Incentivising for climate change mitigation in the context of adaptation to climate and market changes at the farm level in North Savo region

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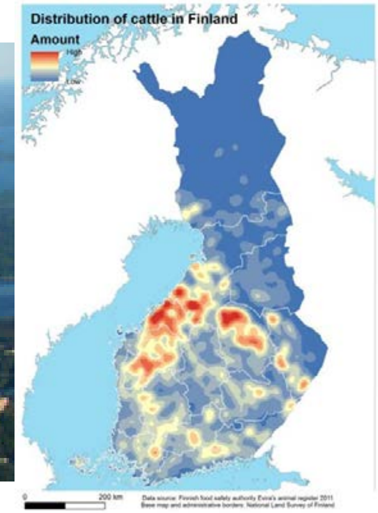
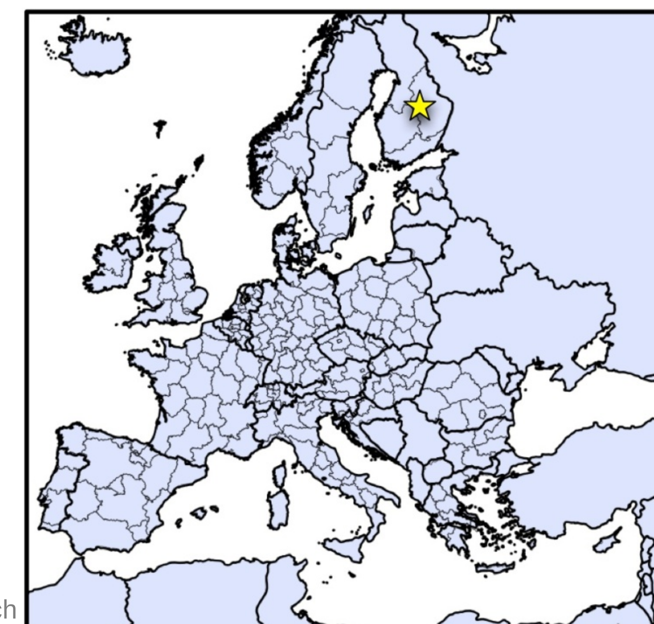
Agenda

- Introduction of pilot region – Northern Savo region in Finland
- Research purpose and description of the research
- Dynamic economic optimization model
- Specification of parametres and settings
- Simulation results
- Conclusion

Introduction: Basic facts on North Savo region



Total area 20 367 km2, 17.5% under water, beachline length 17000 km,
Population density 14.8 persons/km2 (Finland average 17.7)
247000 inhabitants (2010)
148000 ha farmland (8.8% of land area)
4200 farms
38000 dairy cows (10% out of whole Finland)
Income/cap: 17000 eur (Finland average 18800 eur 2010)
http://www.pohjois-savo.fi/fi/pohjois-savo/



