Irrigation as an adaptation and mitigation measure to climate change

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Introduction

Observations for Europe (IPCC Fifth Assessment Report - AR5):

- Decadal average land surface temperature for 2002-2011 is 1.3 ^{o}C above the average of 1850 – 1899
- Warming has been strongest over Scandinavia in winter, the Iberian Peninsula warmed mostly in summer
- High temperature extremes have become more frequent, while low temperature extremes less frequent
- The frequency of heat waves has increased in large parts of Europe
- Annual precipitation has increased in Northern Europe and decreased in parts of Southern Europe
- Frequency or intensity of heavy precipitation events has increased in Europe

Introduction

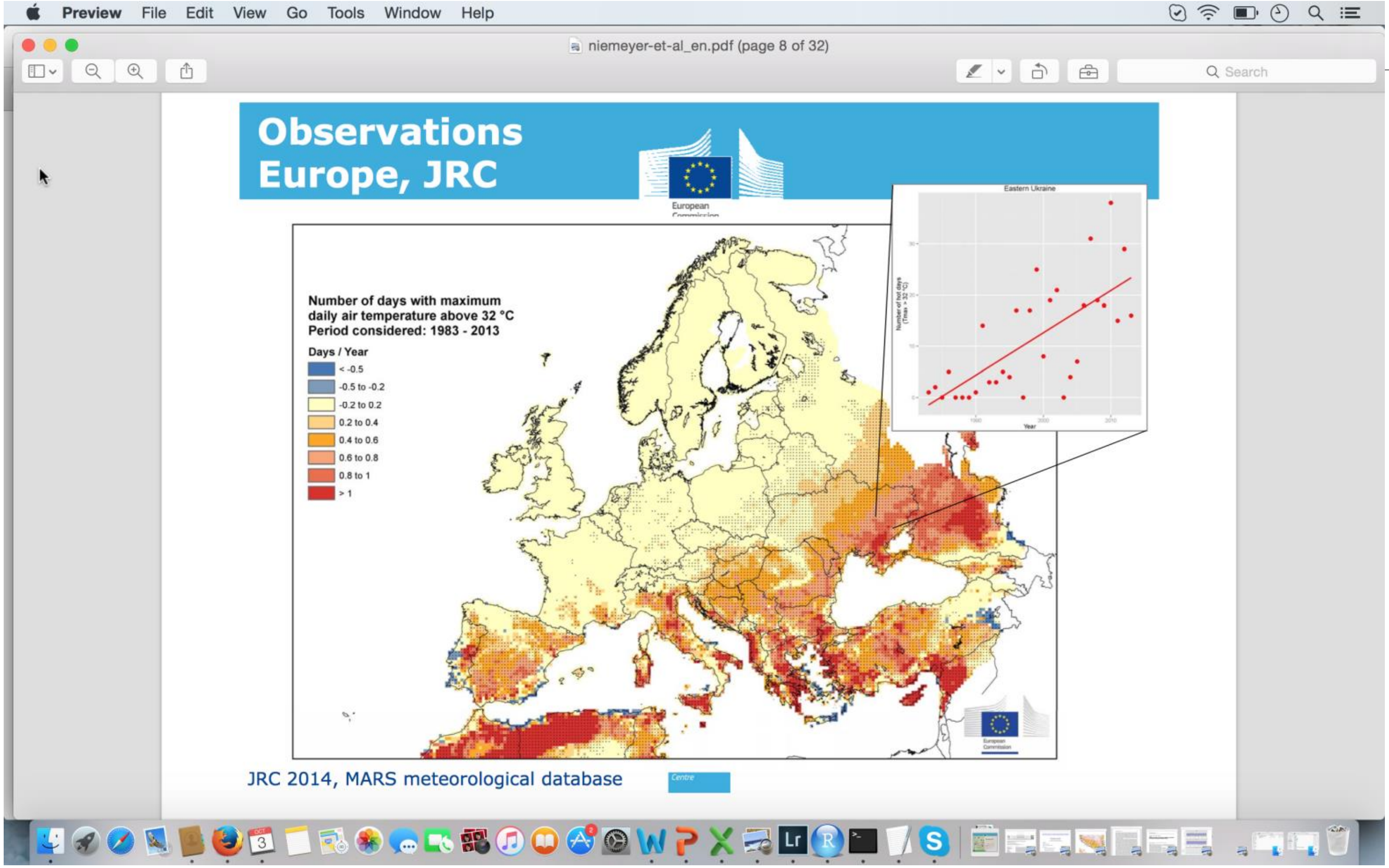
IPCC 5th Assessment Report, WG2: "Based on many studies covering a wide range of regions and crops, negative impacts of climate change on crop yields have been more common than positive impacts (high confidence)"

For Europe:

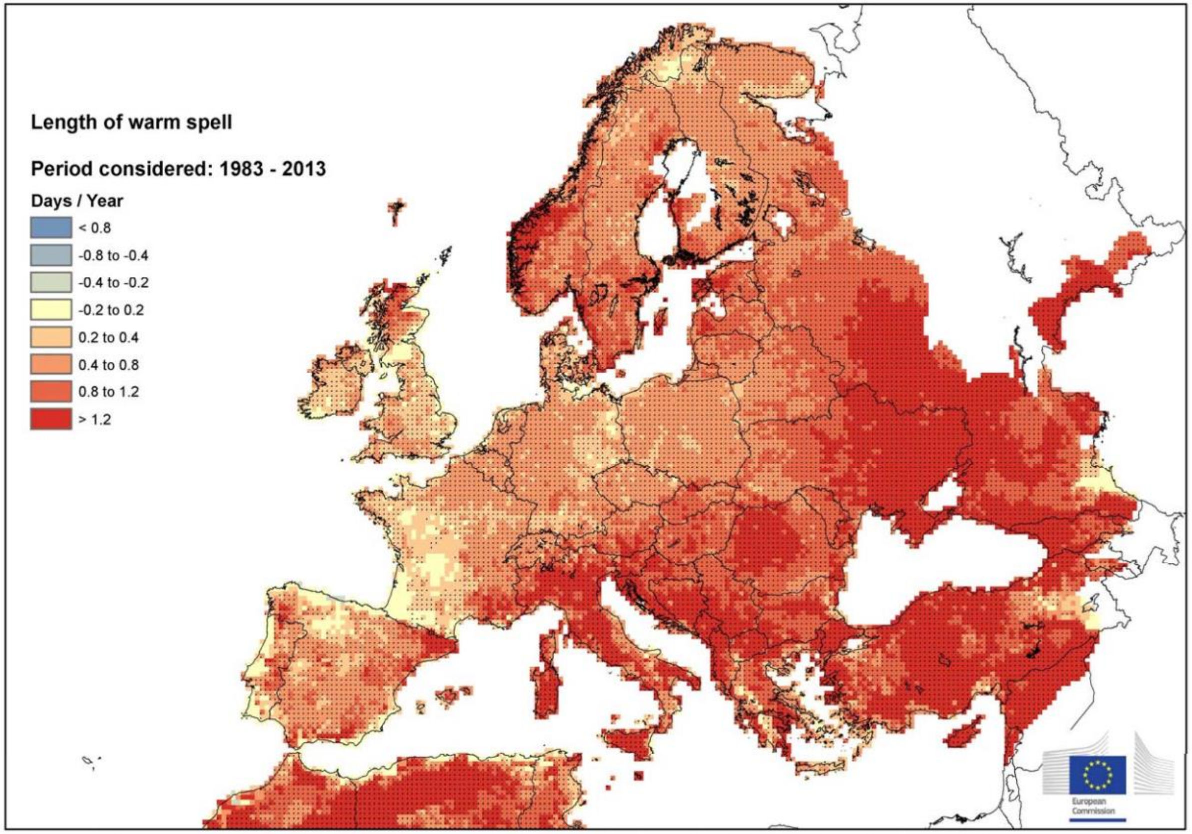
- Flooding, coastal zones
- Extreme heat events
- Increased water restriction:

