Ozone impacts on vegetation in various scenarios

Reviewing the effectiveness of the Gothenburg Protocol

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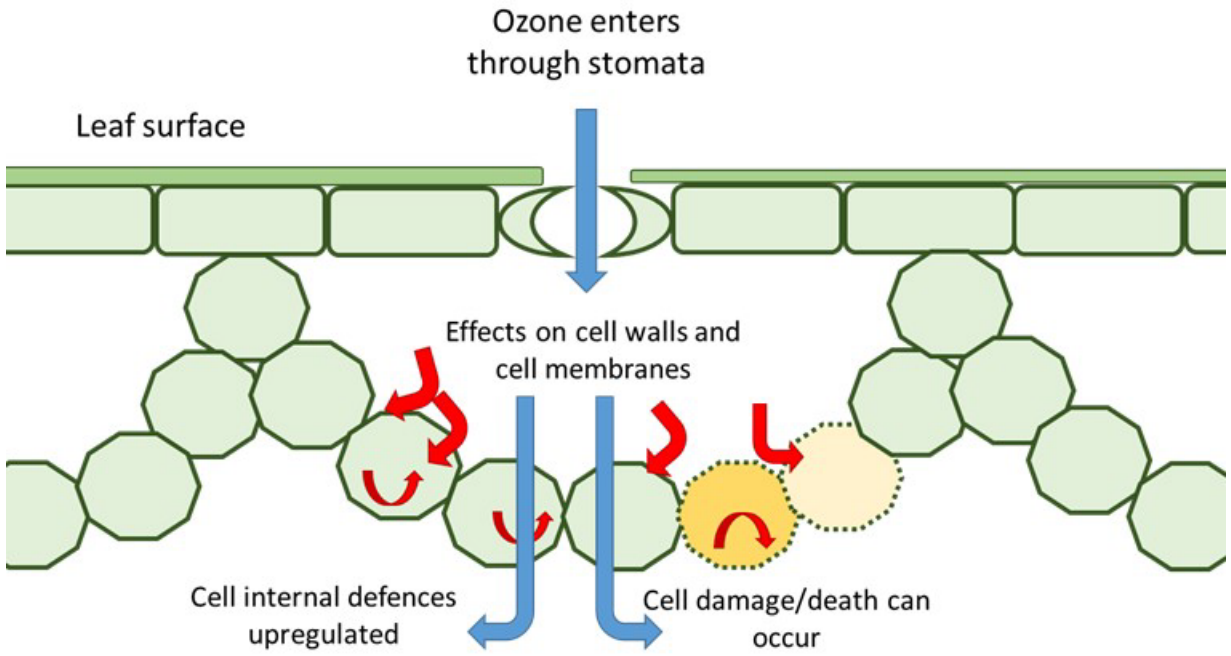
Overview

Ozone Impacts

Gothenburg Scenario work

Remaining Questions and Future work

Ozone Pollution: Crop Plant Impacts



Ozone + favourable environmental conditions

↓

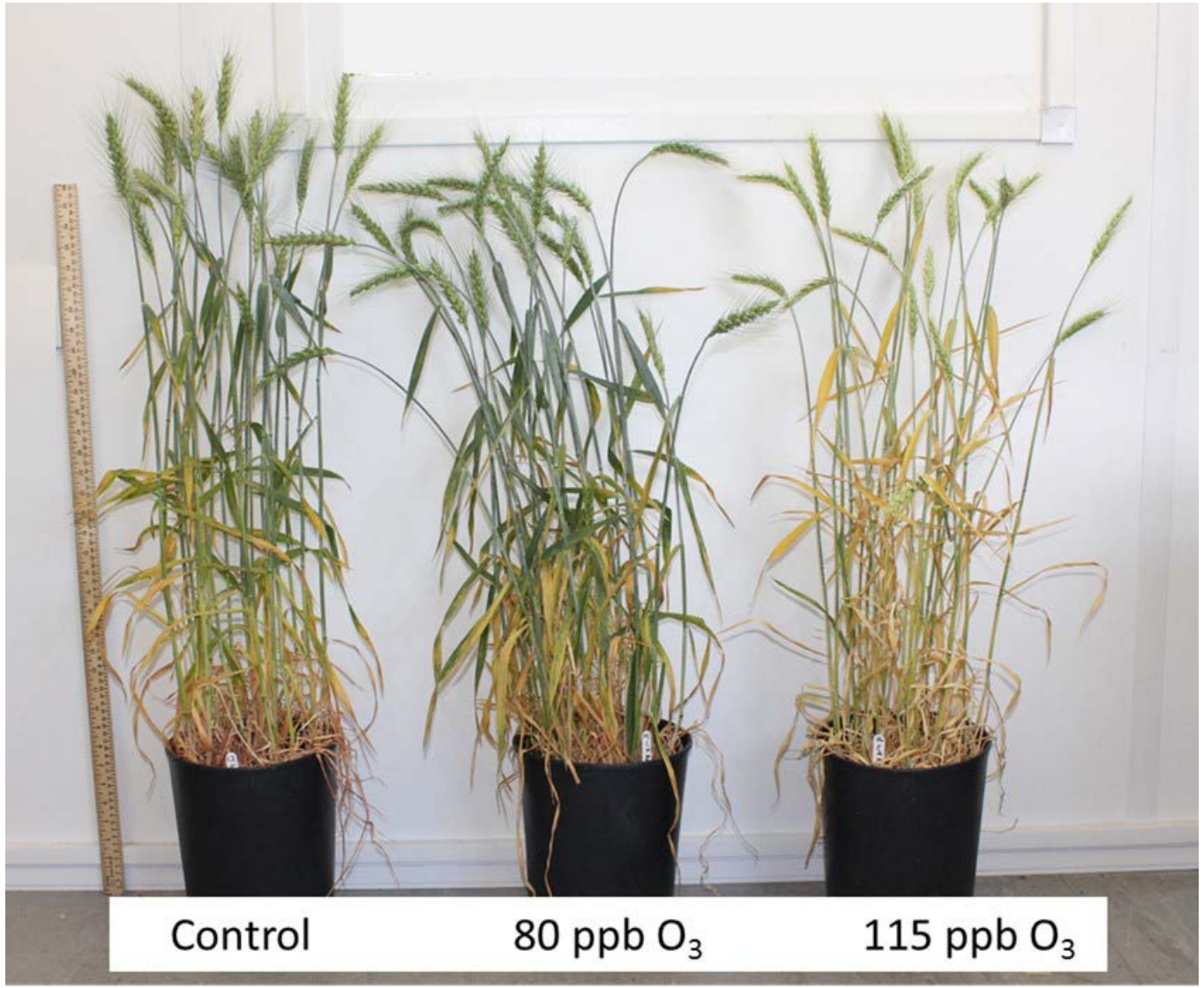
Ozone enters plants through stomata

↓

Damage occurs (some detoxification capacity)

