

Land use optimization and sustainable agricultural intensification

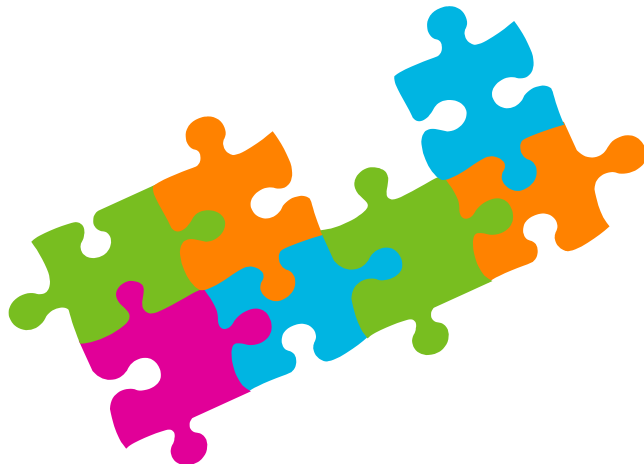
Pirjo Peltonen-Sainio
Natural Resources Institute Finland (Luke)

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- What?
- Why?
- How?
- Where?
- When?



What is going on – at global scale?

- More farming than ever in our planet
- High resource intensity (and dependency)
- High environmental footprint caused by food production

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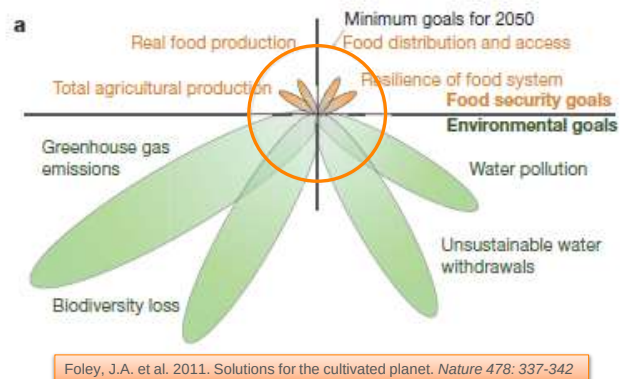
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What is going on – at global scale?



- State of current agricultural systems compared to goals for **food security** and **environment** set for 2050
- To decrease environmental footprint while increase agricultural production and security

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What is going on – at global scale?

- More farming than ever in our planet
- High resource intensity (and dependency)
- High environmental footprint caused by food production
- High share of agricultural production allocated to animals, biofuels and other non-food uses
 - ~50 % more food calories
 - Grassland, permanent pastures, natural meadows

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- One third to quarter of global production regions have undergone evident yield stagnation or decline

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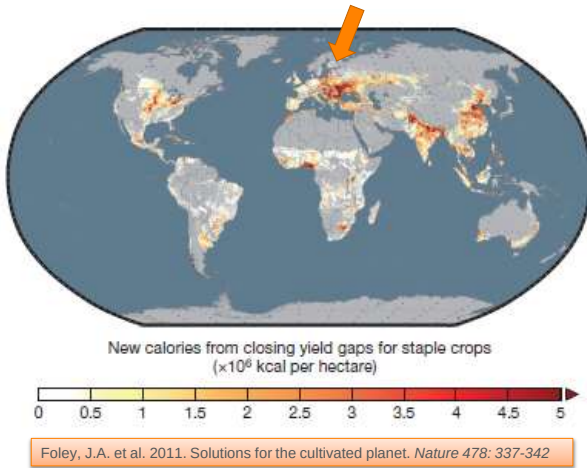
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What is going on – at global scale?



- Yield gap is the difference between potential and attained yields
- Regional differences in yield gaps are high: in Europe eastern regions exhibit high yield gaps
- 16 most important staple crops
- 58% increase in food production available by closing yield gaps

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Why to change direction?



- The Finnish agri-environmental program (AEP) has been in operation for 20 years with > 90 % farmer commitment
- AEP has been successful especially by reducing e.g. N balance
 - From 90 to 50 kg/ha already in the early phase of the AEP)

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Why to change direction?



- Many contemporary changes in agricultural practices, driven by changes in prices and farm subsidies, also including the AEP, were likely reasons, together with reduced N use, for yield stagnation or decline and adverse changes in quality in Finland
 - Lack of basic investments → ? %
 - No-tillage → in total ≤5 %
 - Monoculture → in wheat 5-10 %
 - Soil degradation → ? %
 - Organic farming → in total ~1.4 %

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Why to change direction?