Less water from rivers and groundwater, increased water demand, more evaporation especially in Southern Europe=>impact on agriculture

Introduction – number of days above 32°C

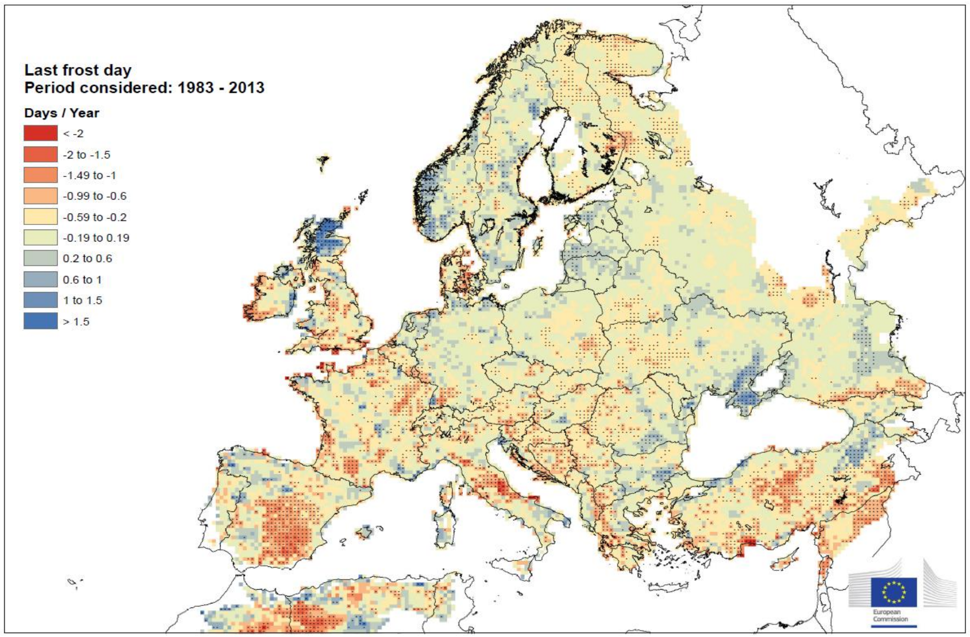


Introduction - length of warm spell



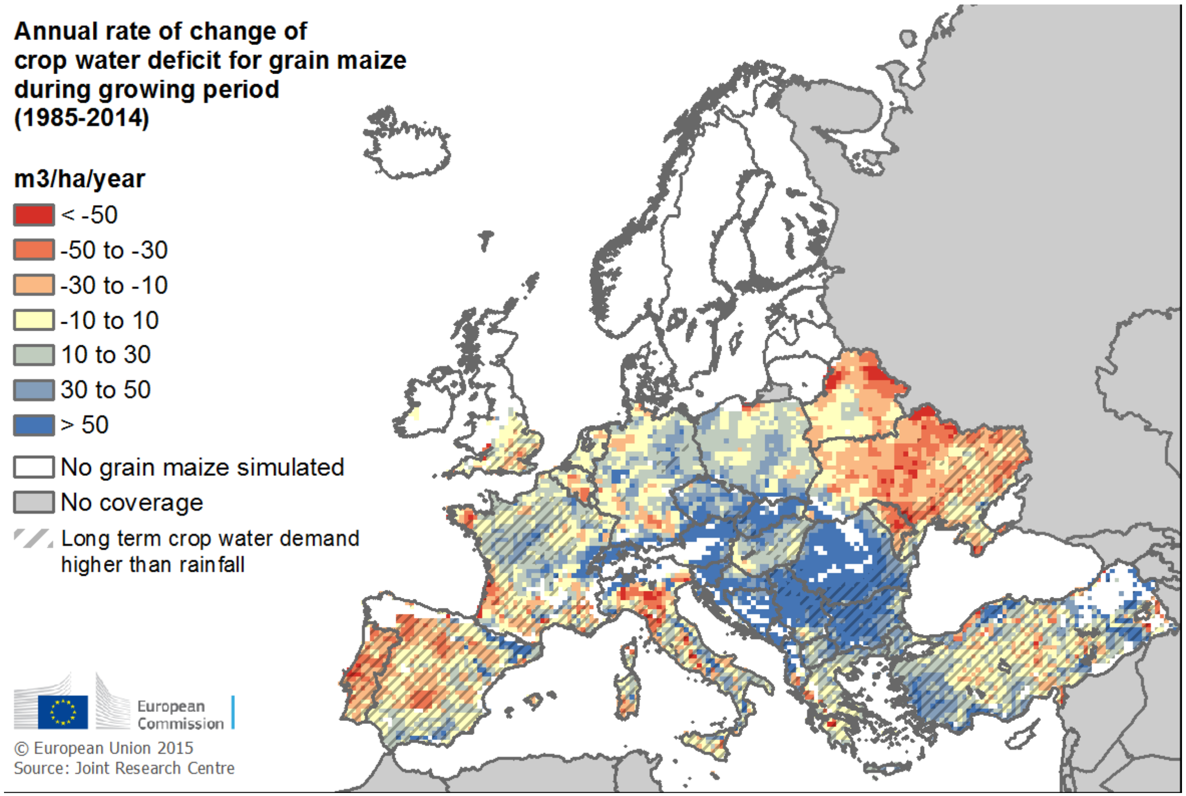
Introduction

- Last frost day not changing significantly, but spring temperature increasing



Introduction

Annual rate of change of the crop water deficit during the growing season of grain maize for the period 1985-2014 in Europe.



