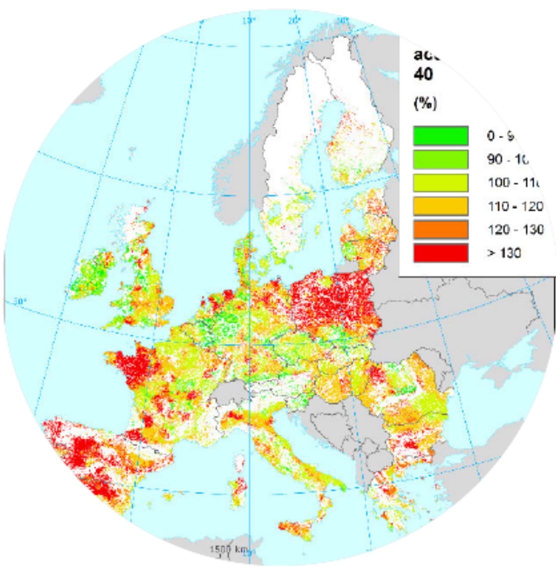
Cadmium Balances at EU-27

Background and some issues to consider

Paul Römkens, Wim de Vries, Hans Kros, Erik Smolders



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Content

- Some issues to keep in mind
- Results current approach
- Main discussion items
- Analysis of model impact: crop models and leaching models

Issues to keep in mind

- Discussion on Cd high on political agenda
- Huge (financial) interest

[redacted]

- Contrasting results (relatively!) on acceptable (=no accumulation at EU level) with previous study (Smolders, 2017) leading to debate on scientific approaches (leaching)

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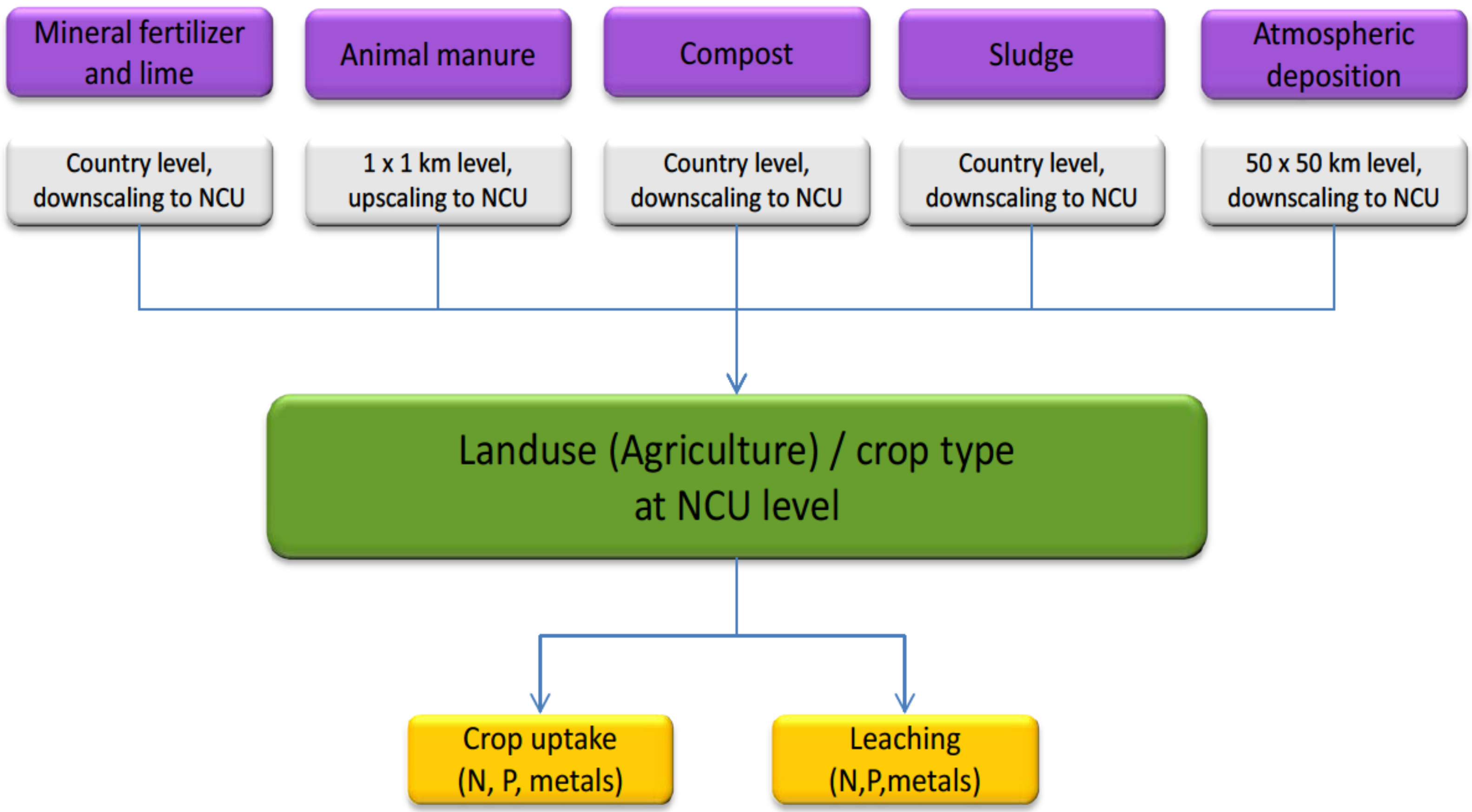
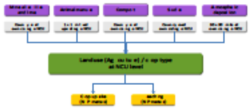
Main approach