Table 2 Changes in national mean yields, in genetic yield improvements, and in degree of realization of yield potentials for spring cereals. National yield improvements are given in kg and % year⁻¹. Figures for the highest yield improvement for any of the subperiods are shown in parentheses

Period	Barley	Oat	Wheat
<i>Change in national yield (kg ha⁻¹ year⁻¹)</i>			
1920–1969	24	27	20
1970–1980	30	26	28
1981–1994	60	50	76
1995–2013	7	–3	15
Whole period (kg ha ⁻¹ year ⁻¹)	27	25	29
Whole period (% year ⁻¹)	1.24 (2.05)	1.13 (1.73)	1.29 (2.52)
<i>Genetic improvement (kg year⁻¹)</i>			
1970–1980	28	5	49
1981–1994	37	25	33
1995–2013	68	29	63
Whole period	50	23	51
<i>Change in realized yield potential (±% unit year⁻¹)</i>			
1970–1980	0.26	0.65	–0.94
1981–1994	0.78	0.72	1.28
1995–2013	–0.68	–0.62	–0.41
Whole period	0.04	0.12	0.09

Pelttonen-Sainio, P., Salo, T., Jauhainen, L., Lehtonen, H. & Sieviläinen, E. 2015. Static yields and quality issues: Is the agri-environment program the primary driver? *AMBIO*, DOI: 10.1007/s13280-015-0637-9

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Why to change direction?

Table 5 The average grain weight and hectoliter weight for different soil types and time periods. Total number of fields analysed was 37 577.

Cereal	Period	Grain weight (mg)				P value	Hectoliter weight (kg)				P value		
		Clay	Sand	Organic	Mean		Clay	Sand	Organic	Mean			
Malting barley	1988–1994	45.1	43.7	43.8	44.2	Period	<0.001	70.3	70.1	69.6	70.0	Period	<0.001
	1995–2005	39.6	39.1	38.1	38.9	Soil	<0.001	67.0	67.0	66.0	66.7	Soil	0.03
	2006–2012	40.1	38.6	39.7	39.5	$P \times S$	>0.08	66.4	66.2	66.1	66.2	$P \times S$	>0.7
	Change 1	-5.5	-4.6	-5.7	-5.3	Change 1	<0.001	-3.3	-3.1	-3.6	-3.3	Change 1	<0.001
	Change 2	-7.0	-8.1	-4.1	-4.8	Change 2	<0.001	-3.9	-3.9	-3.5	-3.8	Change 2	<0.001
Feed barley	1988–1994	40.9	40.0	39.9	40.3	Period	<0.001	66.4	65.9	65.0	65.8	Period	<0.001
	1995–2005	37.5	37.0	36.6	37.0	Soil	<0.001	64.7	64.0	63.4	63.9	Soil	<0.001
	2006–2012	37.6	37.2	37.6	37.5	$P \times S$	>0.1	64.0	63.9	63.1	63.6	$P \times S$	>0.2
	Change 1	-3.4	-3.0	-3.3	-3.3	Change 1	<0.001	-2.2	-1.9	-1.6	-1.9	Change 1	<0.001
	Change 2	-3.3	-2.8	-2.3	-2.8	Change 2	<0.001	-2.4	-2.0	-1.9	-2.1	Change 2	<0.001
Oat	1988–1994	33.4	33.4	32.9	33.2	Period	<0.001	55.0	55.6	55.3	55.6	Period	<0.001
	1995–2005	32.7	32.5	32.3	32.5	Soil	<0.001	55.6	55.2	55.0	55.2	Soil	<0.001
	2006–2012	32.7	32.7	32.4	32.6	$P \times S$	>0.6	56.0	55.5	54.8	55.4	$P \times S$	>0.1
	Change 1	-0.7	-0.9	-0.6	-0.7	Change 1	<0.001	-0.3	-0.4	-0.3	-0.4	Change 1	<0.001
	Change 2	-0.7	-0.7	-0.5	-0.6	Change 2	<0.001						
Wheat	1988–1994	37.1	36.5	36.8	36.8	Period	<0.001	80.1	79.1	78.8	79.3	Period	<0.001
	1995–2005	34.7	34.9	34.4	34.7	Soil	<0.001	78.4	78.6	78.2	78.4	Soil	<0.001
	2006–2012	33.8	33.1	31.6	32.8	$P \times S$	<0.001	78.4	78.5	77.9	78.2	$P \times S$	<0.001
	Change 1	-2.4	-1.6	-2.4	-2.2	Change 1	<0.001	-1.7	-0.5	-0.6	-1.0	Change 1	<0.001
	Change 2	-3.5	-3.4	-5.2	-4.0	Change 2	<0.001	-1.7	-0.8	-0.9	-1.1	Change 2	<0.001