Expected CC in North Macedonia compared to 1961-1990 period

The source of climate data is the bias-corrected ENSEMBLE datasets of Dosio&Paruolo (2011) composed by two realization of the A1B emission scenario:

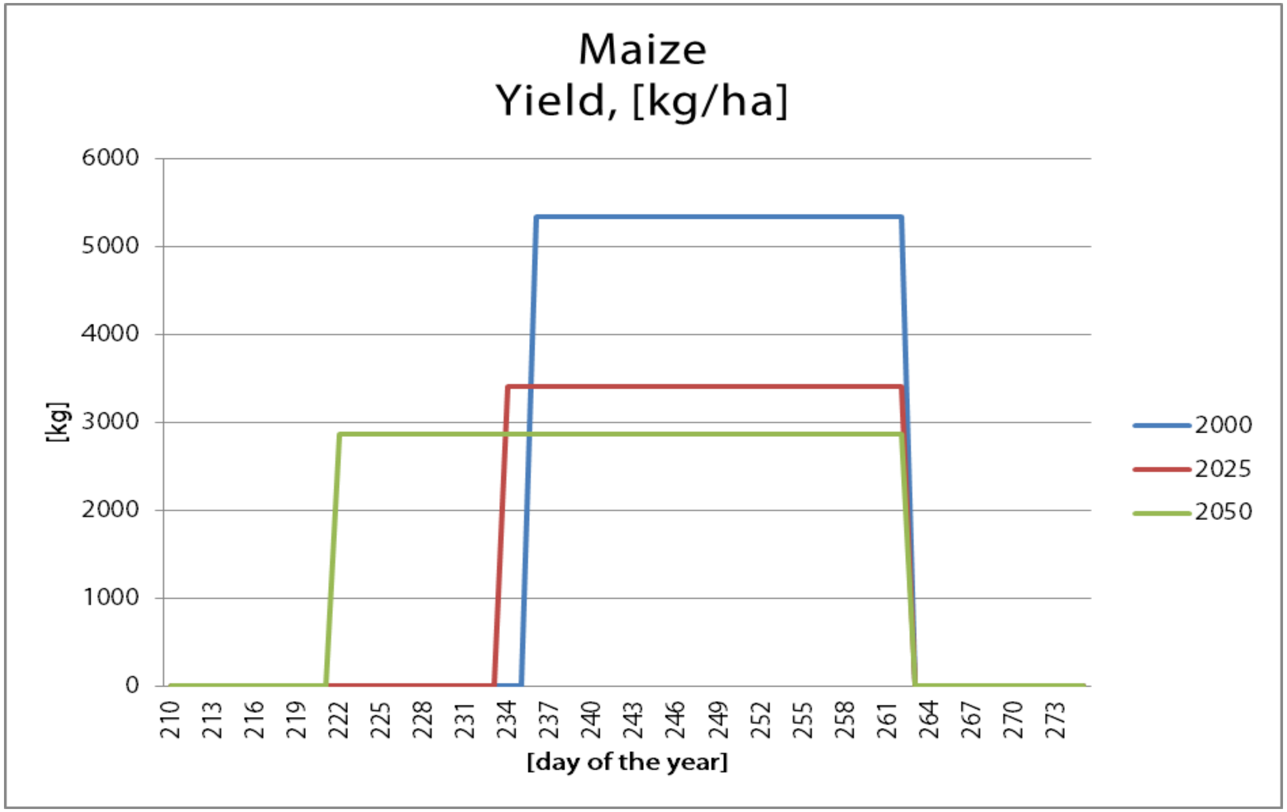
HADCM3 (warm realization) and ECHAM5 (cold realization)

Time Horizon	Temperature Projections		Precipitation Projections	
	Ensemble Averages^{0}C	Ensemble Ranges^{0}C	Ensemble Averages%	Ensemble Ranges%
2025	1	0.9 – 1.1	-3	-1 – -6
2050	1.9	1.6 – 2.1	-5	-2 – -7

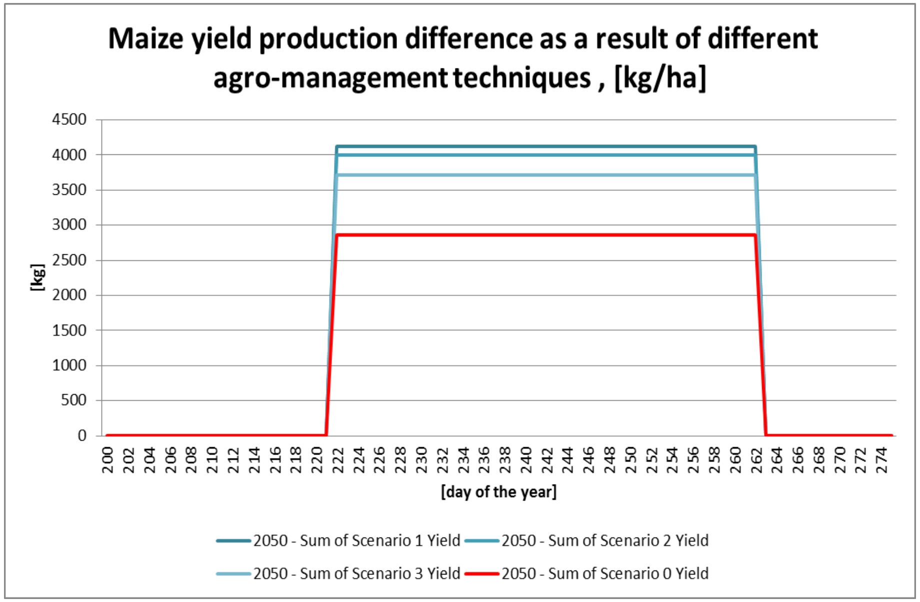
Maize, irrigation scenarios for simulation

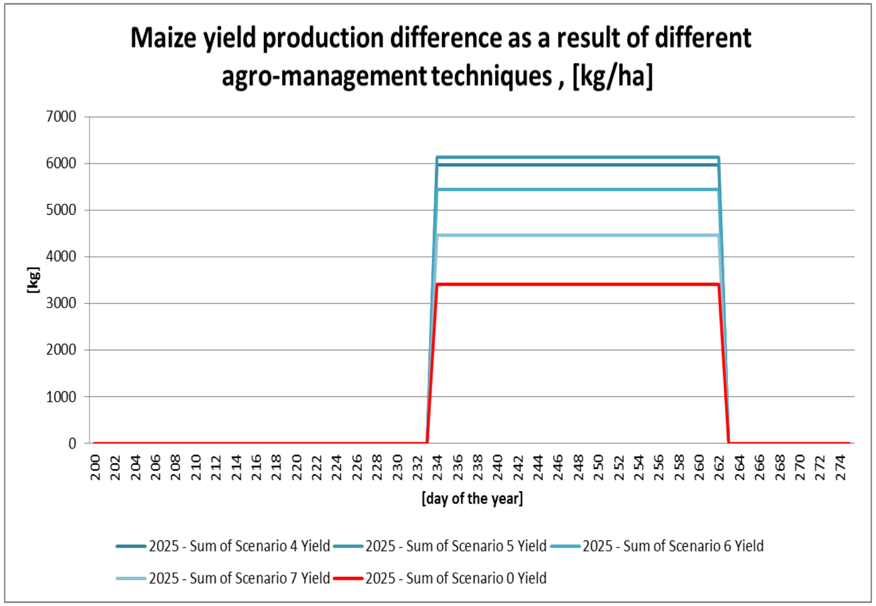
	SC 0	SC 1	SC 2	SC 3	SC 4	SC 5	SC 6	SC 7	SC 8	SC 9
PLANTING										
Planting depth [m]	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Day of the year	110	110	110	110	110	110	110	110	110	110
HARVESTING										
Yield loss fraction [%]	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Day of the year	263	263	263	263	263	263	263	263	263	263
IRRIGATION										
Start-Day of the year	NO IRRIGATION	157	177	171	157	157	177	171	160	160
End-Day of the year		216	216	206	227	216	216	206	225	225
Irrigation type		SPRINKLER	SPRINKLER	SPRINKLER	DRIP IRRIGATION	FURROW	FURROW	FURROW	SPRINKLER	BORDER IRRIGATION
Irrigation volume [mm]		60	60	80	30	60	60	80	30	30
Max. No of irrigations		5	4	2	13	5	4	2	ON 14d	ON 14d