↓

Ozone impacts

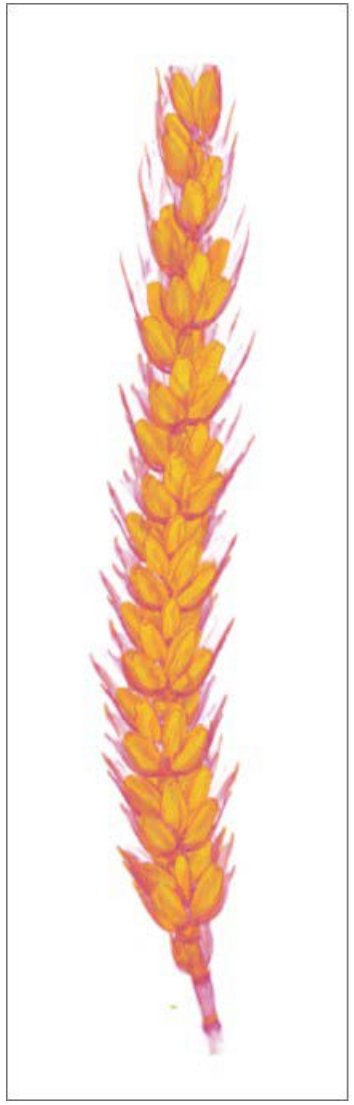


WHEAT:

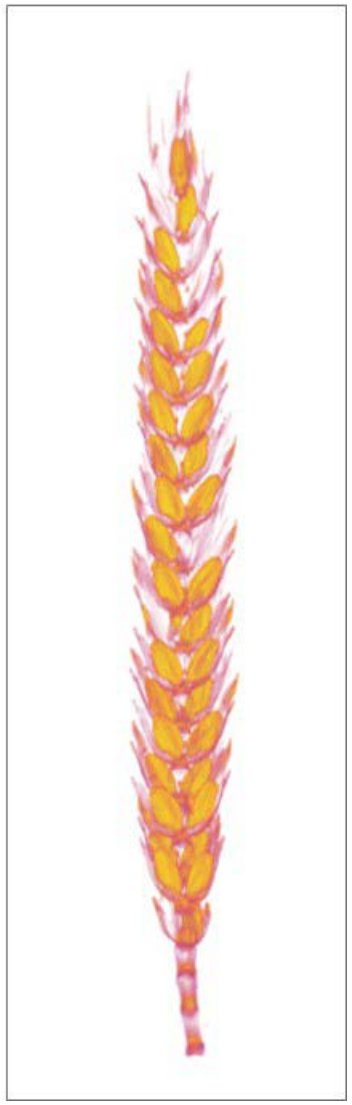
Accelerated ageing

Damaged photosynthesis

Reduced yield



Low ozone



High ozone

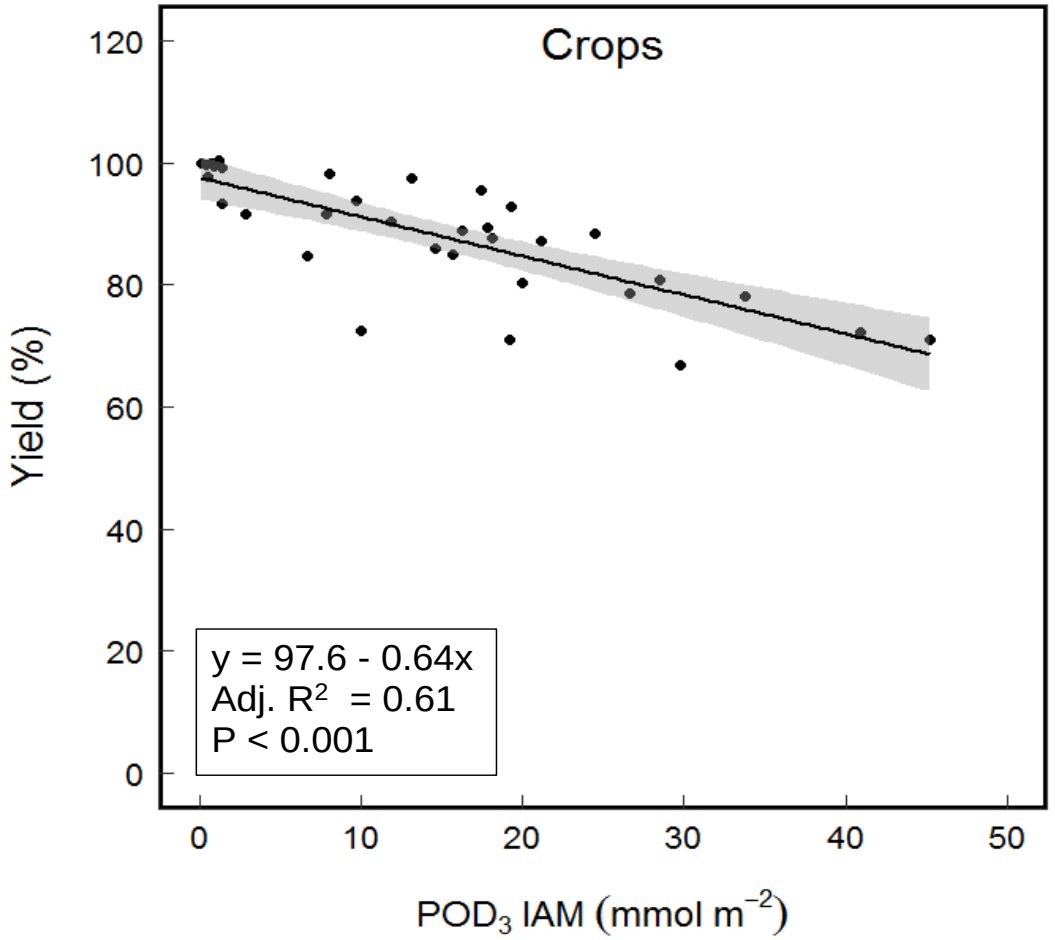
WHEAT:

Reduced grain fill / grain number

Image courtesy:
Clare Brewster (UKCEH)
&
National Plant Phenomics Centre,
Aberystwyth University

Experiments used to find impacts on yield

Open-top chambers in a wheat field in Sweden



Ozone flux (''IAM'' is for large scale modelling)

Scenarios – for the review of the Gothenburg Protocol

- Scenarios from the EMEP Centre for Integrated Ecosystem Assessment Modelling (CIAM)

- Current energy and climate policies (significantly more ambitions in the European Union compared to other regions).