Change 1 indicates change in a trait from 1988–1994 to 1995–2005 period while Change 2 that from 1988–1994 to 2006–2012. Only significant changes are shown

Peltonen-Sainio, P., Salo, T., Jauhainen, L., Lehtonen, H. & Sieväläinen, E. 2015. Static yields and quality issues: Is the agri-environment program the primary driver? *AMBIO*, DOI: 10.1007/s13280-015-0637-9

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Why to change direction?

Table 7 Differences between crops and cultivars in yield-removed nitrogen (YRN) and residual nitrogen (ReN) and changes in time according to data from farmers' fields during 1988–2010 (data from Evira). Total number of fields analyzed was 31 406. S.E., standard error of the mean

Crop	Mean	SE	P value	Variation between cultivars*			Period**				
				Minimum	Maximum	s.d.	1988–1994	1994–2005	2006–2010	Change 1	Change 2
YRN (%)											
Malting barley	0.76	0.022	<0.001	0.73	0.79	0.02	0.73	0.76	0.80	–	–
Feed barley	0.78	0.027	<0.01	0.54	1.14	0.10	0.76	0.80	0.86	–	0.10
Oat	0.84	0.022	mC	0.76	0.98	0.05	0.79	0.83	0.88	–	0.09
Wheat	0.79	0.025	<0.01	0.63	1.02	0.07	0.74	0.82	0.84	0.09	0.10
ReN (kg ha ^{–1})											
Malting barley	25.7	2.14	<0.001	24.4	26.6	0.9	30	24	21	–	–9
Feed barley	23.4	2.63	<0.01	–7.2	43.4	9.5	27	21	17	–	–10
Oat	18.1	2.21	mC	7.2	27.8	4.8	22	18	14	–4	–8
Wheat	27.2	2.47	<0.001	9.5	38.8	7.1	35	22	20	–13	–15

* For YRN between cultivars $F_{3,313} = 24.79$, $P < 0.001$; for ReN $F_{3,313} = 27.51$, $P < 0.001$

** For YRN P values were <0.001 for crops, 0.18 for periods, and 0.01 for crop-period interaction, while for ReN, they all were <0.0001. Change 1 indicates change in a trait from 1988–1994 to 1995–2005 period while Change 2 that from 1988–1994 to 2006–2010. Dot indicates nonsignificant change

Peltonen-Sainio, P., Salo, T., Jauhainen, L., Lehtonen, H. & Sieväläinen, E. 2015. Static yields and quality issues: Is the agri-environment program the primary driver? *AMBIO*, DOI: 10.1007/s13280-015-0637-9

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Why to change direction?



- We do not need to be content with such trade-offs
- Instead we need to further develop the future AEPs to ensure that the changes are environmentally, economically and socially sustainable, and acceptable
- The concept of sustainable intensification is worth considering as a means to develop northern European agricultural systems to combine environmental benefits with productivity

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What is going on – at global scale?

- More farming than ever in our planet
- High resource intensity (and dependency)
- High environmental footprint caused by food production
- High share of agricultural production allocated to animals, biofuels and other non-food uses
- One third to quarter of global production regions have undergone evident yield stagnation or decline

Not only a question of agricultural production *per se*:

- Uneven distribution of goods
- High share of waste production at different steps of food chain
- High standard of living and wasteful lifestyle
- Low standard of living and high post-harvest losses

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Why to change direction?

Agriculture and food system that it underpins are at the crossroads: we have evidenced that

- ...the growth trends of the yields of major crops have stagnated or declined
- ...food insecurity has increased
 - shocks, changes in vulnerability of systems and lack of democracy
 - actions have been insufficient to overcome the chronic food and nutrition security problems - to achieve the hunger reduction goals
- We have a serious dilemma in maintaining high production capacity without environmental sacrifices
- "Business as usual" is not an option - what is?