Maize, no adaptation

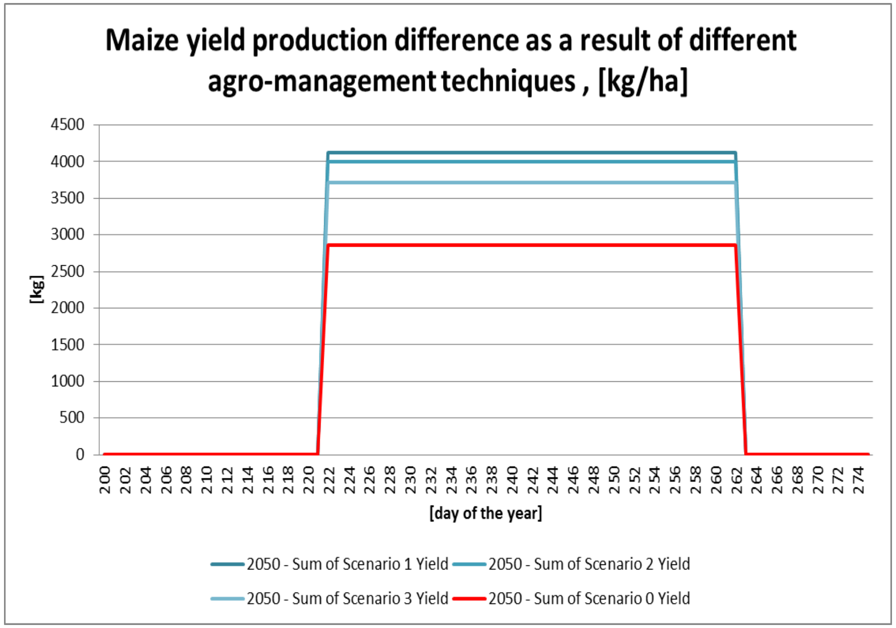


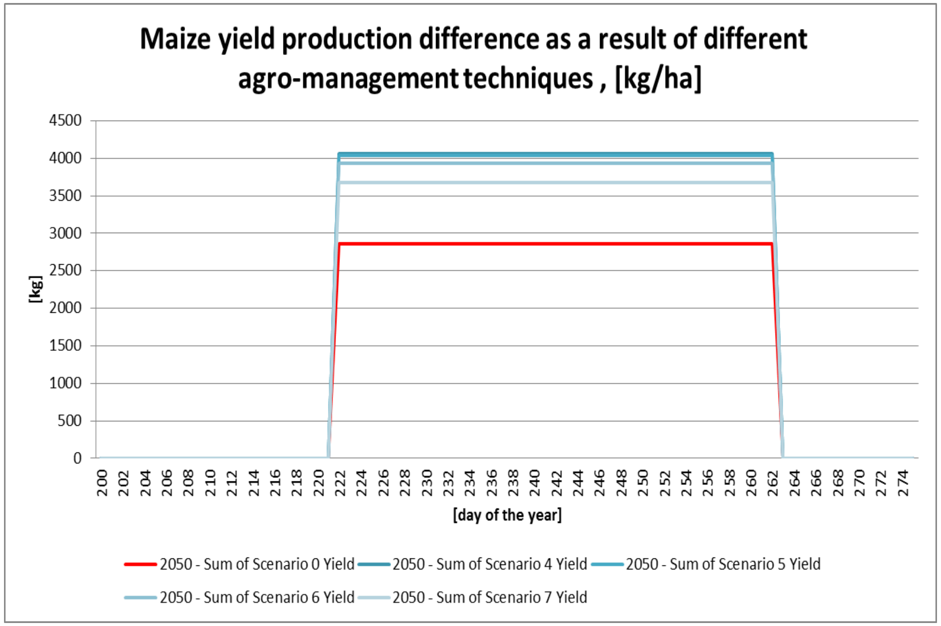
Maize, yield response 2025





Maize, yield response 2050





Winter wheat best adaptation option is irrigation combined with later sowing

Irrigation regardless of the number of pplications, type, and water regime, increased the yield of maize in future climate.

Comparing with the baseline scenario, the best adaptation option for winter wheat is:

2025 (scenario SC 1), yield increase by 35%

- Sprinklers, 5 applications between 157 and 216 DOY, with application depth of 60 mm.

2050 (scenario SC 1), yield increase by 45%

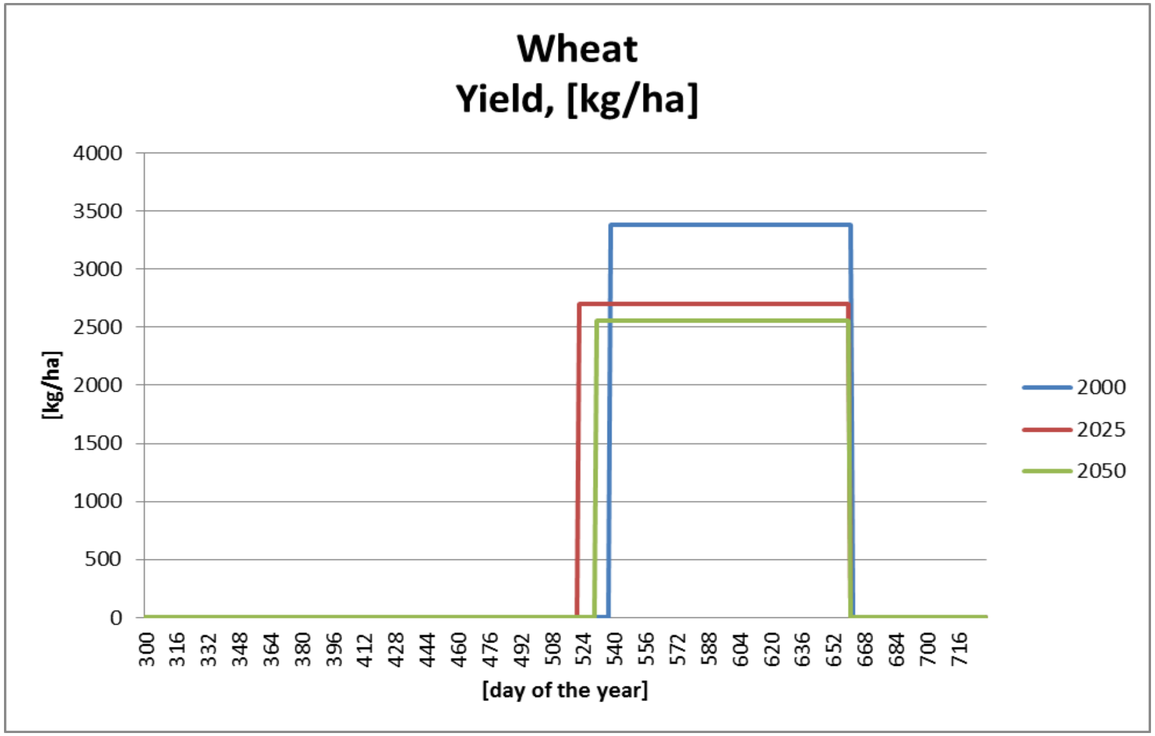
- Sprinklers, 5 applications between 157 and 216 DOY, with application depth of 60 mm.

