How will future climate depending agronomic management impact the yield risk of wheat cropping systems?

A regional case study of Eastern Denmark

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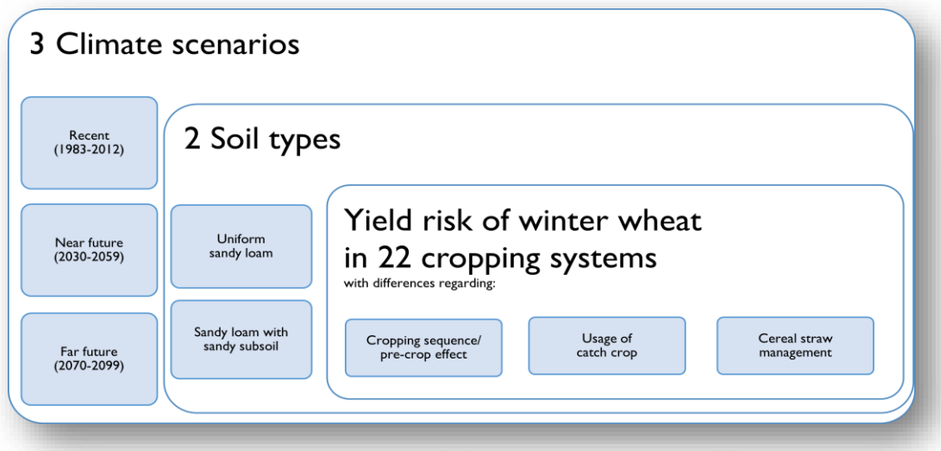
Regarding climate change, a detailed understanding of how yield risks of wheat cropping systems (CSs) will be affected by future climate is essential to ensure food security.

But most studies only focus on improving the overall yield level and neglect the yield risk of wheat CSs depending on soil type, climate and agronomic management conditions.

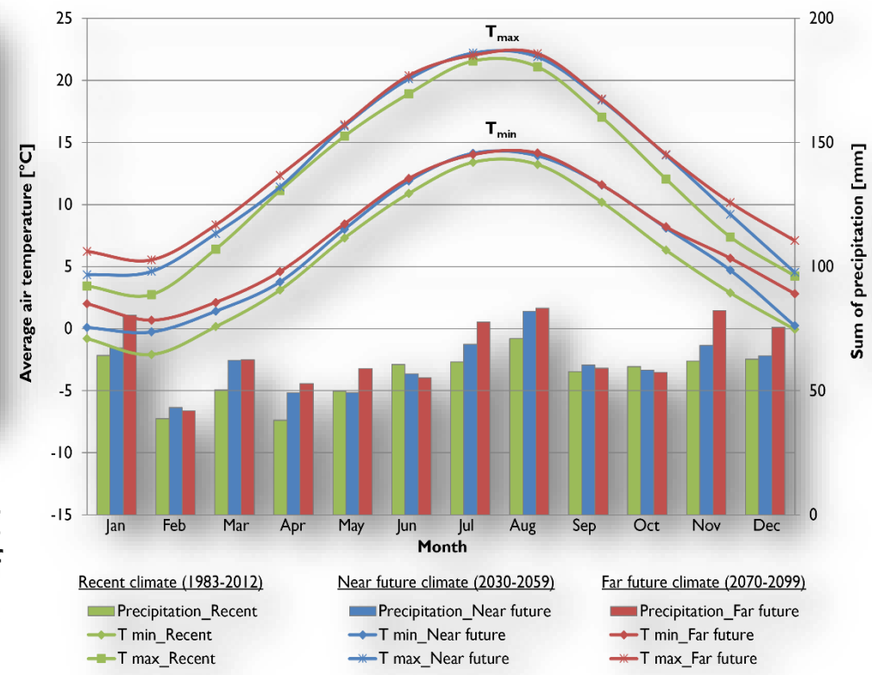
Through systems modelling, this study aims to quantify the impact of recent, near and far future climate on the yield risk of 22 wheat CSs for 2 common soil types of Eastern Denmark.