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Why sustainable intensification?

- Feeding the rising world population – almost a billion more hungry people
- Avoiding forest clearance to get more arable land for food production
- Meeting all the interplaying challenges by:
 - Population growth and high demand for feed due to increase in standard of living in high income regions
 - Increasing demand for balanced production of crop based protein feed
 - Arable land used to production of bioenergy
 - Climate change, extreme events, increased vulnerability and

Conflict with the need to enhance global food availability by 100-180% without further endangering planetary bearing capacity

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- Meeting all the interplaying challenges caused by:
 - Population growth and higher demand for feed due to increase in standard of living in highly populated regions
 - Increasing demand and unbalanced production of crop based protein feed
 - Arable land devoted to production of bioenergy
 - Climate change, extreme events, increased vulnerability and volatility

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How?

- By reducing yield gaps
- By halting agricultural expansion
- By increasing agricultural resource use efficiency
- By diversifying cropping systems and benefitting from ecosystem services that more diverse systems provide
- By gaining environmental benefits without sacrificing productivity
- By increasing food delivery
- By shifting diets
- By reducing waste, increasing recycling
- By adapting to, mitigating and improving resilience to climate change

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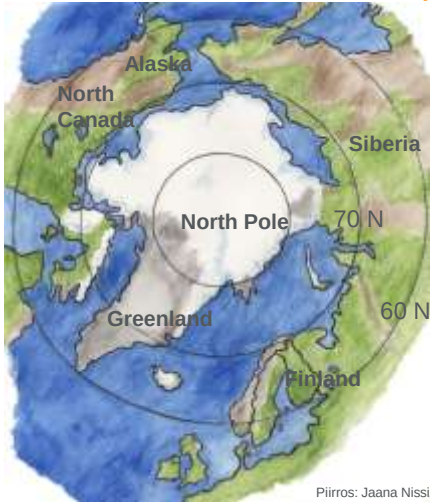
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Where?



- Finland – a pilot region and test-bed?
 - High yield gaps
 - Agri-environment program
 - Potential for higher agricultural production in a changing climate
 - Potential for more diverse crop production in a changing climate

Peltonen-Sainio, P., Rajala, A., Känkänen, H. & Hakala, K. 2014. Improving farming systems in northern European conditions. In: Edited by Victor O. Sadras & D. Calderini. Crop Physiology: Applications for Genetic Improvement and Agronomy, pp. 65-91.

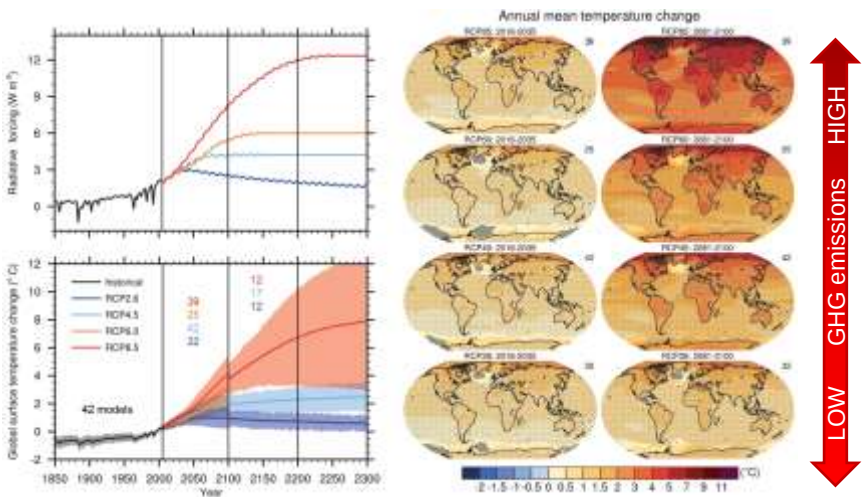
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Where?