The yield in 2050 is lower than yield in 2000, regardless irrigation applied, therefore different adaptation scenarios should be developed, targeting other limiting factors, not only water.

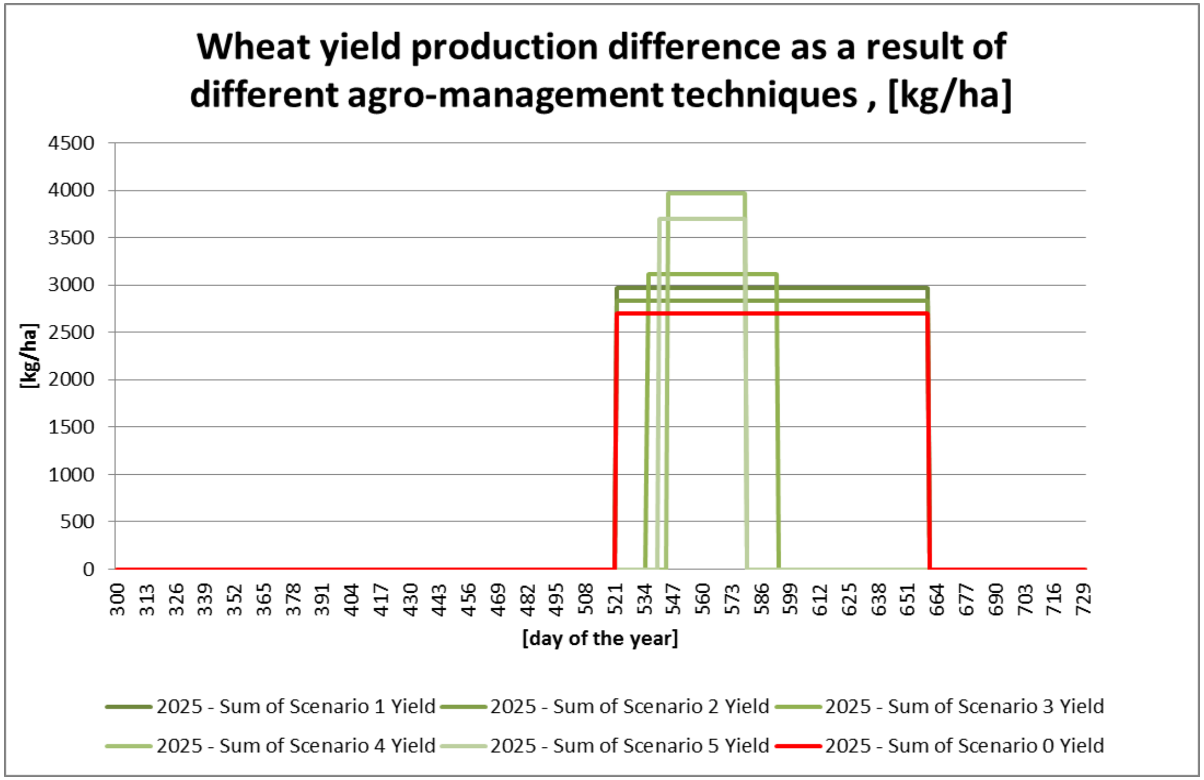
Winter wheat, irrigation scenarios for simulation

	SC 0	SC 1	SC 2	SC 3	SC 4	SC 5
PLANTING						
Planting depth [m]	0.03	0.04	0.04	0.04	0.04	0.04
Day of the year	296	297	297	319	328	328
HARVESTING						
Yield loss fraction [%]	0.0	0.1	0.1	0.1	0.1	0.1
Day of the year	253	254	254	230	216	216
IRRIGATION	NO IRRIGATION					
Start-Day of the year		202	220	165	150	130
End-Day of the year		224	220	191	191	190
Irrigation type		SPRINKLER	SPRINKLER	SPRINKLER	SPRINKLER	SPRINKLER
Irrigation volume [mm]		60	80	60	60	60
Max. No of irrigations		2	1	2	2	4 (20d)