- A “Low” scenario had been developed that also included an ambitious climate policy (Paris Agreement targets), and a significant transformation in the agricultural sector. (reduction in food waste and livestock numbers, especially cattle and pigs, resulting in additional mitigation of NH_3 and methane).

Methods

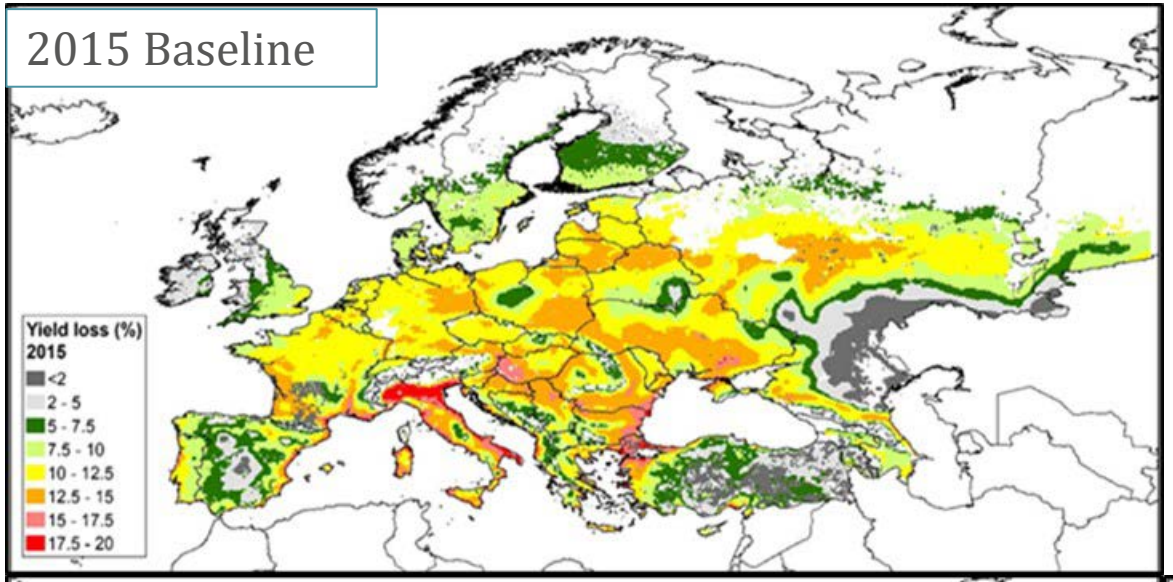
- Post-hoc analysis using the 3 scenarios (produced by CIAM)
  - 'low' also involves large changes to diet
- ozone metrics produced from EMEP model: POD_3IAM for wheat, POD_1IAM for deciduous forest

Met data	Emissions	Scenario
2005	2005	Baseline
2015	2015	Baseline
2015	2030	Baseline
2015	2030	MFR
2015	2050	Baseline
2015	2050	MFR
2015	2050	LOW