Some considerations on approach



- Distribution of biosolids simplified
  - No application to grassland
  - All biosolids equally distributed on high demand (N) crops
  - Real world: some high input areas (UK), largely zero input
  - At EU level possibly limited issue (< 5% of total inputs)
- Crop uptake models based on limited data, no consideration of regional differences (wheat: N-S)
- Leaching model based on Dutch database (large range)

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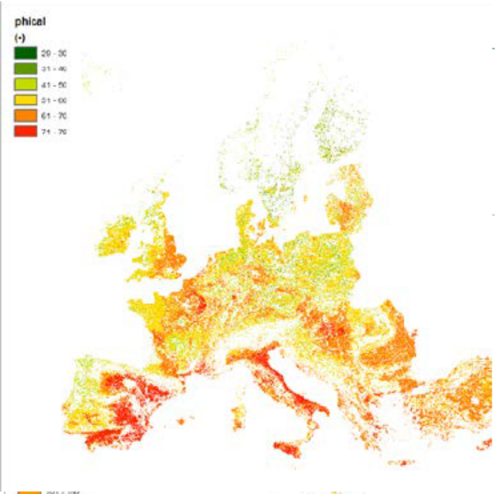
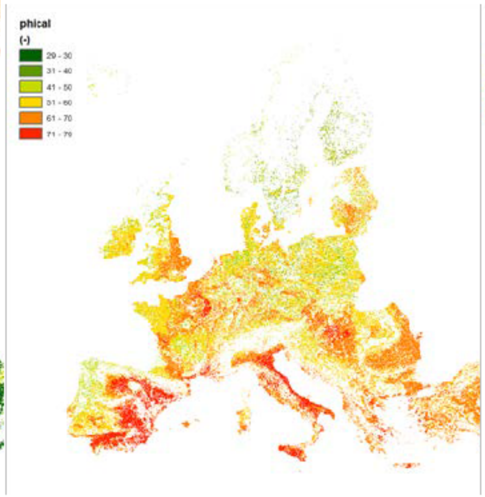
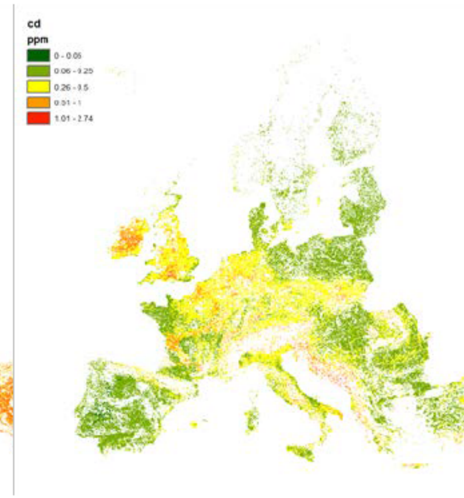