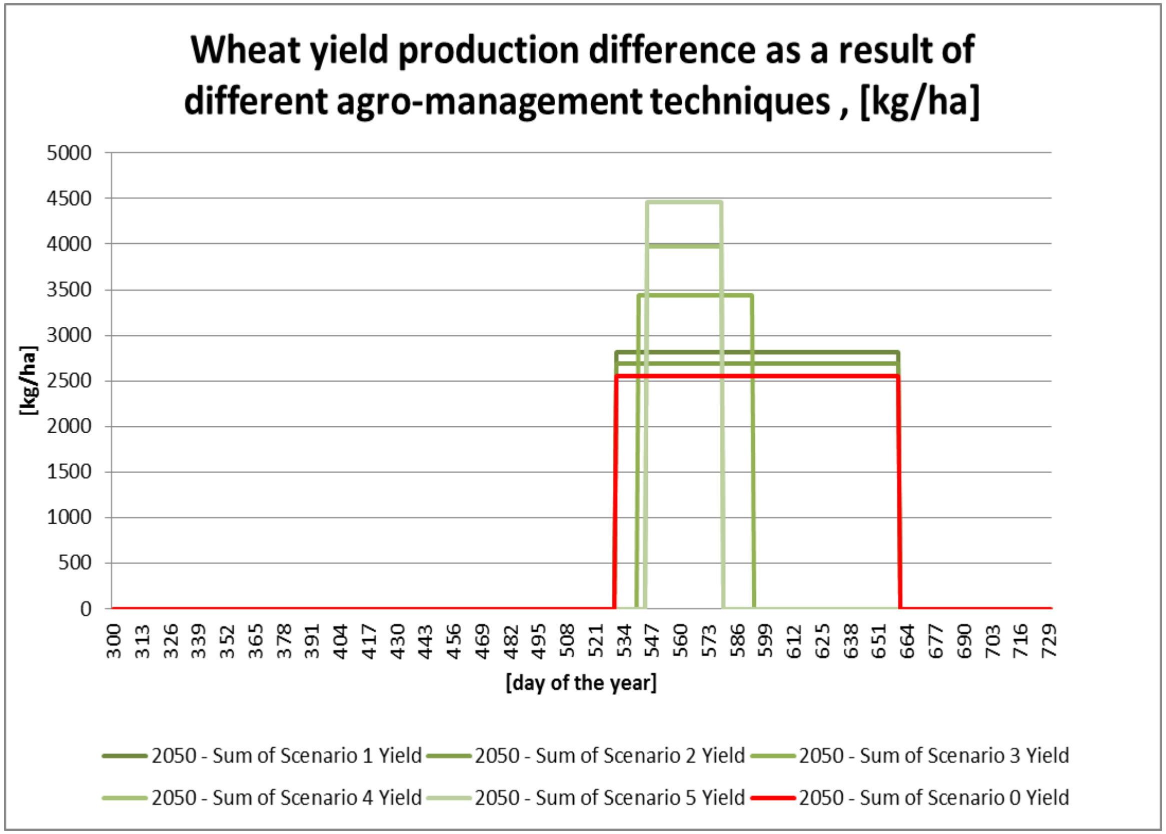
Winter wheat, no adaptation



Winter wheat, yield response 2025



Winter wheat, yield response 2050



Winter wheat best adaptation option is irrigation combined with later sowing

Comparing with the baseline scenario, the best adaptation option for winter wheat is:

2025 (scenario SC 3), yield increase by 33%

- applying two irrigation rates (60mm each) between 165 and 191 DOY
- delaying the sowing at 319 DOY

2050 (scenario SC 5), yield increase by 43%

- irrigation practice every 20 days (4 applications 60mm each), starting from DOY 130 and finishing at DOY 190
- delaying the sowing at 328 DOY

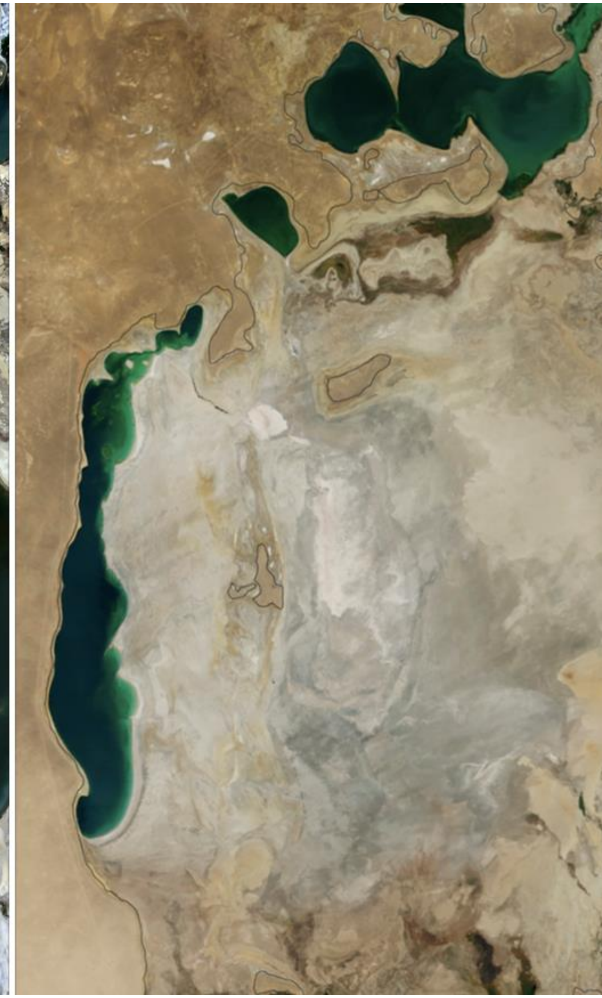
(co-benefit from increased CO2 rate)

Is irrigation as adaptation measure solution for CC?

- Irrigation is good adaptation measure when water is available and water price is affordable.
- Some other factors will probably limit the yield regardless eliminating water limitation
- Irrigation contribute to the GHG emission by using the fossil energy for water distribution and creating the pressure
- Irrigation can cause serious environmental problems (overexploitation of the water, environmental pollution, soil degradation etc.)

Anything wrong???

Aral Sea 1989



Aral Sea 2014

Is this normal???

- Australia - Murray Irrigation District in January 2015 price of irrigation water was 850-1250 $/ML. In same month 2019, only 5 years after water price doubled to 2070 $/ML.
- Getting similar water prices in North Macedonia will kill crop production as we know. Irrigation cost will be 6210 $ for 3000 m^3 or irrigation of 1 ha of maize.
- With expected maximal yield of 4,2 t/ha in year 2050 in North Macedonia only the water cost will be 1000 EUR for 1 ton of maize valued as 150 EUR in present.

WATER SAVING in IRRIGATION

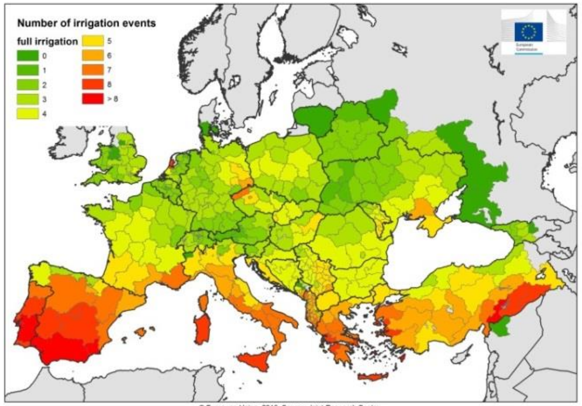
Analysis of different irrigation strategies for growing maize in Europe

Three different irrigation strategies were analysed for the impact on grain maize yield:

▪Full irrigation – applied water amount completely meets climatic water deficit

▪Deficit irrigation – apply water during the most sensitive crop development stages

▪Supplemental irrigation – try to simulate farmers behaviour; apply irrigation after longer period without rainfall, constant irrigation water amount applied after long period without rainfall



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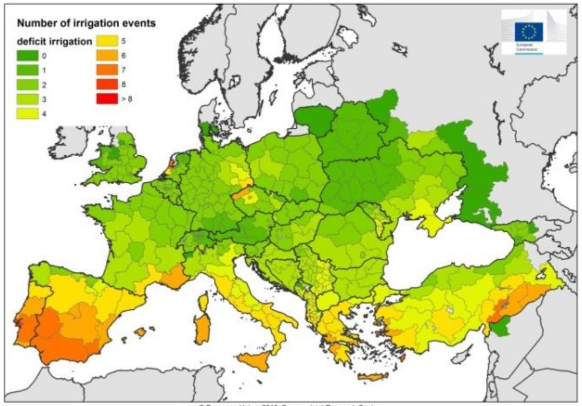