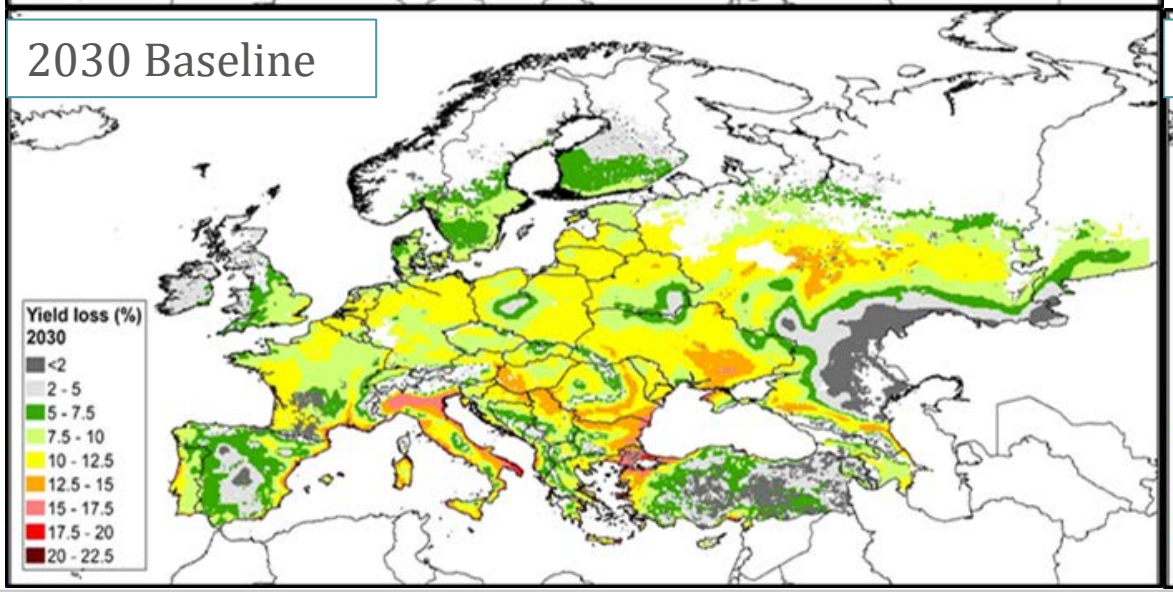
0.1 x 0.1 degree EMEP grid

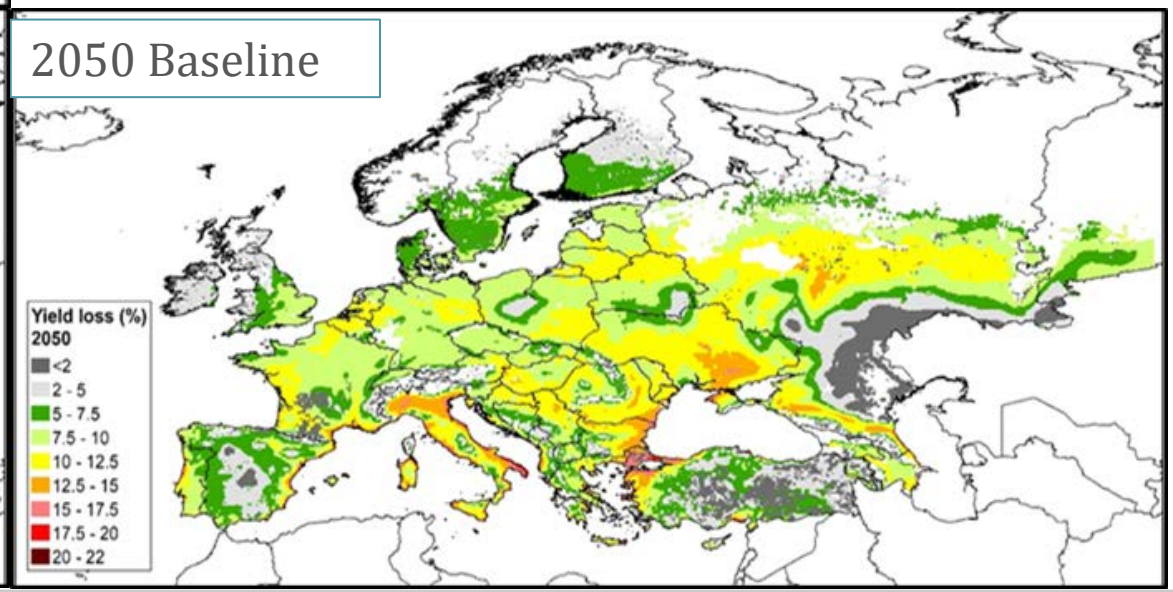
- Spatial wheat production data (SPAM), for the year 2010 (converted to 2015 using FAO data).
- Global land cover data for 2015 (ESA CCI), to calculate how much deciduous forest per EMEP grid square.

Wheat: % Yield loss due to ozone (POD_3IAM)



- Highest losses in Italy and parts of central-southern Europe.
- Negligible losses in the most northern areas and also hot, dry areas.
- Much of Europe has >10% yield loss in the baseline scenario.
- Estimated yield losses decrease with time





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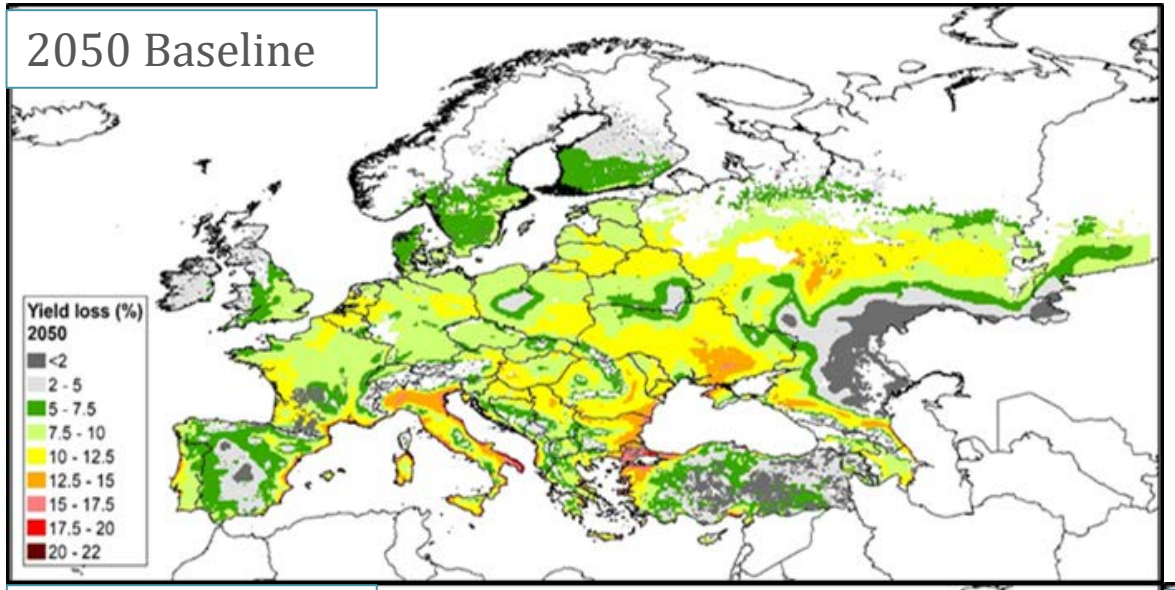
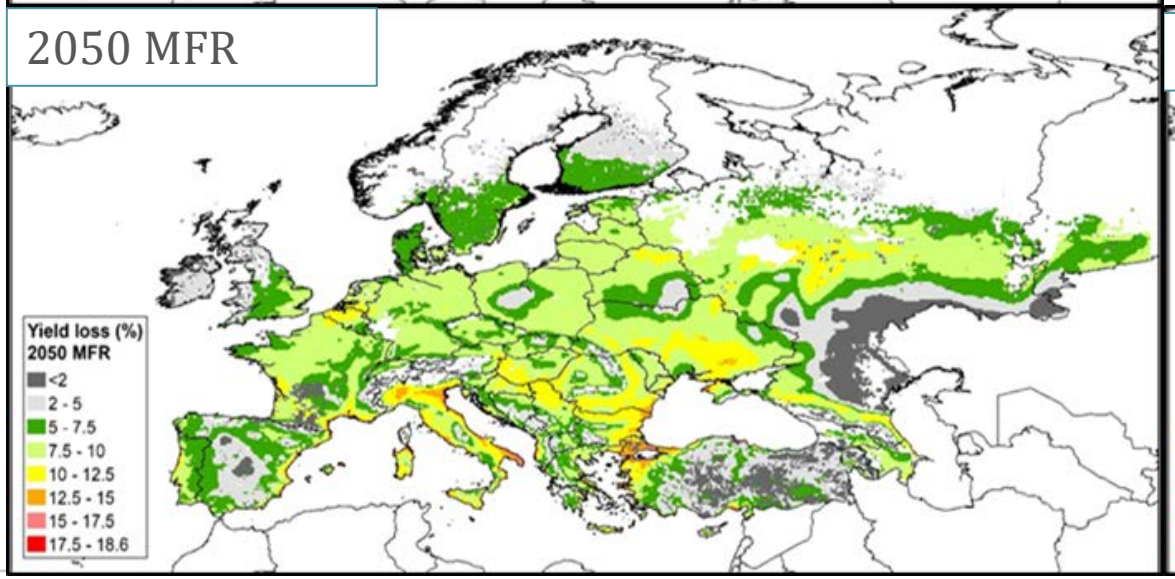
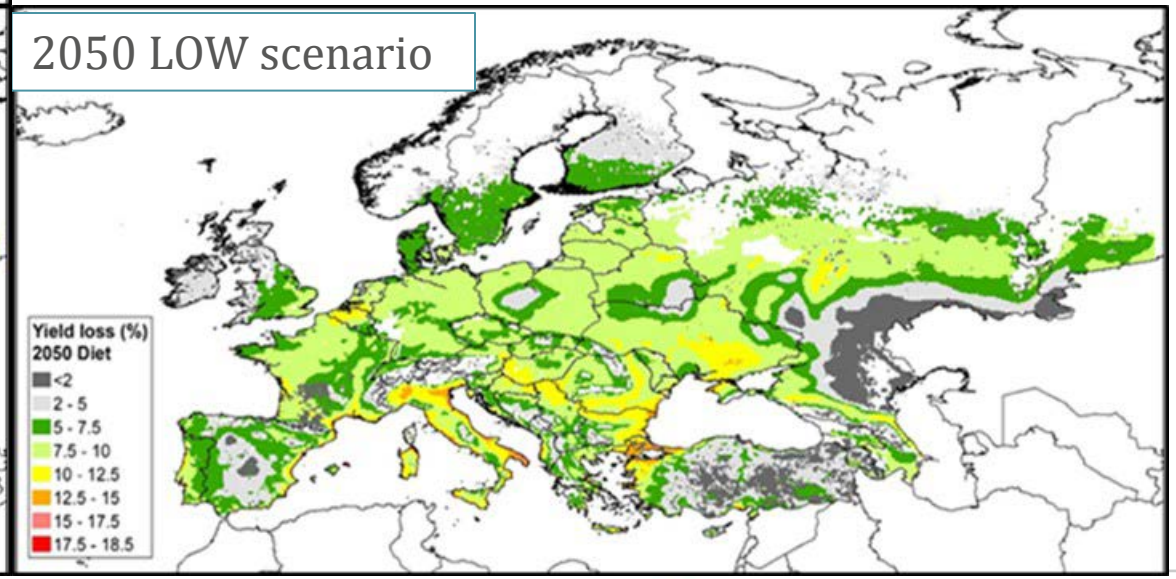
Wheat: % Yield loss due to ozone (POD_3IAM)