International Panel on Climate Change, IPCC. 2013. Fifth Assessment Report (AR5). Technical report. <http://www.ipcc.ch/report/ar5/>

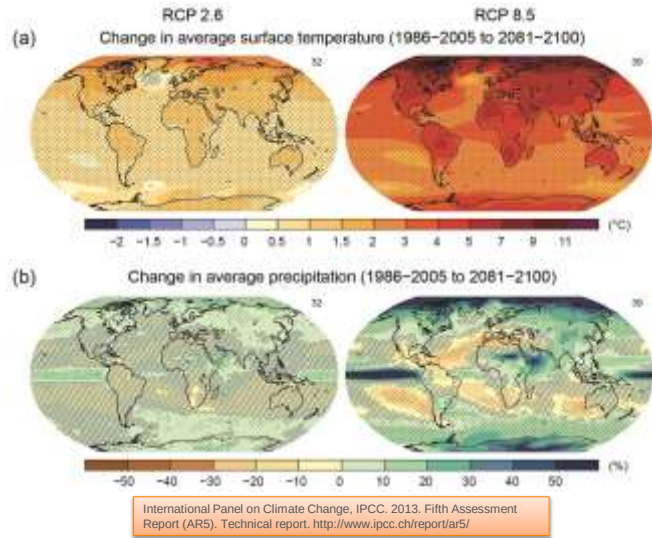
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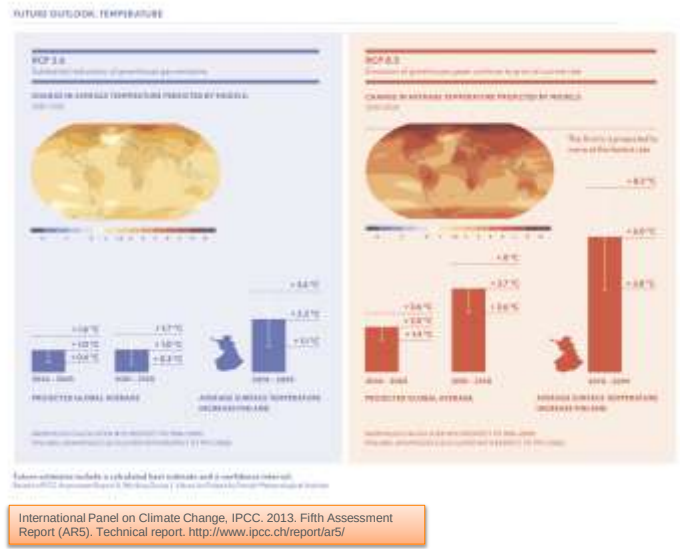
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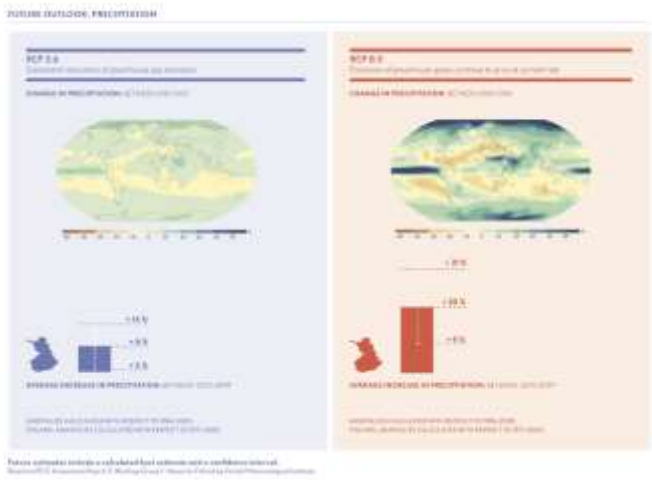
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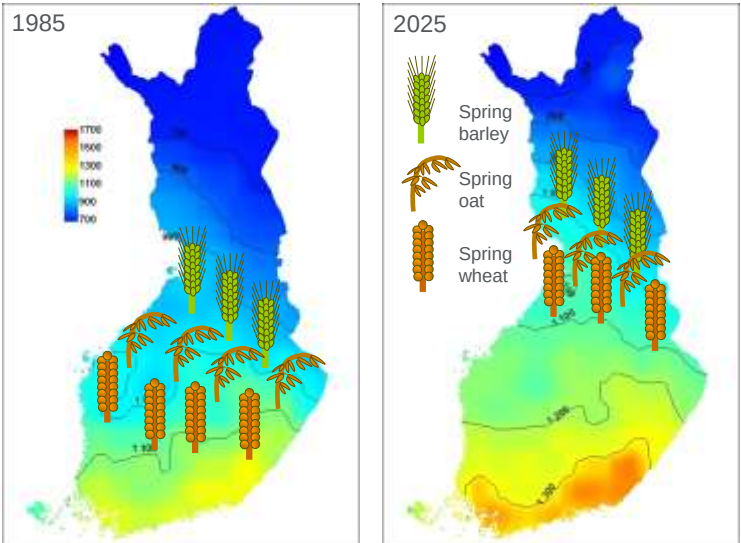