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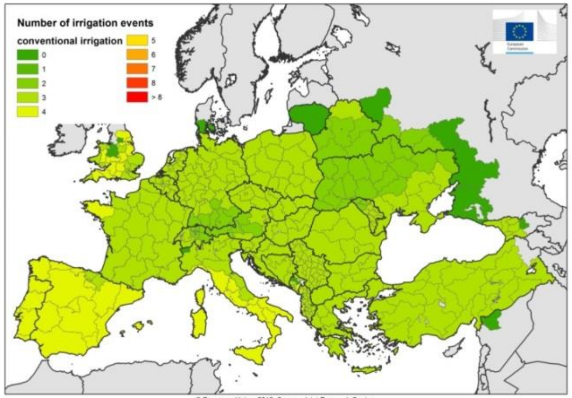

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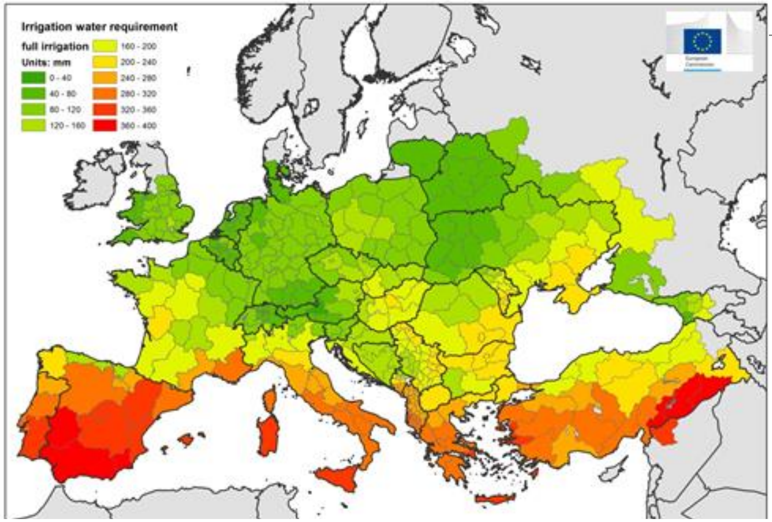
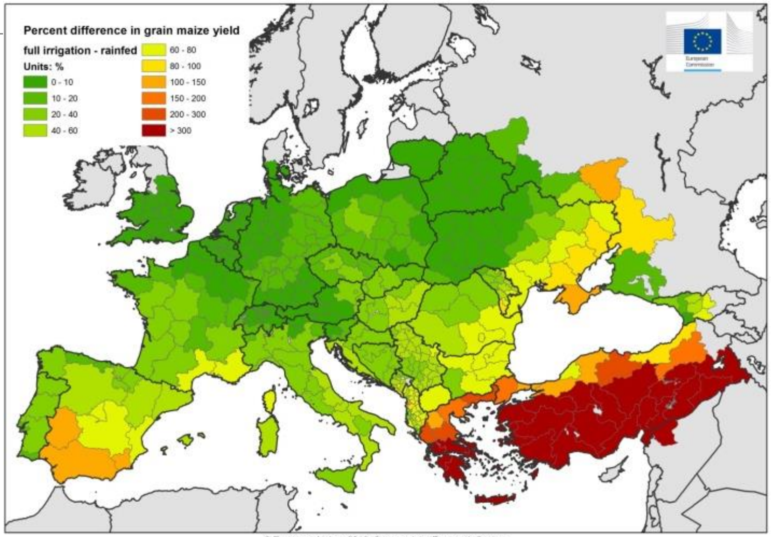
Analysis of different irrigation strategies for growing maize in Europe

Irrigation water requirement

Relative difference in maize productivity





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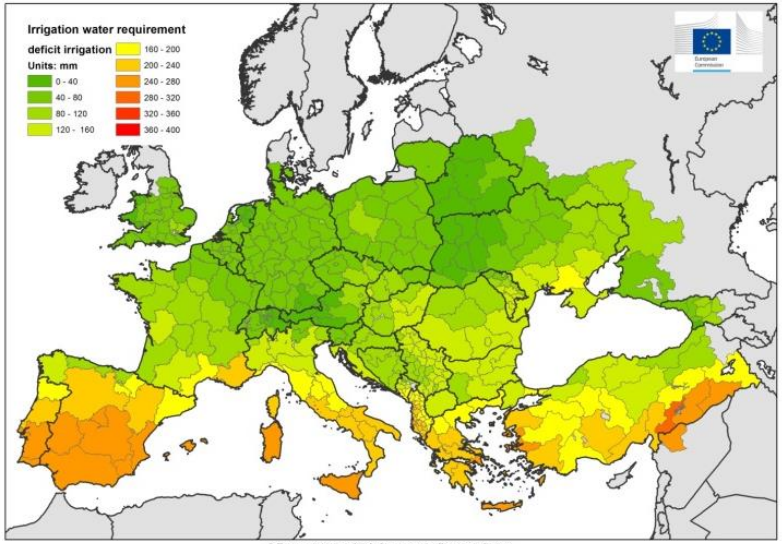

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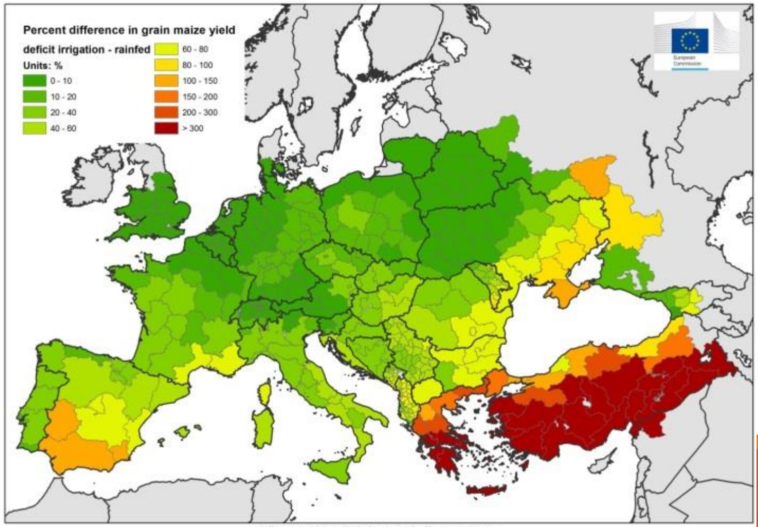

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More…

- Many other possibilities are tested for reducing the irrigation water use…
- We produce fancy research, fancy graphs, maps, and stick to our field of expertise
- But probably full picture is much bigger

Irrigation as mitigation measure

- Usually, irrigation is increasing emission by using the energy to distribute water and/or creating pressure for pressurized applications
- However, the irrigation is promoting the biomass production, hence increase carbon uptake from the atmosphere
- The analyse of the GHG emission per unit of product instead of unit of area can put the light on mitigation potential of irrigation

Irrigation as mitigation measure

Carbon intensity per kilogram maize yield, [kg CO_2 -eq/kg yield]