- Estimated yield losses decrease with increasingly stringent emissions scenario.

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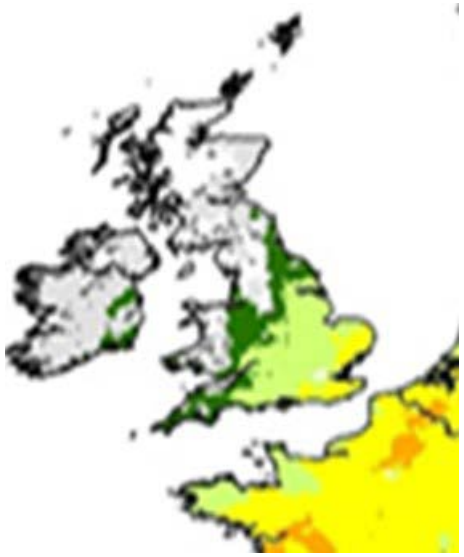
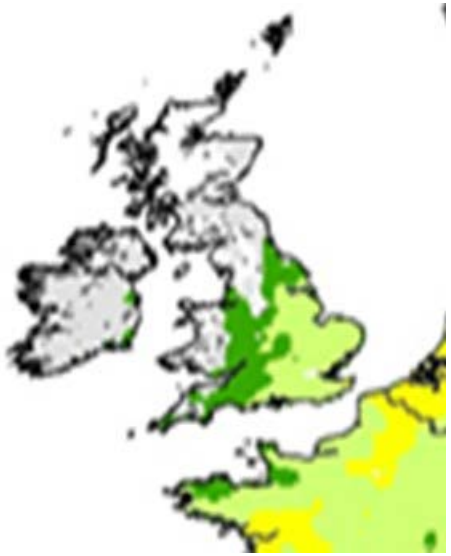
Wheat: % Yield loss due to ozone (POD_3IAM)

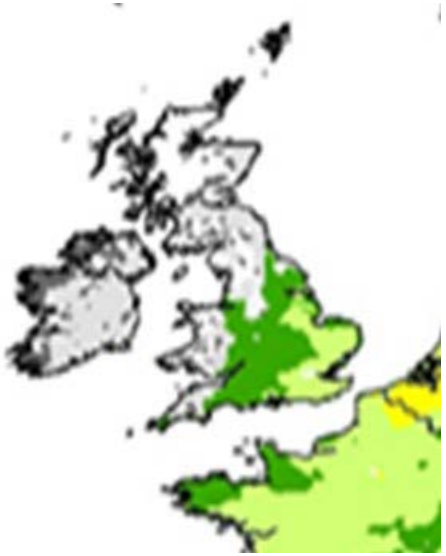
2015 Baseline



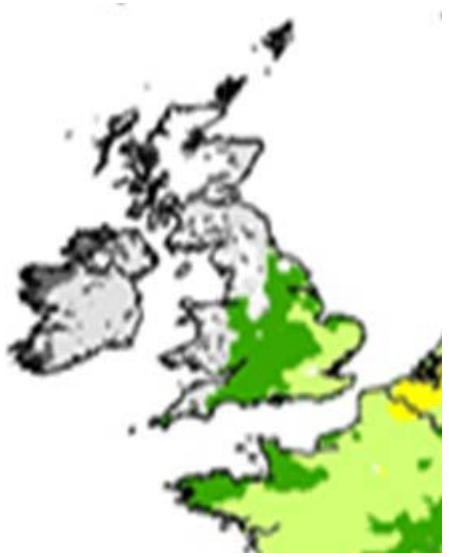
2050



2050 MFR



2050 LOW scenario



- Improvements with the MFR and Low (Diet) scenarios, but still significant losses in wheat yield