International Panel on Climate Change, IPCC. 2013. Fifth Assessment Report (AR5). Technical report. <http://www.ipcc.ch/report/ar5/>

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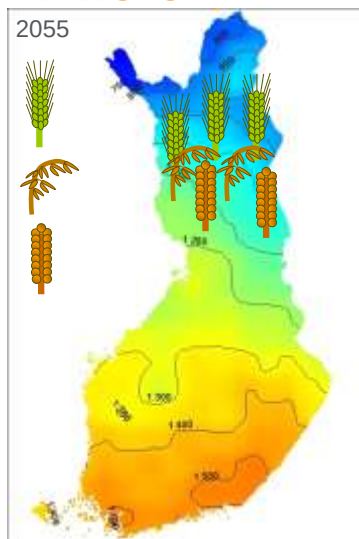


19 climatic models, Finnish Meteorological Institute (± 15 years)
Peltonen-Sainio, P., Jauhainen, L., Hakala, K., Ojanen, H., 2009. Climate change and prolongation of growing season: changes in regional potential for field crop production in Finland. *Agricultural and Food Science* 18: 171–190.

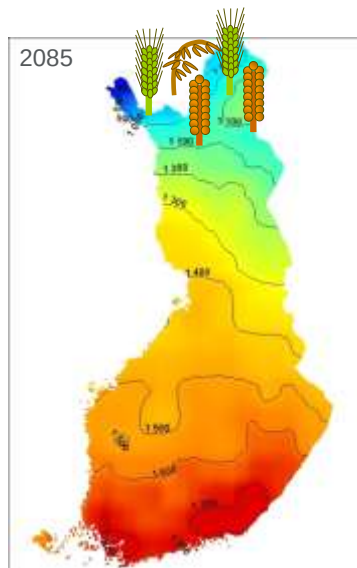
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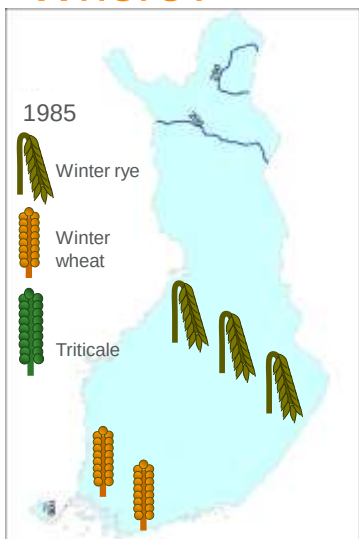
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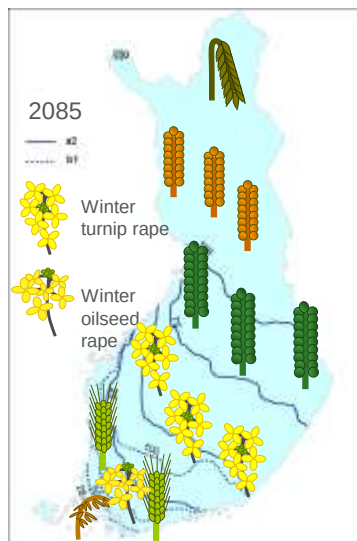
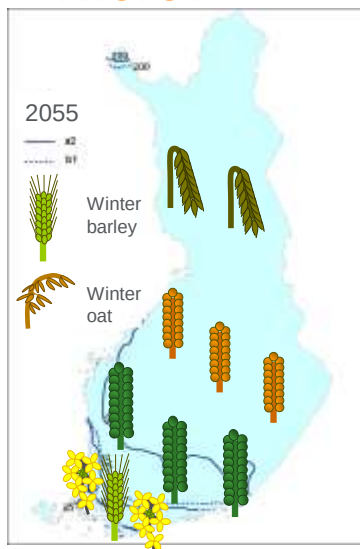
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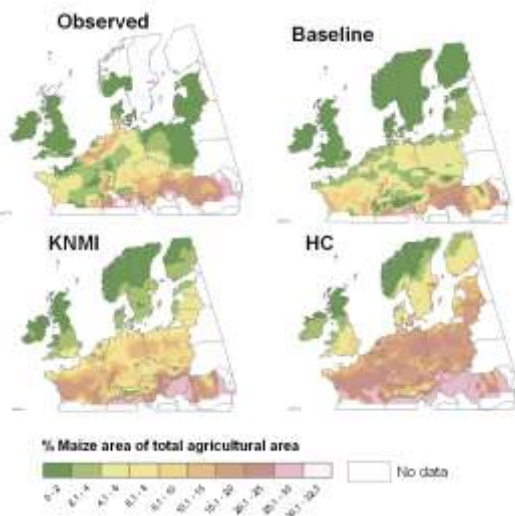
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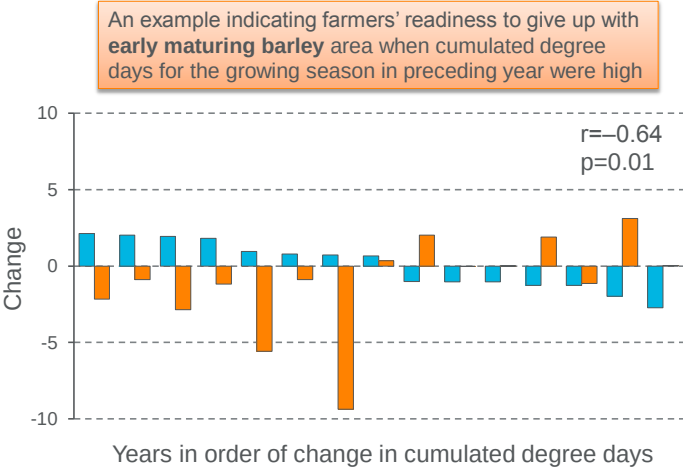
Elsgaard, I., Börgesen, C.D., Olesen, J.E., Siebert, S., Ewert, F., Peltonen-Sainio, P., Rötter, R. & Skjelvåg, A. 2012. Shifts in comparative advantages for maize, oat and wheat cropping under climate change in Europe. *Food Additives and Contaminants, Part A* 29: 1514-1526.