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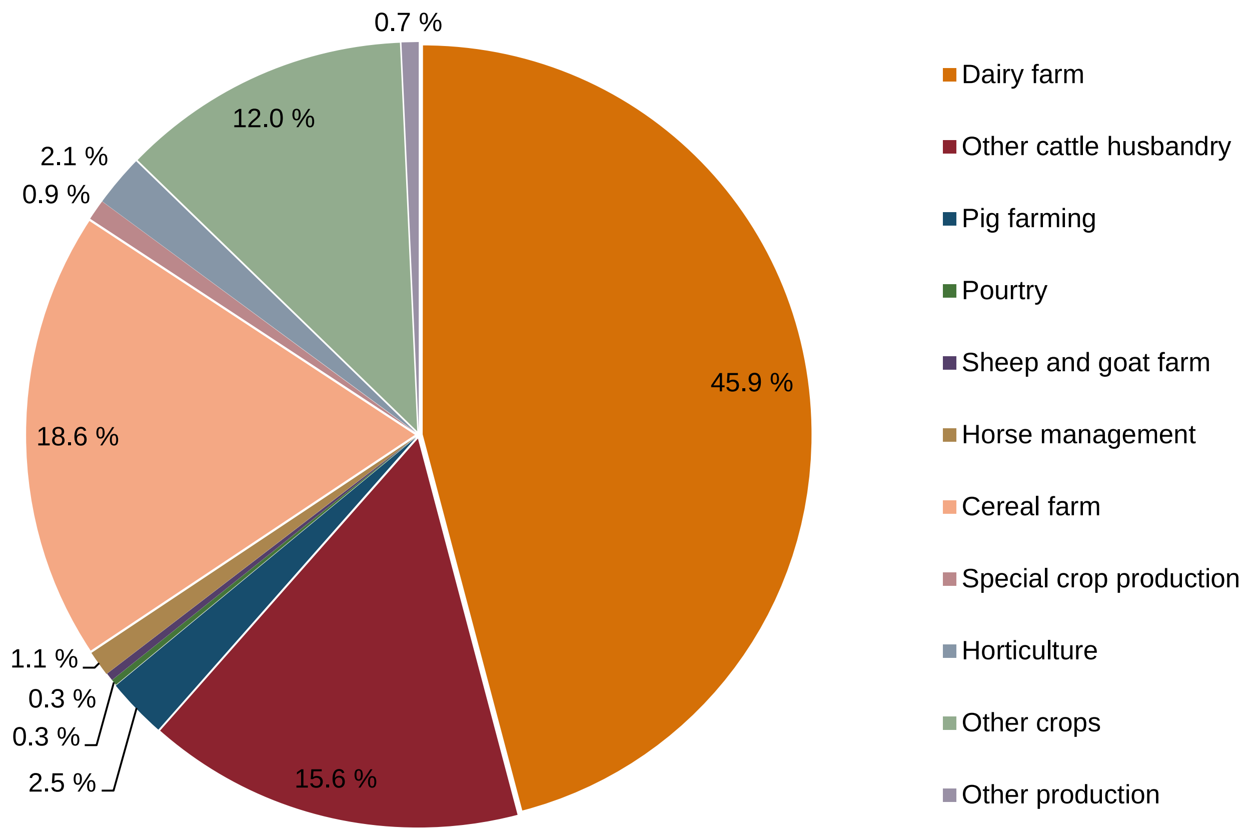
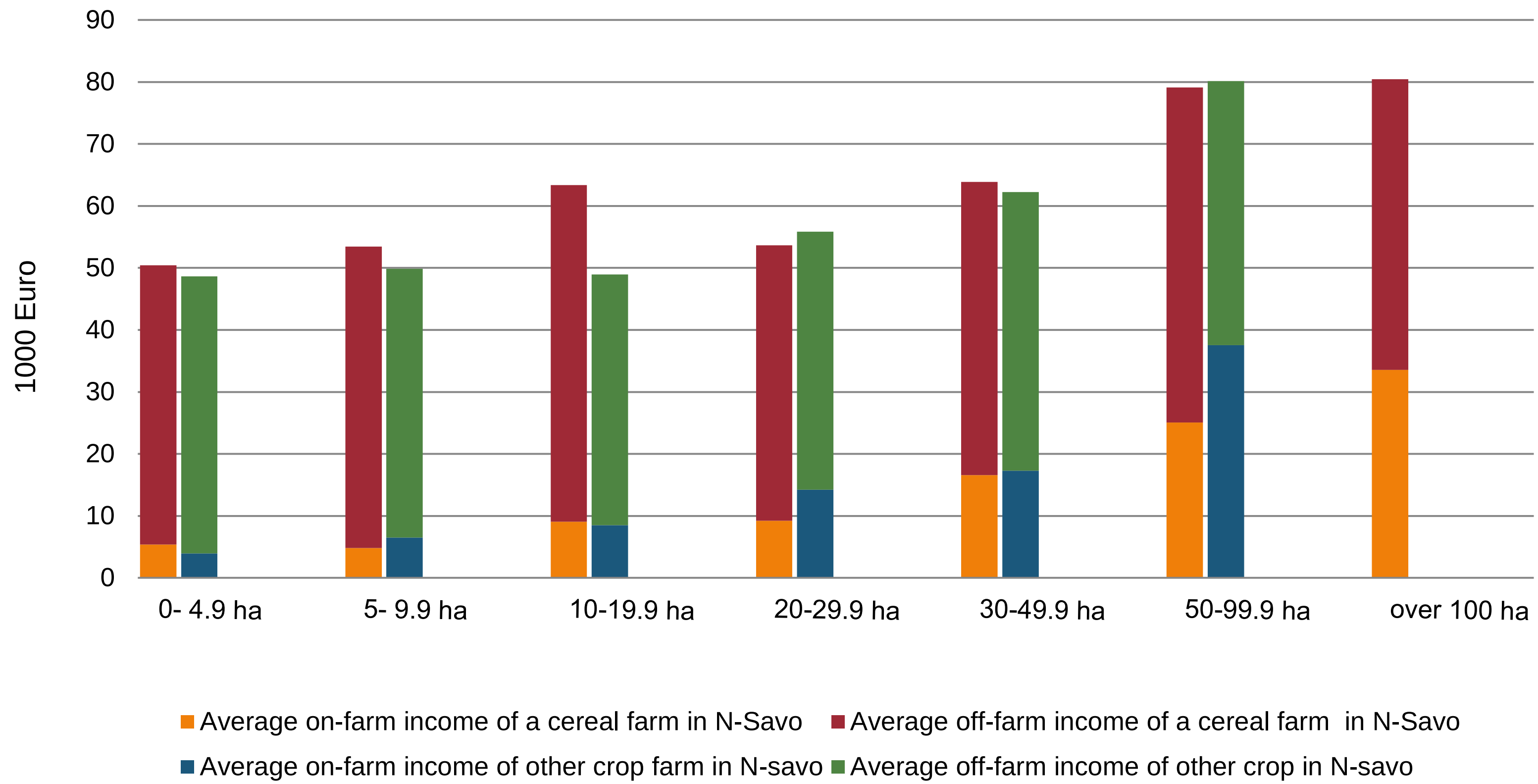
Land use in North Savo farm types