lution results

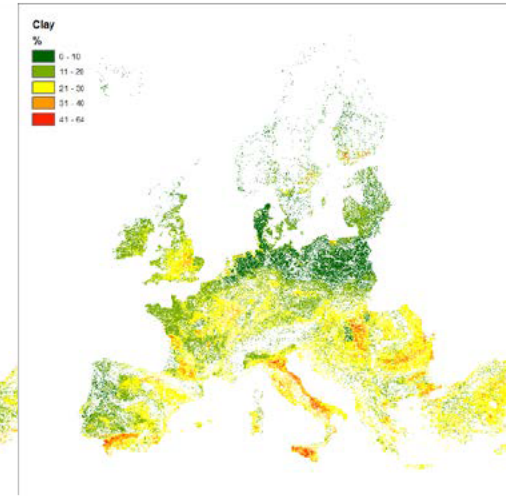
pH



Cd in soil



Clay



Note:

- methods to derive European maps of soil properties need to be screened on consistency
- Cd maps consistent with a.o. GEMAS
- Update based on JRC (LUCAS) not yet implemented
- Map of pH depends on data used (good representation needed to avoid shift to lower pH)

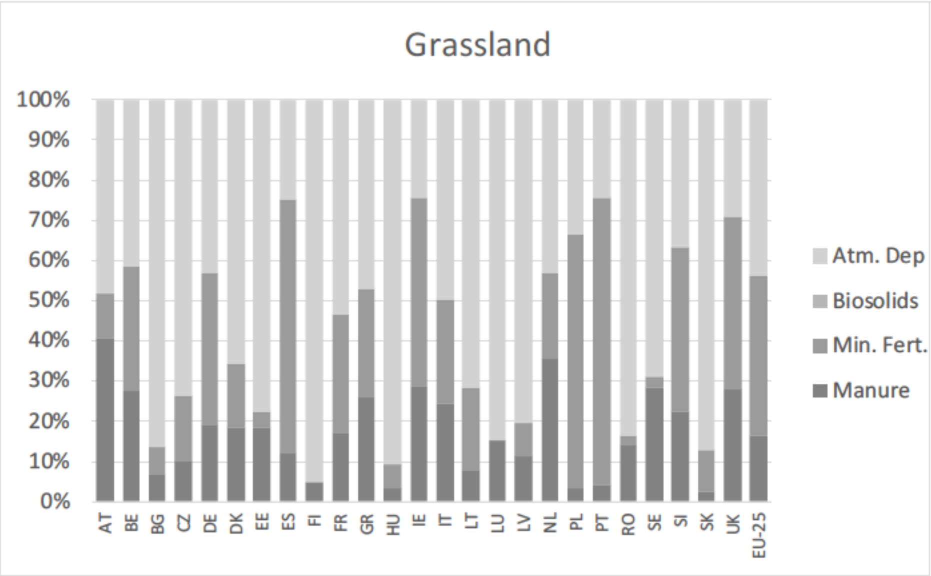
Overview of data on soils

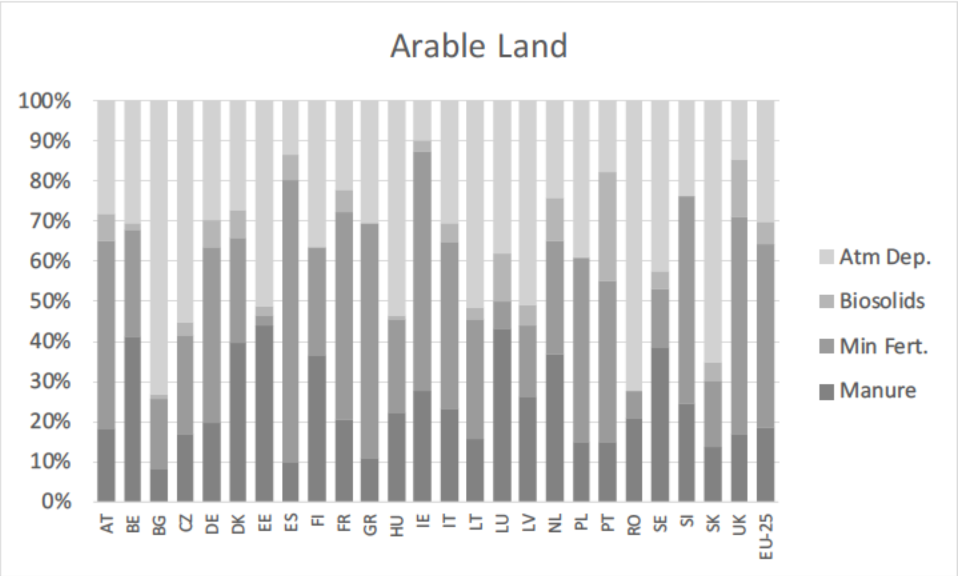
	percentile	Area (ha)	Cd soil (mg kg^{-1})	pH $CaCl_2$	SOM %	Clay % < 2 µm	Net water flux mm yr^{-1}
Grassland Soils	min	1	0.04	4.1	0.9	6	25
	5	35	0.14	4.9	2.3	12	45
	25	105	0.23	5.4	3.5	18	174
	50	355	0.30	5.8	4.5	22	259
	75	1289	0.40	6.3	5.9	26	366
	95	7147	0.57	7.0	12.5	35	663
	100	163353	1.29	7.7	100.0	57	1362
Arable Soils	min	36	0.03	4.2	1.0	3	25