Material & methods

➔ The agro-ecosystem model DAISY was used to simulate arable, conventional cropping systems.



➔ Yield risk assessment: (1) mean yield, (2) temporal yield variability; (3) Kang`s rank-sum considering mean yield & yield variability; (4) probability of yield falling below a certain threshold. Analyses separately for each CS × climate × soil scenario.



Results

Cropping system (CS) description			CS	Yield performance of winter wheat on the sandy loam with sandy subsoil (soil type 2) depending on the climate scenario								
				Mean yield** [t/ha]			Yield variability σ^2_i			Kang's rank-sum		
Cropping sequence incl. catch crop (CC) position	Catch crop (CC)	Cereal straw management*		Recent climate	Near future climate	Far future climate	Recent climate	Near future climate	Far future climate	Recent climate	Near future climate	Far future climate
OR-WW-BY	none	removed	1	8.69 BCD a	8.53 BCE a	8.46 BC a	2.13	0.66	0.65	39	40	41
		incorporated	2	9.76 F a	9.65 FG a	9.84 F a	1.88	0.20	0.20	21	17	15
OR-WW-(CC)-BY	Winter rye	removed	3	9.27 DE a	9.20 EF a	9.29 D a	2.13	0.50	0.50	37	36	35
		incorporated	4	9.84 F a	9.75 G a	9.99 F a	1.90	0.20	0.22	21	9	9
RG-WW-BY	none	removed	5	9.47 EF a	9.48 FG a	9.40 DE a	0.50	0.18	0.32	27	18	30
		incorporated	6	9.55 EF a	9.68 FG a	9.87 F a	0.63	0.21	0.35	24	14	24
RG-WW-(CC)-BY	Oilseed radish	removed	7	9.52 EF a	9.60 FG a	9.72 EF a	0.58	0.16	0.27	26	15	24
		incorporated	8	9.53 EF a	9.67 FG a	9.88 F a	0.65	0.22	0.36	26	18	24
	Winter rye	removed	9	9.52 EF a	9.62 FG a	9.77 EF a	0.59	0.17	0.28	26	15	24
		incorporated	10	9.53 EF a	9.68 FG a	9.88 F a	0.65	0.22	0.37	28	16	24
SB-WW-BY	none	removed	11	8.11 A b	7.87 A a	7.72 A a	0.45	0.43	0.25	34	42	31
		incorporated	12	9.50 EF a	9.33 FG a	9.24 D a	0.20	0.14	0.19	14	15	19
SB-WW-(CC^1)-BY-(CC^2)	CC^1: Oilseed radish	removed	13	8.84 CD b	8.78 CDE ab	8.56 BC a	0.20	0.29	0.26	19	33	28
	CC^2: Winter rye	incorporated	14	9.60 F a	9.64 FG a	9.84 F a	0.40	0.23	0.18	15	23	11
SB-WW-(CC^1)-BY-(CC^2)	CC^1: Winter rye	removed	15	8.91 CD a	8.84 DE a	8.67 C a	0.21	0.27	0.26	19	31	26
	CC^2: Oilseed radish	incorporated	16	9.61 F a	9.64 G a	9.86 F a	0.41	0.23	0.19	15	23	12
WR-WW-BY	none	removed	17	8.24 AB a	8.16 AB a	8.17 B a	0.42	0.34	0.31	32	40	37
		incorporated	18	9.60 F a	9.66 G a	9.78 EF a	0.30	0.16	0.16	11	9	11
WR-WW-(CC)-BY	Oilseed radish	removed	19	8.40 ABC a	8.38 BC a	8.38 BC a	0.35	0.31	0.29	26	38	35
		incorporated	20	9.64 F a	9.74 G ab	9.96 F b	0.36	0.18	0.18	11	9	6
	Winter rye	removed	21	8.45 ABC a	8.45 BCE a	8.46 BC a	0.33	0.31	0.28	24	36	32
		incorporated	22	9.65 F a	9.75 G ab	9.98 F b	0.37	0.19	0.20	11	9	8
			Average across all CS	9.24	9.23	9.31	0.71	0.26	0.29			