Introduction (Cont.): Income from on-farm and off farm in Northern Savo region in 2010



Research purpose and description of the research

- Crop rotation has various benefits in comparison to monocropping such as:
  - improve or maintain crop yield, soil structure
  - reduce the risk and extend of flooding, and soil trafficability in wet conditions
  - promote a more diverse ecosystem
  - reduce reliance on a chemical approach to pest management
- The objective of this study is to evaluate how adaptation to climate change, as well as the mitigation of greenhouse gases, may realise at two different farm types
  - Crop farms selected because they have better possibilities for GHG abatement, especially on organic soils, than dairy farms in the North Savo region
  - Can we expect ”easy and cheap” GHG mitigation, without sacrificing adaptation?

- METHOD: Apply dynamic economic model of crop rotation on Finnish pilot region – Northern Savo to evaluate adaptation measures in inter-temporal decision-making at farm level, for the next 30 years
  - under different market and policy conditions
  - with key adaptation mechanism at the farm level, e.g. fungicide and liming practices
  - risk aversion behaviour considered
  - with different parcel locations in a farm, implying logistic costs
  - with selected two farm types (e.g. specialised cereal farm, other crop farm)
  - organic soil parcels taken explicitly into consideration

Dynamic Economic Optimization Model

Objective:

Find optimal sequence of crops, which can be grown in rotation during H period of years, i. e. $A(p,t,c)$ for all crops *c*, parcels *p* and years *t*. If profit maximizing producers are risk neutral ones, the objective function is

$$\underset{A(p,t,c)}{Max}\sum_{t=1}^{H}\sum_{p=1}^{10}\sum_{i=1}^{M}e^{-rt}\left(Y\left(A(p,t,c^{i}),p,t,c^{i}\right)A(p,t,c^{i})P(c^{i})+A(.)S(c^{i})-A(.)C(p,t,c^{i})\right), \qquad (1)$$

Otherwise, the function adds additional part that includes the risk-averse parameter and variance-covariance matrix of total gross margin (*X*). Consequently, decision-making of farmers not only consider the mean payoff, but are also sensitive to risk, that is the variability of the payoff.

$$Max\sum_{t=1}^{H}\sum_{p}^{10}\sum_{i=1}^{M}e^{-rt}\left(Y\left(A(p,t,c),p,t,c\right)A(p,t,c)P(c)+A(.)S(c)-A(.)C(c)\right)-\Phi\sum_{t-1}^{H}\sum_{c}\sum_{c2}e^{-rt}A'XA \qquad (2)$$

where

$$\sum_{\forall c}A(p,t,c)=1,$$

$$Y(A(p,t,c),p,t,c)=Y_{MEAN}(p,c)(1-Y_{RED}(p,t,c)),$$

$$Y_{RED}(p,t,c)=\sum_{\tau=1}^{5}\sum_{\forall c_2}A(p,t-\tau,c_2)(1-T(c,c_2))^{\tau}).$$

Dynamic Economic Optimization Model (Cont.) – Nitrogen response and other management options

- Nitrogen response function

$$Y_m(N) = m(1 - ke^{-bN}) \quad (2)$$

$$Y_q(N) = a + bN + cN^2 \quad (3)$$

- Adaptation practices
  - Fungicide treatment for barley
  - Liming for all selected parcels

$$Y(A(p,t,c^i) = \begin{cases} Y_{MEAN}(p,c^i)Y_{RED}(p,t,c^i)(1+LF(p,t)+F(p,t,c^i)-lD(c^i)) & if \quad i = barley \\ Y_{MEAN}(p,c^i)Y_{RED}(p,t,c^i)(1+LF(p,t)) & if \quad i = other\ than \quad barley \end{cases} \quad (4)$$

$$LF(p,t) = \alpha_{lc}(SPH(p,t) + L(pH\_incr)) \quad (5)$$

$$F(p,t,c^i) = \sum_{j=1}^{\gamma} \beta_j K_j(p,t,c^i) \quad (6)$$

$$D(p,t,c^i) = \sum_{j}^{\gamma} K_j(c^i) \quad (7)$$

Data and scenario settings:

- Average crops yields are aggregated from Statistics Finland
- Crop prices, subsidies, variable costs aggregated from Dremfia (Lehtonen, 2013)
- 10 parcels are set, in which one of parcel is under organic soil
- The distance from each parcel to the farm centre varies between 0-7km – average distance 3 km
  - Average distance 2.9 km in the region
- The location of the organic soil is 3 km from the compound
- Two farm types are chosen: “Specialized cereal farms” and “Other crop farms”
- Higher production cost, labour cost, but lower risk aversion on other crop farms, compared to specialised farm

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Data and scenario settings (Cont.) – Validation of disease pressure matrix

Crops	Spring wheat	Winter wheat	Barley	Oats	Hay	Oilseed	Set-aside	NMF
Spring wheat	0.99	0.99	0.99	0.995	1.00	1.00	1.00	1.00
Winter wheat	0.99	0.99	0.99	0.995	1.00	1.00	1.00	1.00
Barley	0.99	0.99	0.99	0.995	1.00	1.00	1.00	1.00
Oats	0.995	0.995	0.995	0.99	1.00	1.00	1.00	1.00
Hay	1.00	1.00	1.00	1.00	0.99	1.00	1.00	1.00
Oilseed	1.00	1.00	1.00	1.00	1.00	0.70	1.00	1.00
Set-aside	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
NMF	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

- Calibrated from reports of Finnish crop protection society (Kasvinsuojeluseura) and expert judgement (MTT crop experts views based on long-term field trial experiments, consulted in various projects)
  - ✓Cereals have many common diseases
  - ✓Values are based on suitability of crops in rotation with other crops:
    - -Main diseases, their occurrence and harmfulness
    - -Role of crops for different diseases (host, non-host, maintaining)
    - -Current and future (expected) disease pressure
- Carry-over effect of yield loss due to monoculture could affect five years

Data and scenario settings (Cont.) – Validation of degree of risk aversion

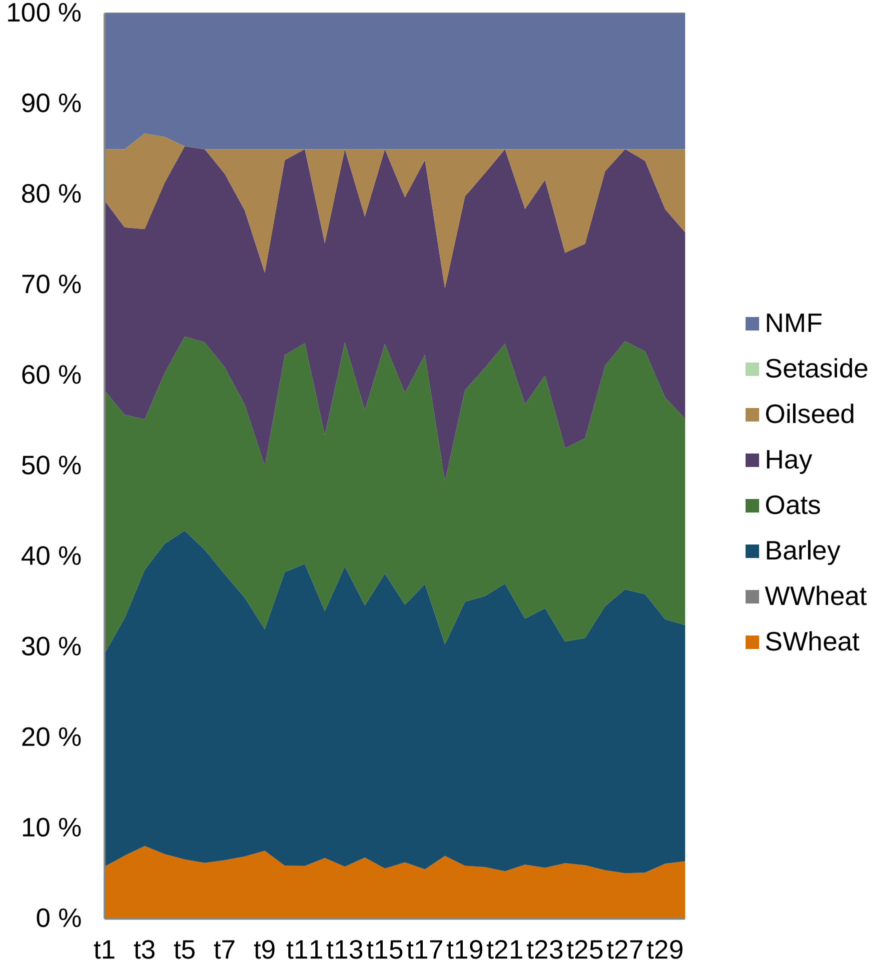
- We replicate average land use by our model for the two farm types with current price setting and under current disease pressure
- Risk aversion parameters act as an fitting factors, with which we can produce corresponding simulated land uses
- We compare these simulated land uses with the observed land use (2008-2013) at the two different farm types
- The risk aversion parameters providing the best fit of the simulated land uses with respect to the observed land uses are chosen for the further simulation under future price settings.