	5	79	0.12	5.2	1.4	9	33
	25	218	0.22	5.8	1.9	19	146
	50	864	0.27	6.2	2.4	22	216
	75	3694	0.36	6.7	3.0	28	300
	95	23344	0.51	7.3	5.4	37	502
	max	318586	1.36	7.7	81.7	60	1141

Overview of net balance at EU scale: Current situation

	Cd Load (g Cd ha^{-1} yr^{-1})			Total load (ton Cd yr^{-1})		
	Grassland	Arable	Total	Grassland	Arable	Total
Surface Area	3.82E+07[1]	1.13E+08	1.52E+08	3.82E+07[1]	1.13E+08	1.52E+08
				ha	ha	ha
Manure	0.16	0.26	0.23	6.1	29.5	34.9 (18%)
Min. Fert.[2]	*0.39*	*0.64*	*0.58*	14.9	72.6	87.9 (45%)
Compost	0	0.02	0.01	0.0	2.3	1.5 (1%)
Sludge	0	0.06	0.04	0.0	6.8	6.1 (3%)
Atm. Dep.	*0.43*	*0.42*	*0.42*	16.4	47.6	63.7 (33%)
Plant Uptake	-0.26	-0.26	-0.26	-9.9	-29.5	-39.4 (27%)
Leaching	-1.21	-0.55	-0.71	-46.3	-62.4	-107.7 (73%)
Accumulation	**-0.49**	**+0.59**	+0.32	-18.7	+66.9	+48.5