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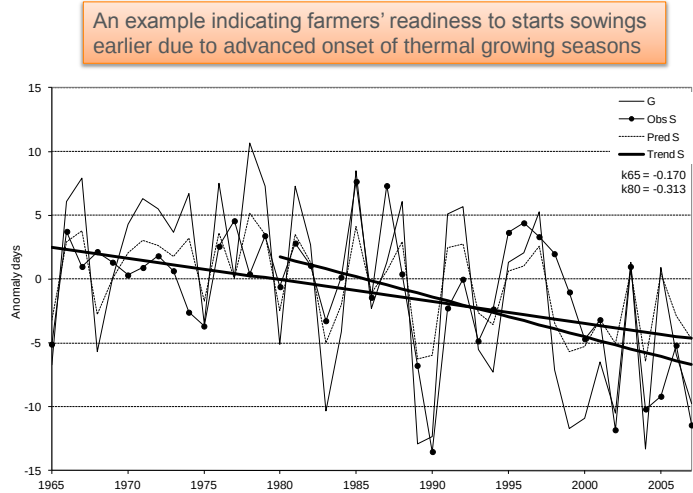


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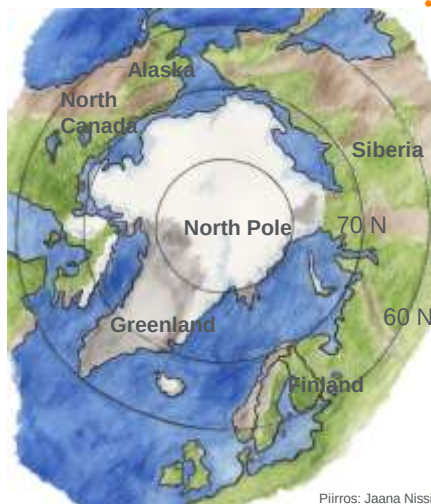
Peltonen-Sainio, P., Jauhainen, L., Nieminen, J.K., Hakala, K. & Sipiläinen, T. 2013. Do farmers rapidly adapt to past growing conditions by sowing different proportions of early and late maturing cereals and cultivars? *Agricultural and Food Science* 22: 331-341.