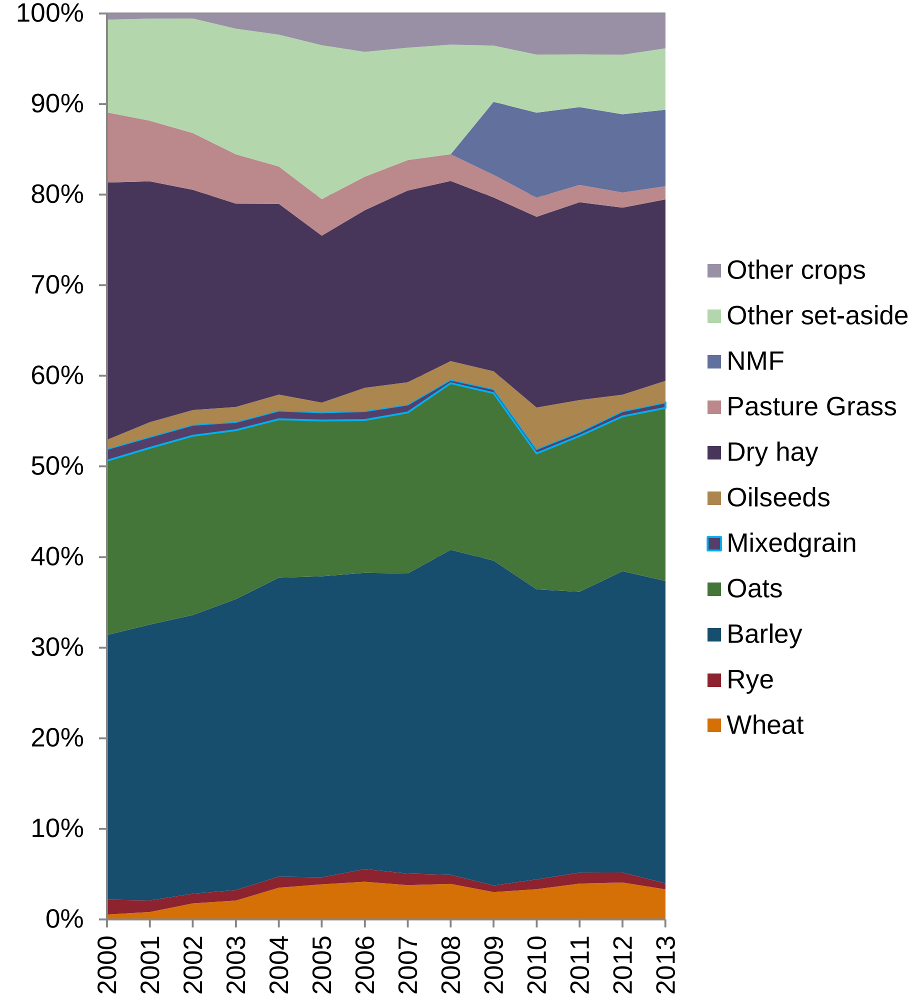
Data and scenario settings (Cont.) – Validation of risk aversion parameters for two types of farms

Cereal Farm	θ =0	θ =0.005	θ =0.01	θ =0.015	θ =0.017	θ =0.02	θ =0.021	θ =0.022	observed
SWheat	0.19	0.31	0.29	0.13	0.09	0.06	0.05	0.04	0.04
WWheat									
Barley		0.19	0.23	0.28	0.28	0.29	0.28	0.28	0.33
Oats		0.27	0.25	0.12	0.18	0.23	0.27	0.29	0.18
Oilseed				0.05	0.05	0.05	0.05	0.05	0.03
Hay	0.81	0.12	0.13	0.27	0.25	0.21	0.20	0.20	0.22
Setaside									0.06
NMF		0.11	0.10	0.15	0.15	0.15	0.15	0.15	0.09
RMSD	0.2735	0.1319	0.1159	0.0642	0.0511	0.0494	0.0574	0.0627	-