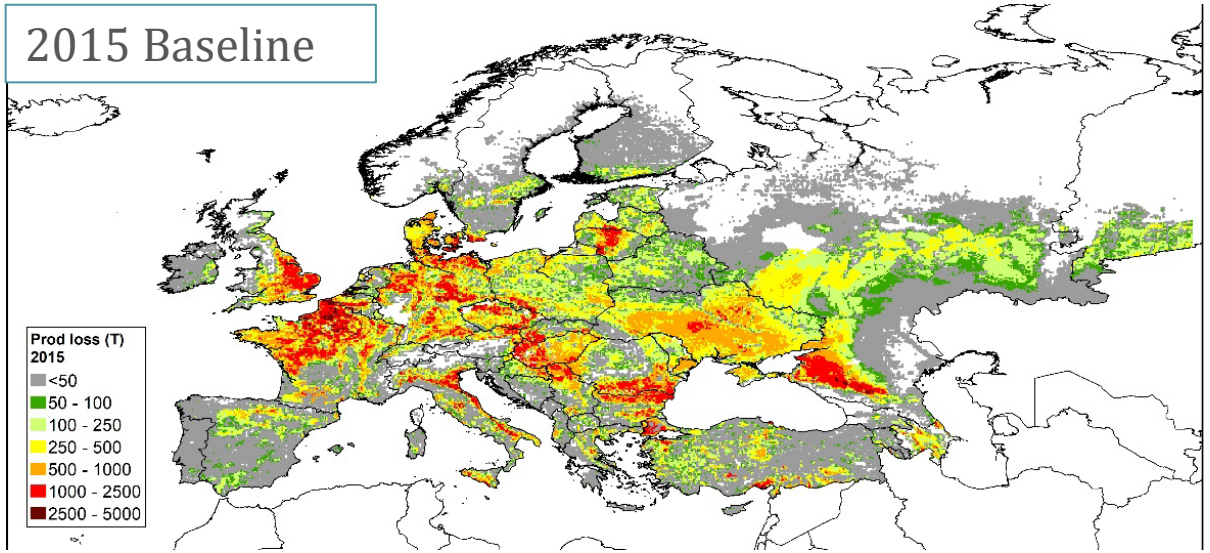
Wheat: % Yield loss due to ozone (POD_3IAM)

POD_3IAM	2015	2030	2030 MFR	2050	2050 LOW
Country	% loss	% loss	% loss	% loss	% loss
Russian Fed.	7.95	7.60	7.09	7.40	5.95
France	10.27	8.81	8.35	8.19	7.19
Ukraine	11.49	10.63	9.93	10.30	8.50
Germany	11.65	10.03	9.56	9.06	8.12
Turkey	4.95	4.67	4.40	4.65	3.83
UK	6.11	5.84	5.58	5.53	4.91
Poland	11.56	9.82	9.26	8.81	7.83
Romania	12.12	10.86	10.14	10.19	8.81
Italy	14.49	12.37	11.80	11.54	9.98
Spain	7.14	6.37	6.10	6.07	5.39
Hungary	13.09	11.18	10.49	10.23	8.94
Czech Rep.	11.33	9.40	8.84	8.38	7.47
Bulgaria	12.20	11.12	10.34	10.41	8.86
Denmark	8.79	7.90	7.57	7.22	6.52
Lithuania	12.43	10.99	10.44	10.03	8.93
Sweden	7.56	6.70	6.44	6.17	5.60
Serbia	11.63	10.33	9.65	9.63	8.27
Belarus	10.32	9.21	8.66	8.64	7.32
Slovakia	11.02	9.25	8.64	8.34	7.24
Azerbaijan	8.86	8.88	8.61	9.09	7.21
Latvia	11.30	10.03	9.58	9.15	8.22
Belgium	11.30	10.76	10.36	10.20	9.21

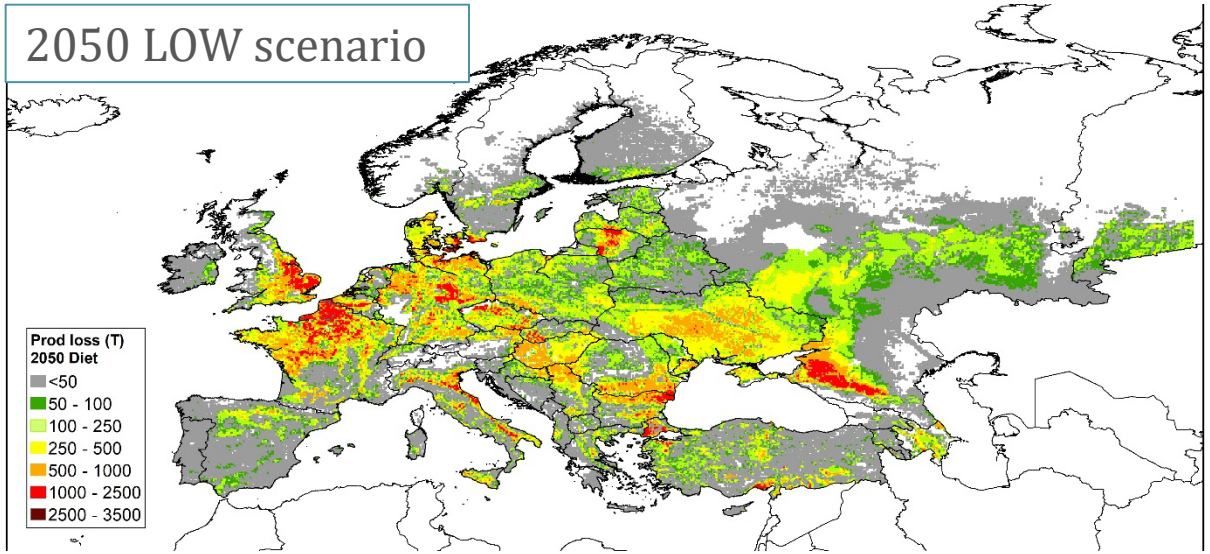
POD_3IAM	2015	2030	2030 MFR	2050	2050 LOW
Country	% loss	% loss	% loss	% loss	% loss
Austria	10.83	8.78	8.29	7.90	7.00
Greece	10.66	9.59	9.00	9.14	7.67
Finland	6.26	5.51	5.29	5.08	4.57
Netherlands	10.54	10.35	10.03	9.85	8.97
Moldova	11.41	10.45	9.77	10.03	8.39
Croatia	13.09	11.12	10.48	10.28	8.97
Estonia	10.40	9.21	8.83	8.38	7.54
Ireland	3.09	2.90	2.75	2.82	2.45
Switzerland	8.94	7.52	7.13	6.81	5.86
Armenia	3.64	3.59	3.50	3.73	3.14
Norway	5.52	4.97	4.78	4.66	4.20
Bosnia & Herz.	9.02	7.84	7.34	7.28	6.25
Albania	9.19	8.28	7.75	7.91	6.56
FYR Macedonia	8.50	7.59	7.08	7.12	6.00
Georgia	7.01	6.90	6.70	7.05	5.49
Slovenia	12.41	10.09	9.53	9.02	7.85
Portugal	10.02	9.12	8.75	8.77	7.66
Luxembourg	9.32	8.71	8.25	7.96	6.96
Cyprus	6.26	5.79	5.35	5.76	4.34
Montenegro	5.64	5.02	4.73	4.72	4.06
Malta	0.27	0.24	0.23	0.23	0.20