Large Variation at Country Level





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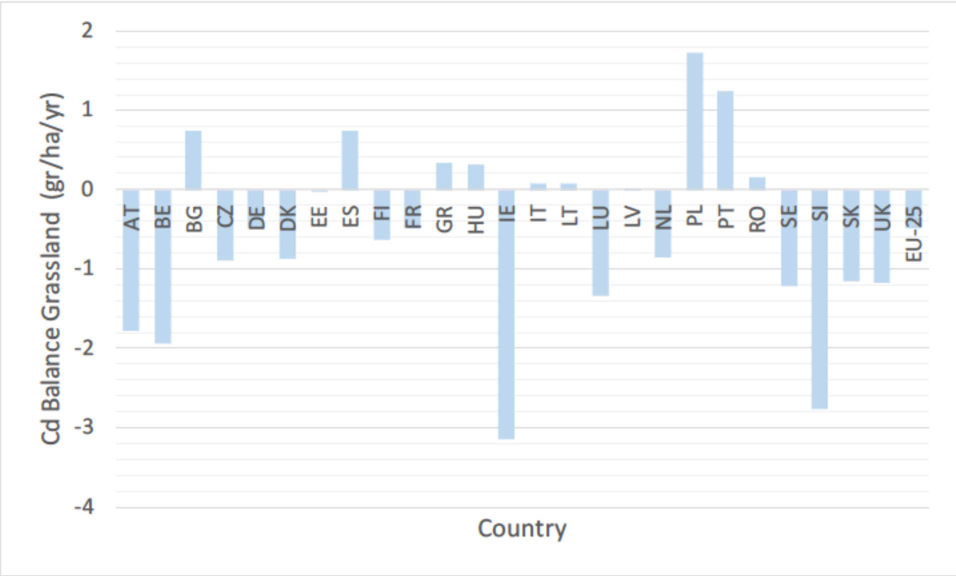
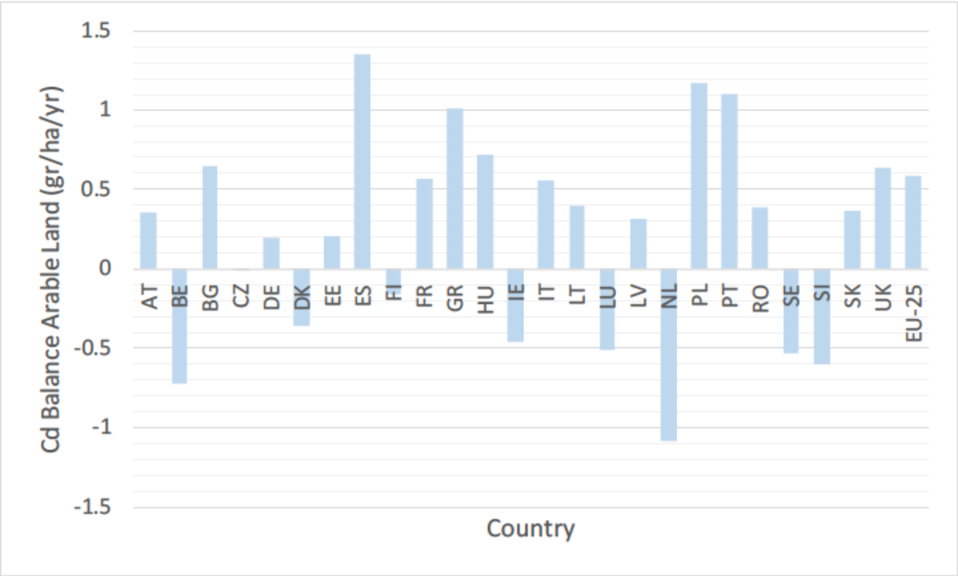
Resulting Balance also variable





Main reasons for differences between country:

1. Leaching rates (linked to pH/water balance) – negative balance IE, AT, BE, SL
2. Inputs from mineral fertilisers – positive balance ES, PL, PT