Where?



Kaukoranta, T., Hakala, K. 2008. Impact of spring warming on sowing times of cereal, potato and sugar beet in Finland. *Agricultural and Food Science* 17: 165-176.

Where?



Piirros: Jaana Nissi/MTT

Peltonen-Sainio, P., Rajala, A., Känkänen, H. & Hakala, K. 2014. Improving farming systems in northern European conditions. In: Edited by Victor O. Sadras & D. Calderini. *Crop Physiology: Applications for Genetic Improvement and Agronomy*, pp. 65-91.

Finland – a pilot region and test-bed?

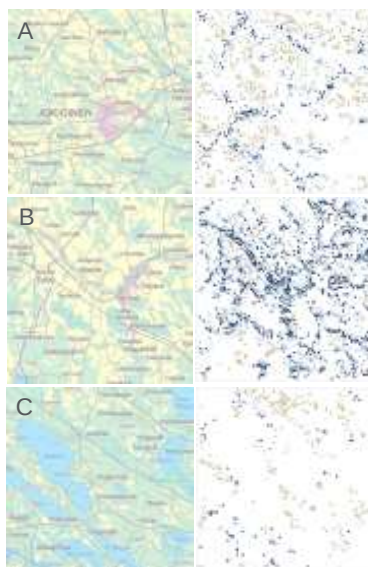
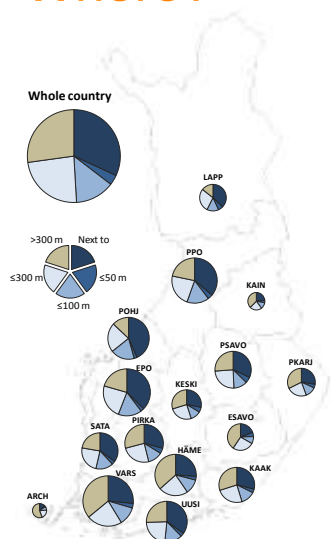
- High yield gaps
- Agri-environment program
- Potential for higher agricultural production in a changing climate
- Potential for more diverse crop production in a changing climate
- Potential for large-scale land use planning and optimization
- Valuable ecosystem services, natural handicaps and vulnerable environment

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Where?



Peltonen-Sainio, P., Laurila, H., Jauhainen, L. & Alakukku, L. 2015. Proximity of waterways to Finnish farmlands and associated characteristics of regional land use. *Agricultural and Food Science*, in press.

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How?

- By better combining **plant breeding** induced opportunities with developments available for crop management and cropping systems
 - Improved resistance or tolerance against diseases, pests, weeds
 - Means to extend the lifespan of resistance
 - Improved resource use efficiencies (nutrients, water)
 - Improved crop robustness
 - ... breeding for resilience

How?

- By better combining plant breeding induced opportunities with developments available for **crop management and cropping systems**
 - Diversified cropping systems
 - Rotations (crops), cultivars, intercrops
 - Land sparing and land sharing: **Fields with high, but presently underutilized production capacity to be sustainably intensified, whilst low productive, poorly responsive fields in vulnerable environments to be extensified**
 - Better integration of crop and animal farms
 - Also efficient utilization of manure, recycled nutrients
 - Water management systems
 - Information and communication technologies (ICT)...

When?

- Sustainable intensification is an on-going, gradually progressing process but we need to set the targets and move from crop and plant stand level to system level
- Depends on timing of outcomes and breakthroughs from plant breeding and technological development processes
 - Low-hanging-fruits available
- High yield-gap regions is “in the vanguard of the movement”
 - Lessons to learn and adapt by other regions
- By this means we can aspire for significant future improvements in resilience, environmental footprint and biodiversity

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Summary

- Food production is next to the major turning point
- We see lots of potential in these northernmost European regions to
 - cope with manifold challenges and changes
 - rethink how to manage our agricultural systems
 - close yield gaps and gain environmental benefits

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Summary

- Food production is next to the major turning point
- We see lots of potential in these northernmost European regions to
 - cope with manifold challenges and changes
 - rethink how to manage our agricultural systems
 - close yield gaps and gain environmental benefits
 - find a whole new inspiration for joint efforts aiming to secure healthy food in the future

A large, vibrant green leaf with prominent veins, partially obscured by a white circular shape, serves as the background for the "Thank you!" text.

Thank you!