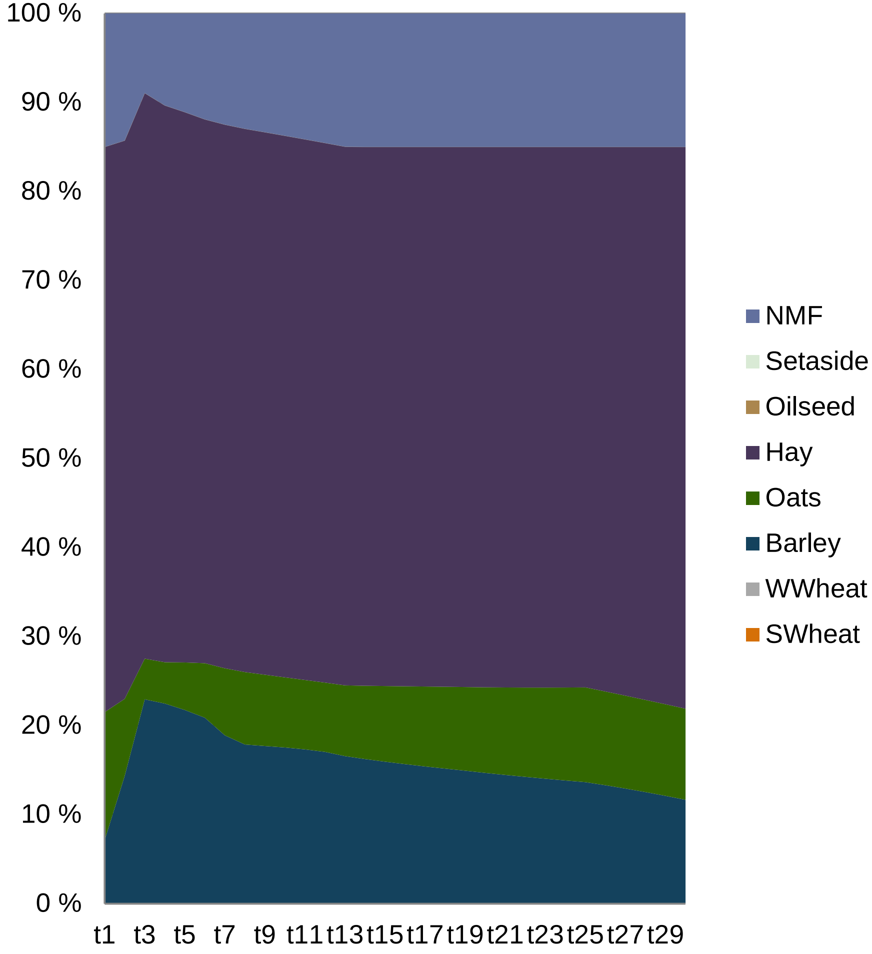
Other crop farm	θ =0	θ =0.005	θ =0.01	θ =0.015	θ =0.0165	θ =0.017	θ =0.0175	observed
SWheat	0.19							0.01
WWheat								0
Barley			0.04	0.18	0.16	0.16	0.14	0.11
Oats				0.03	0.09	0.10	0.13	0.08
Oilseed								0.01
Hay	0.81	1.00	0.95	0.67	0.61	0.60	0.58	0.59
Setaside								0.04
NMF			0.01	0.12	0.14	0.14	0.15	0.07
RMSD	0.1240	0.1667	0.1468	0.0534	0.0399	0.0401	0.0429	-

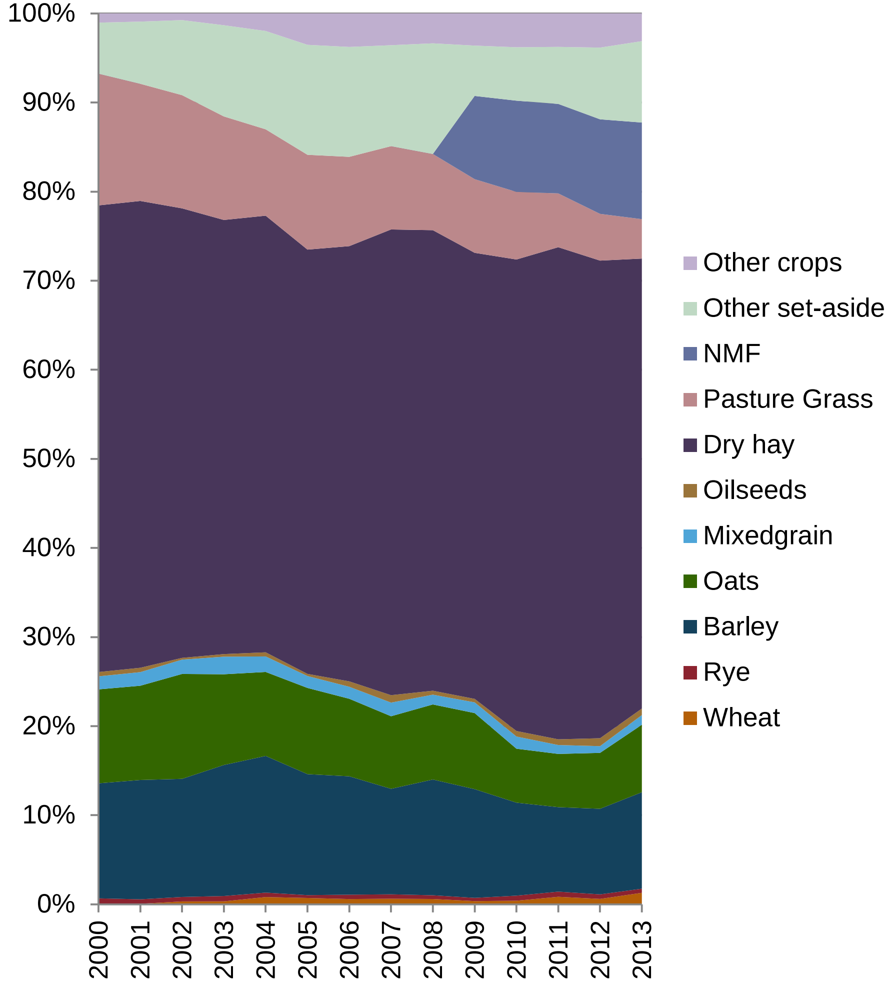
Simulated (low disease pressure, median price, left) land use over 30 years vs observed land use (right) on cereals farms in North Savo region Finland 2000-2013