MAIZE	[kg CO_2 -eq/kg yield]								
Year	SC 0	SC 1	SC 2	SC 3	SC 4	SC 5	SC 6	SC 7	SC 8
Irrigation type		Sprin-kler	Sprink-ler	Sprink-ler	Drip Irr.	Furrow	Furrow	Furrow	Sprink -ler
[mm] water per irr.		60	60	80	30	60	60	80	30
irr. number		5	4	2	13	5	4	2	ON 14d
2000	/	0.06	0.05	0.04	0.14	0.20	0.17	0.12	0.03
2025	/	0.13	0.06	0.04	0.23	0.24	0.19	0.14	0.05
2050	/	0.16	0.09	0.06	0.28	0.36	0.29	0.20	0.06

Irrigation as mitigation measure

Carbon intensity per kilogram winter wheat yield, [kg CO_2 -eq/kg yield]

WHEAT	[kg CO_2 -eq/kg yield]					
Year	SC 0	SC 1	SC 2	SC 3	SC 4	SC 5
Irrigation type		Sprinkler	Sprinkler	Sprinkler	Sprinkler	Sprinkler
[mm] water per irr.		60	80	60	60	60
irr. number		2	1	2	2	every 20d
2000	/	0.12	0.08	0.10	0.10	0.15
2025	/	0.15	0.10	0.14	0.11	0.18
2050	/	0.16	0.11	0.13	0.11	0.15

Irrigation as mitigation measure

- Even though irrigation add certain amount of GHG emission to the unit of yield, higher increasing of yield reduces GHG emission per unit of yield
- Nort Macedonia has not developed national emission factors, therefore we can not estimate GHG emission per unit area (or unit yield), but we can calculate only increment of GHG added due to irrigation
- However, smaller increament means smaller GHG emission per unit of yield, therefore we can use mitigation for decreasing GHG emission per unit yield.

Photovoltaic Irrigation as mitigation measure

Description:

Installation of photovoltaic system for irrigation purposes with 2.4 KW installed capacity, capable to run 1.1 KW 3 phase pump.

The two cases are considered as mitigation practice:

- **replacing the petrol pump with consumption of 0.3l petrol per hour**
- **replacing 1.1 kw electricity pump with 3 phase AC**

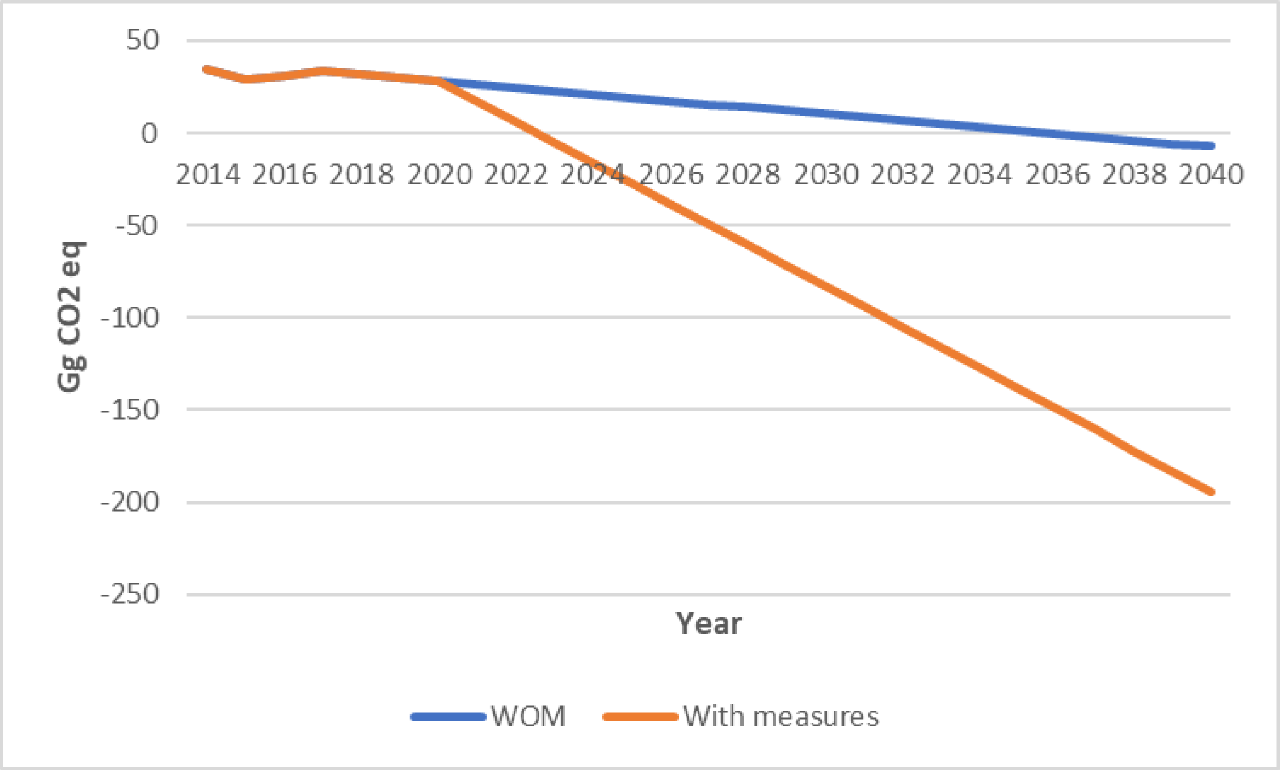
Photovoltaic Irrigation as mitigation measure

Programing the measure:

- **About 1000 installations annually in the period of 20 years, reaching about than 20,000 hectares irrigated by photovoltaic as energy source.**
- **Saving annually up to 9.33 Gg CO2-eq after 20 years of measure life (if all photovoltaic installations will replace electrical energy from public network).**
- **Minimal saving expected is 8.61 Gg CO2-eq (if all installations of photovoltaics will replace fossil fuel pump.**
- **The expected total saving during 20 years timeframe will be from 172.2 to 186.6 Gg CO2-eq.)**

Photovoltaic Irrigation as mitigation measure

Reduced emissions of CO_2 with conversion of 20 000 ha of irrigated land to photovoltaic irrigation



More…

CBA indicators – electricity pump replacement with PV system for 1 ha of crop area

	Baseline electricity motor replacement (without subsidy)			Electricity motor replacement (with subsidy)		
Crop	NPV (MKD)	IRR (%)	ROI (years)	NPV (MKD)	IRR (%)	ROI (years)
Winter wheat	-97,407	-2.49%	/	-27,785	2.36%	/
Maize	-48,410	2.44%	/	21,213	8.31%	17
Tomato	-30,484	3.85%	/	39,139	10.08%	14
Pepper	-19,728	4.64%	/	49,895	11.09%	12
Tobacco	-54,385	1.94%	/	15,238	7.69%	19
Apple	-20,923	4.55%	/	48,700	10.98%	13
Wine Grape	-65,618	0.94%	/	4,004	6.46%	23
Table grape	-48,649	2.42%	/	20,974	8.29%	17

More…

- The measure is not feasible without using the existing subsidies for 60% return of investments
- The real benefit of the measures can be diversification of the farm income if farmers are allowed to distribute excess of production (more than 2000 hours in some cases) in the network
- Moreover if only 20% of the farms in the country install photovoltaic irrigation (about 40 000 farms) the total installation will be 96 MW….

Thank You!!!

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