Wheat: Production loss due to ozone (POD_3IAM)

2015 Baseline



2050 LOW scenario



- High production losses in many countries
- (note this is a combination of how much wheat is grown, and the % loss – so high production losses in many of the main wheat growing areas)

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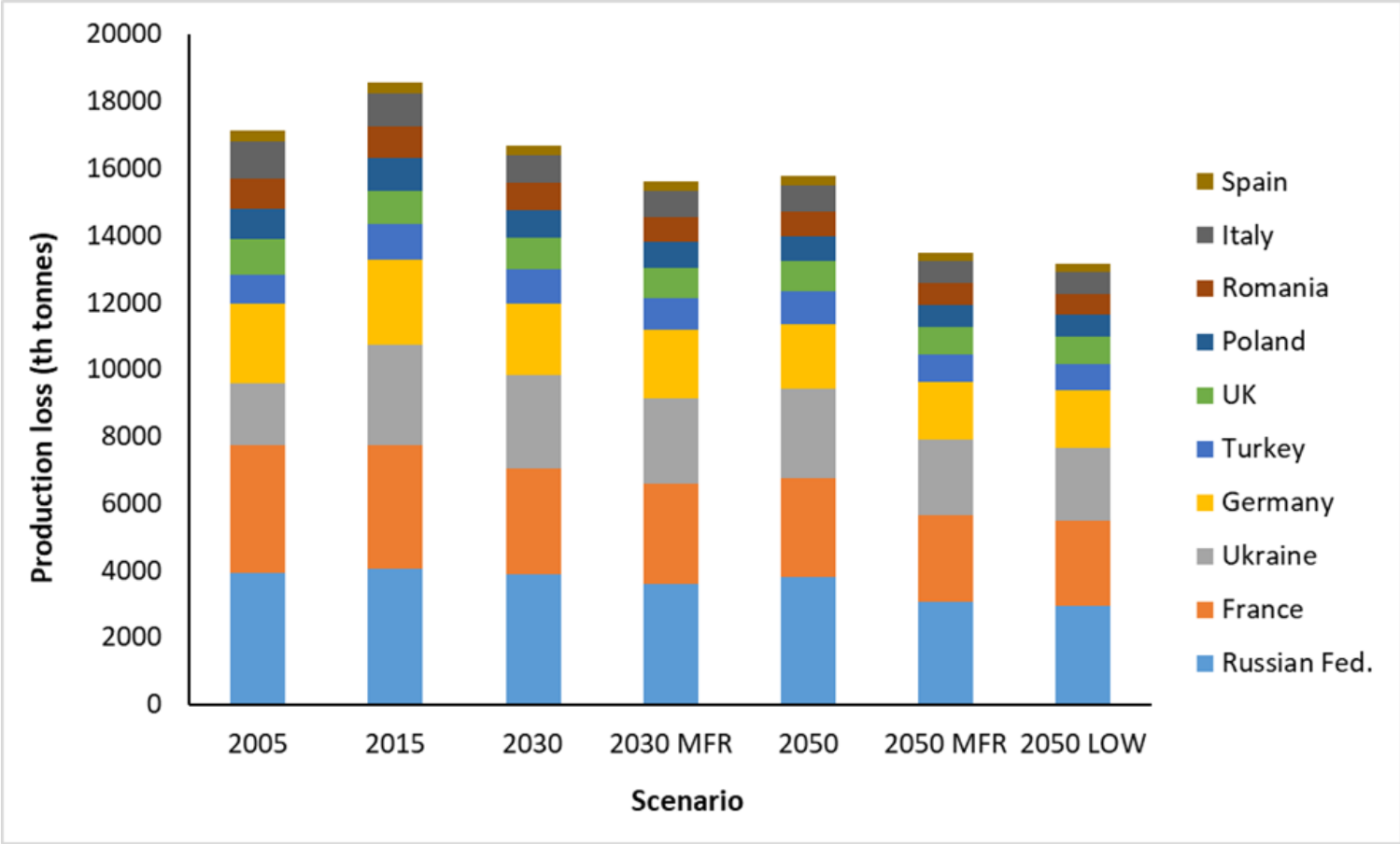
Wheat: Production losses due to ozone (POD_3IAM)



Countries with greatest production loss are Russian Fed., France and Ukraine.

For the most stringent of the scenarios '2050 LOW', there will still be an estimated total loss of 13 million tonnes of wheat (for top 10 producing countries).

Production loss (thousand tonnes) due to ozone for the **top 10** wheat producing countries (using POD_3IAM)

