and rainfall represent the main factor affecting N dynamics into the soil)

EFFECTS OF NITROGEN STRESS ON CROPS

Conclusions

N availability into the soil represent one of the main factor that have to be considered for crop production. Considering climate change and world human population growth the understanding of the abiotic stress for plants as N dynamics represent a priority. Research play a key role to define agricultural sustainable management strategies that allow to produce food for world population reducing the impacts on climate change phenomenon.

Overall conclusion

Over the last decade, climate change has been recognized as an additional factor which will have a significant impact on agricultural production.

Based on literature sources, in the absence of adequate response strategies of crops to long-term climate change consequences, as well as to climate variability diverse and specific impacts will become more apparent. Some of those impacts are expected to be adverse. At times, impacts will be slow to unfold enabling local farmers and governments to respond. Impacts of climate variability and change, on the agricultural sector are projected to steadily manifest directly from affecting deterioration of abiotic factors to plants.

Climate change is expected to result in long term water and nutrient shortages as well as worsening soil conditions, causing drought and salinity. Vulnerable areas (such as some Europe regions) may experience losses in agricultural productivity, primarily due to reductions in crop yields. Early estimates suggest 14-16 percent losses in developing countries of Europe due to climate change-induced effects on crops.

It is unavoidable for producers to experience long term consequences of climate variation, but in a field of agriculture, in terms of declining the stress effect on crops, science has already given many crucial answers. By being familiar with plant physiology, strategies of adaptation and mitigation of new conditions, it is possible to, at least in part, alleviate stressful impacts on crops.