Simulated land use over 30 years vs observed land use on other crop farms in North Savo region Finland 2000-2013





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Result 1: Three scenarios for two farm types

Simulated average yields, profit , pH value and times of fungicide usage over the next 30 years under chosen scenario settings of crop prices with **current** disease pressure setting

		Specialized cereals farm θ = 0.02			Other crop farm θ = 0.0165		
		LP	MP	HP	LP	MP	HP
Average Yields	Spring wheat [3068]	2670 (-14.5%)	3190 (3.8%)	3364 (8.8%)	-	-	-
	Winter wheat [3066]	-	-	-	-	-	-
	Barley [3000]	2555 (-17.4%)	2958 (-1.6%)	3203 (7.9%)	2704 (-9.9%)	2942 (-1.9%)	3207 (6.9%)
	Oats [2786]	2469 (-12.9%)	2898 (3.9%)	3034 (8.2%)	2538 (-8.9%)	2855 (2.5%)	3036 (9.0%)
	Hay [3615]	3191 (-13.3%)	3795 (4.7%)	3963 (8.8%)	3138 (-13.2%)	3634 (0.5%)	3886 (7.5%)
	Oilseed [1305]	1106 (-18%)	1368 (4.6%)	1452 (10%)	-	-	-
Share of fungicide treated barley		0	0	116	0	0	97
Average pH		5.59	6.50	6.63	5.59	6.28	6.61
GHG emissions overall tons /year (normalized 10 ha)		23.49	28.75	31.52	16.90	22.00	24.34
GHG emission from organic soils (normalized 1 ha) /year		18.21	19.30	19.34	15.60	17.01	17.07

Note: [*] show the actual average yields in Northern Savo of Finland 1995–2012 . LP: Low price; MP: Moderate price; HP: High price

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Result 2. Simulated premium paid to prevent cultivation on the organic soils, in the 3 price scenarios

	Specialized farm type			Other crop farm		
	LP	MP	HP	LP	MP	HP
Premium needed €/ha[a)]	150	280	300	45	120	210
GHG emission overall tons CO_2 eq. /year(normalized 10 ha)	20.14	24.58	27.41	16.26	20.29	22.00
CO_2 eq. from organic soils (normalized per 1 ha/year)	15.03	15.03	15.69	15.03	15.03	15.03
Abatement, tons CO_2 eq. per 10 ha	3.35	4.13	4.11	0.64	1.71	2.33
Abatement, % -change to no-premium	14.3%	14.4%	13.0%	3.8%	7.8%	9.6%
Abatement cost, eur/ ton CO_2 eq.	44.8	72.6	73.0	70.4	70.2	90.0