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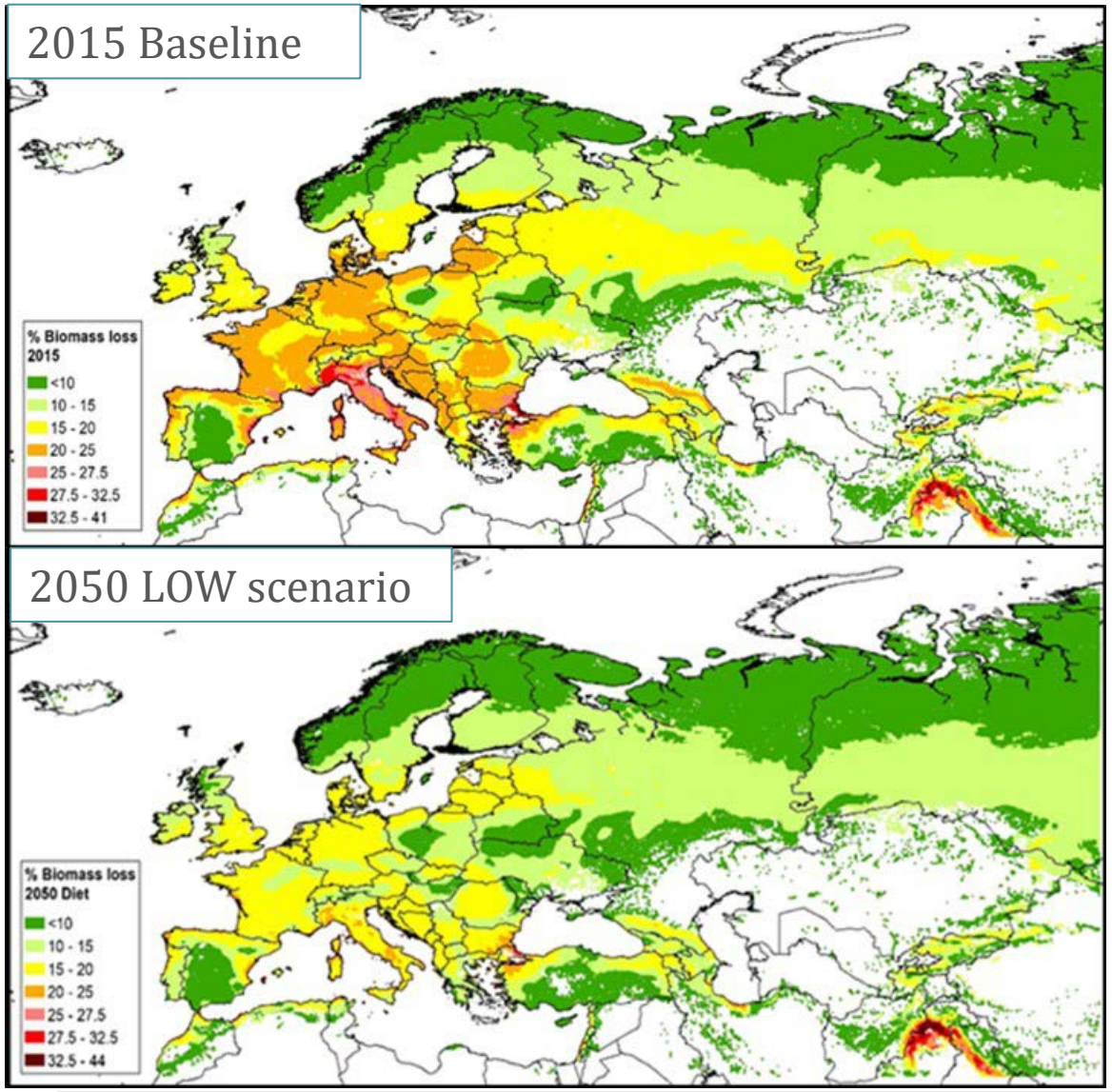
Deciduous forest (POD_1IAM)



- **Risk of reduction in annual growth of living biomass**
- Biomass losses decreasing with time, from 20-25% to 15-20%.
- In 2050 LOW scenario, Montenegro has predicted losses of 17%.
- (carbon offsetting implications?)

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Deciduous forest (POD_1IAM)

POD_1IAM DF	2005	2015	2030	2030 MFR	2050	2050 MFR	2050 Diet
Country	% loss	% loss	% loss	% loss	% loss	% loss	% loss
Montenegro	23.25	22.03	20.28	19.39	19.44	17.74	17.33
FYR Macedonia	25.41	18.71	17.21	16.32	16.40	14.88	14.42
Bosnia & Herzegovina	23.53	21.46	19.41	18.47	18.41	16.69	16.35
Luxembourg	19.30	17.65	17.76	17.16	16.84	15.60	15.44
Georgia	18.25	16.03	15.78	15.34	15.94	13.46	13.08
Albania	25.87	22.88	21.12	20.07	20.36	18.24	17.72
Portugal	18.37	18.00	16.97	16.46	16.55	15.02	14.96
Slovenia	26.55	24.19	20.91	20.02	19.34	17.59	17.39
Croatia	26.99	23.54	21.04	20.06	19.93	17.98	17.74
Serbia	25.43	19.81	18.19	17.24	17.27	15.67	15.26
Spain	14.21	13.81	12.73	12.28	12.28	11.14	11.07
Bulgaria	27.45	23.33	21.88	20.75	20.88	18.88	18.53
Slovakia	24.02	19.09	16.98	16.14	15.81	14.42	14.23
Italy	27.16	25.48	22.57	21.70	21.38	19.13	18.97
Latvia	20.51	19.88	18.41	17.83	17.30	16.16	15.98
Romania	24.48	19.16	17.67	16.77	16.86	15.33	15.08
Turkey	15.29	13.51	12.98	12.43	12.98	11.59	11.25
Greece	27.31	17.01	15.74	14.96	15.17	13.49	13.23
Armenia	18.50	17.06	16.92	16.56	17.37	15.34	14.96
France	23.80	21.62	19.63	18.93	18.69	17.24	17.05
Hungary	26.27	16.42	14.58	13.84	13.61	12.37	12.18
Estonia	19.91	19.03	17.62	17.12	16.57	15.53	15.38
Russian Federation	12.98	11.04	10.73	10.41	10.52	9.70	9.59
Cyprus	20.34	8.68	8.18	7.61	8.18	6.55	6.31
Azerbaijan	14.45	15.32	15.37	14.95	15.68	13.50	13.06

Why hasn't the Protocol solved the problem?

- Some natural sources of ozone formation – it will never reach 0
- In some areas ozone is increasing due to decreased titration by NOx
- Some emissions from outside the UNECE region contribute to 'our' ozone
- Other pollutants also contribute to ozone formation – methane
- Methane reduction scenarios (from 'climate change' conventions) will also have benefits for ozone – how much?

Conclusions

- Ozone causes crop yield reductions and growth reductions of many vegetation types
- Post-hoc analysis for the review of the Gothenburg Protocol shows that current emissions reduction plans will improve air quality and reduce losses in the coming decades.
- Even the most optimistic scenario for 2050 shows considerable production and biomass losses due to ozone.
- **What's next?** Similar post-hoc analysis could show the influence of methane scenarios on ozone impacts to vegetation (a possible win-win for policy makers focussing on SLCFs) – (also possible to look at other scenarios e.g. inside vs outside LRTAP region emissions reductions)

https://unece.org/environment/documents/2022/09/informal-documents/gothenburg-protocol-review-report

Thank you

Any questions?