Note: WW = Winter wheat; BY = Spring barley; Oilseed radish; OR = Oilseed winter rape; RG = Italian ryegrass; SB = Sugar beet; WR = Winter rye. *refers to straw of winter wheat and spring barley (+ winter rye in CS 17-22); **significant ($p<0.05$) differences between CS within a column are displayed by different capital letters and between climate scenarios within a row by small letters.

Cropping system (CS) description			CS	Probability of wheat yield falling a given percentage below the average yield across all CS and scenarios (δ = 9.4 t/ha)									
				Uniform sandy loam (soil type 1)						Sandy loam with sandy subsoil (soil type 2)			
				Recent climate		Near future climate		Far future climate		Recent climate		Near future climate		Far future climate	
Cropping sequence incl. catch crop (CC) position	Catch crop (CC)	Cereal straw management*		-10%	-20%	-10%	-20%	-10%	-20%	-10%	-20%	-10%	-20%	-10%	-20%
OR-WW-BY	none	removed	1	41	10	53	13	60	19	43	9	43	11	46	13
		incorporated	2	2	0	3	0	4	0	14	3	10	1	5	0
OR-WW-(CC)-BY	Winter rye	removed	3	20	3	23	4	27	5	25	6	20	4	17	3
		incorporated	4	1	0	1	0	1	0	13	2	9	1	4	0
RG-WW-BY	none	removed	5	12	2	10	1	17	3	12	2	16	4	16	3
		incorporated	6	12	3	5	0	5	0	26	10	14	3	9	2
RG-WW-(CC)-BY	Oilseed radish	removed	7	11	2	7	1	8	1	27	10	15	3	10	2
		incorporated	8	12	3	5	0	5	0	27	11	14	3	9	2
	Winter rye	removed	9	11	2	6	1	6	1	27	10	14	3	10	2
		incorporated	10	12	3	5	0	5	0	27	11	14	3	9	2
SB-WW-BY	none	removed	11	60	13	85	25	92	36	61	11	73	30	84	33
		incorporated	12	5	0	2	0	12	0	24	7	18	4	15	2
SB-WW-(CC^1)-BY-(CC^2)	CC^1: Oilseed radish	removed	13	29	3	47	5	66	10	38	12	34	9	41	8
	CC^2: Winter rye	incorporated	14	4	0	1	0	1	0	24	8	15	4	8	1
SB-WW-(CC^1)-BY-(CC^2)	CC^1: Winter rye	removed	15	25	2	40	3	58	8	36	11	31	8	35	6
	CC^2: Oilseed radish	incorporated	16	4	0	1	0	1	0	24	8	15	4	7	1
WR-WW-BY	none	removed	17	56	9	73	8	73	11	58	7	64	10	65	8
		incorporated	18	4	0	1	0	1	0	22	7	10	1	4	0
WR-WW-(CC)-BY	Oilseed radish	removed	19	45	5	57	4	60	6	54	16	49	7	49	4
		incorporated	20	4	0	1	0	1	0	22	7	9	1	4	0
	Winter rye	removed	21	41	4	51	3	54	4	51	15	45	6	43	3
		incorporated	22	4	0	1	0	1	0	22	7	9	1	4	0
			Average across all CS	19	3	22	3	25	5	31	9	25	5	23	4

Conclusion

➔ If a CS is characterized by straw removal and no catch crop within the rotation, an increased yield risk of wheat CSs must be expected in the future. In contrast, more favourable CSs, including catch crops and straw incorporation, maintain their capacity and can reduce yield risk.