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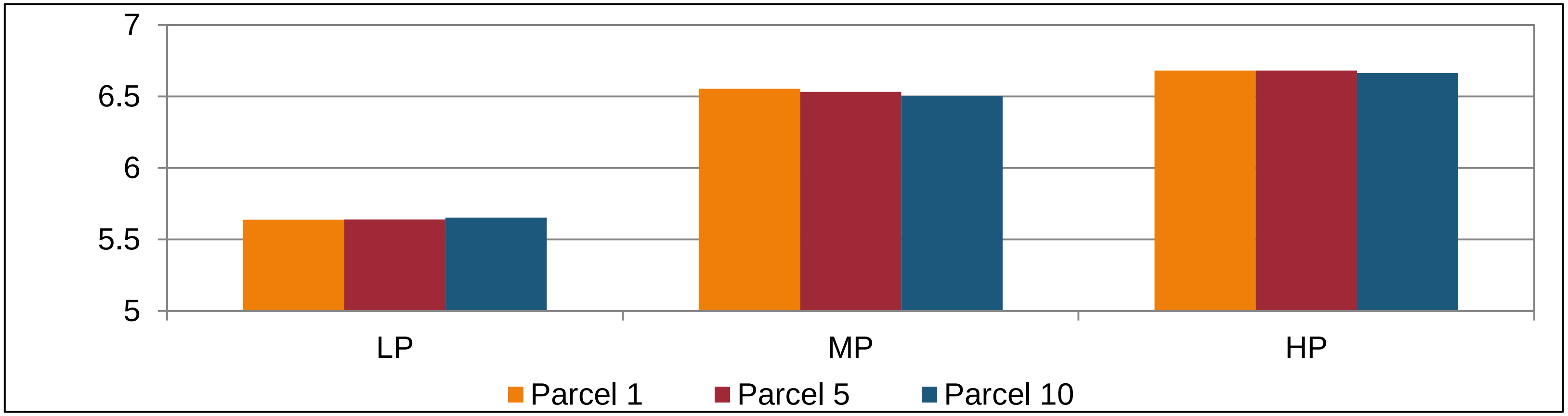
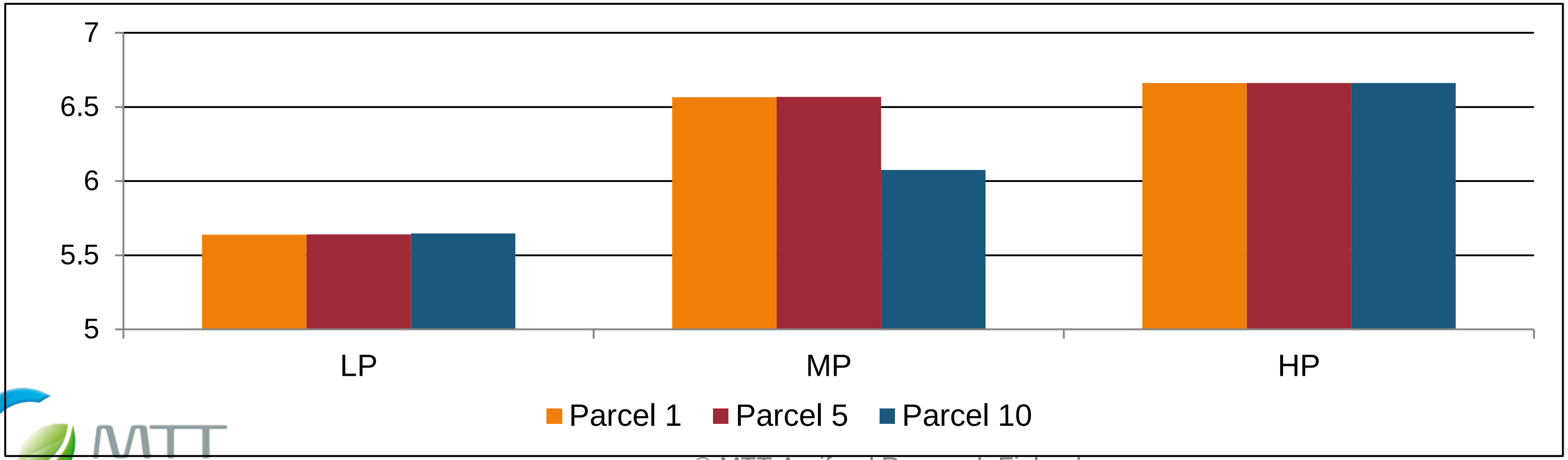
Result 3: Logistic cost effect

➢Average pH-value of soils at parcel 1, parcel 5 and parcel 10 for "Specialized farms" over the next 30 years



➢Average pH-value of at parcel 1, parcel 5 and parcel 10 for "Other crop farms" over the next 30 years



Conclusion

- Some - not all - crop farms with organic soils may accept relatively low compensation levels for mitigation actions
  - For “production oriented farms”, compensation level of appr. 150-300 eur/ha, needed for keeping organic soils under permanent grass cover
  - For less production oriented farms compensation level of appr. 45-210 eur/ha, needed for keeping organic soils under permanent grass cover
- GHG abatement of 4-14% is achieved, depending on farm types and crop prices
- However high abatement costs, 45-73-90 eur/ton CO2
- Policy measures meant to promote other targets, such as biodiversity promotion, may work as important complements for measures aiming for greenhouse gas abatement
- Adaptation is not much different between the farm types
  - However specialised farms get more benefits if prices cover the costs
  - For example, oilseeds and winter cereals become more feasible