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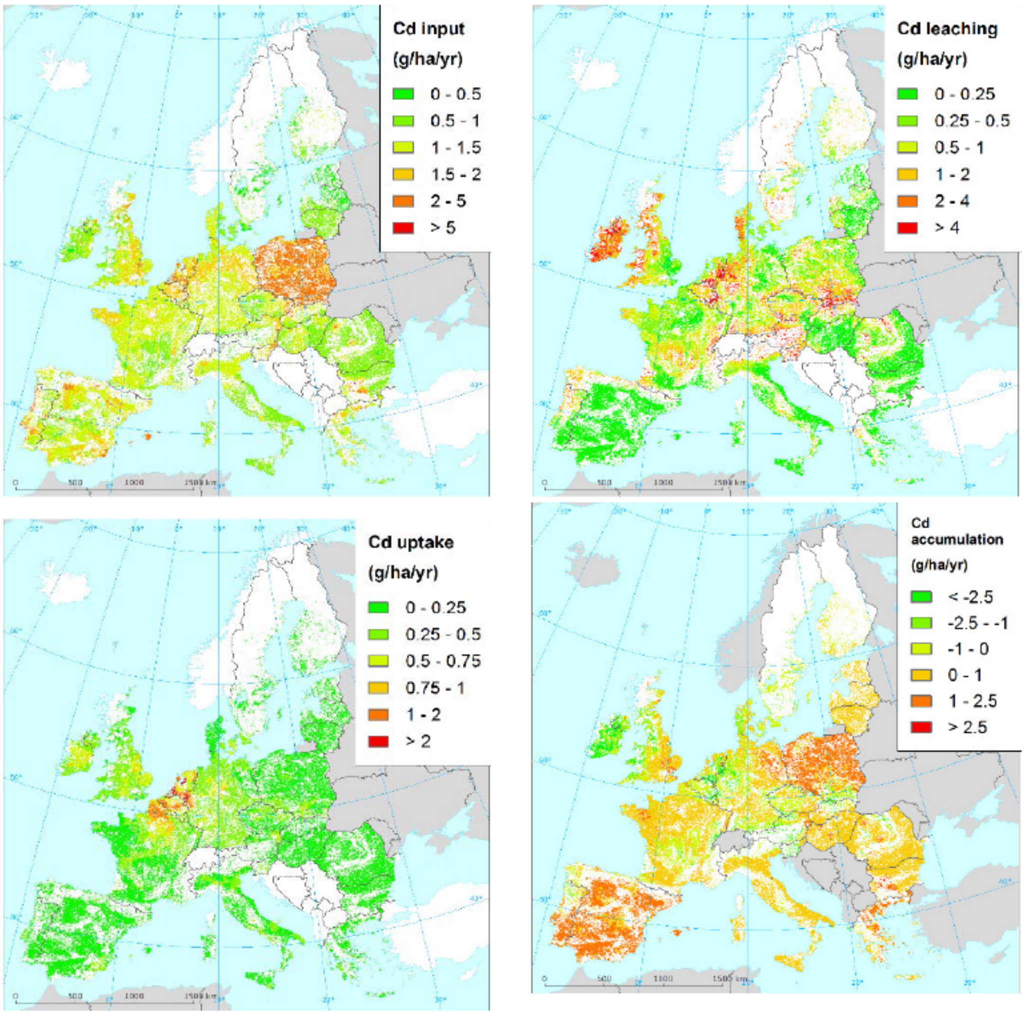
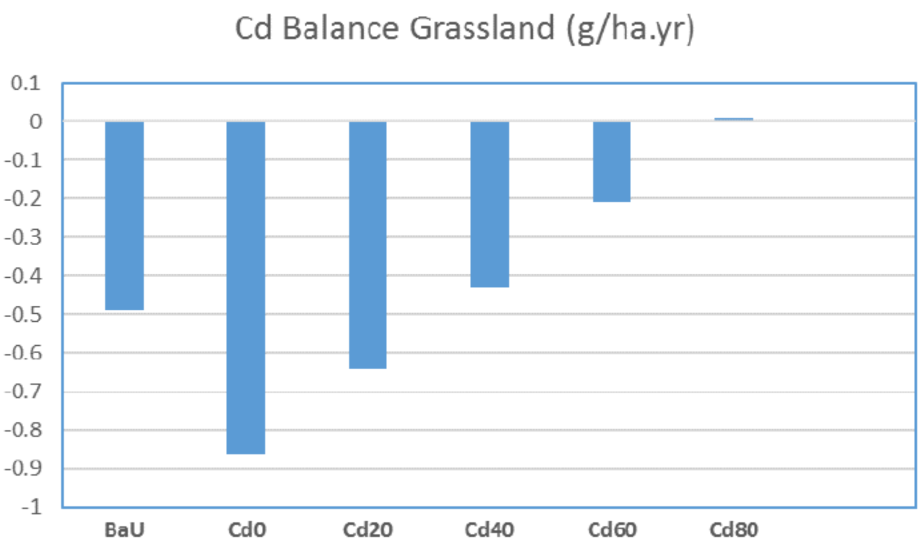
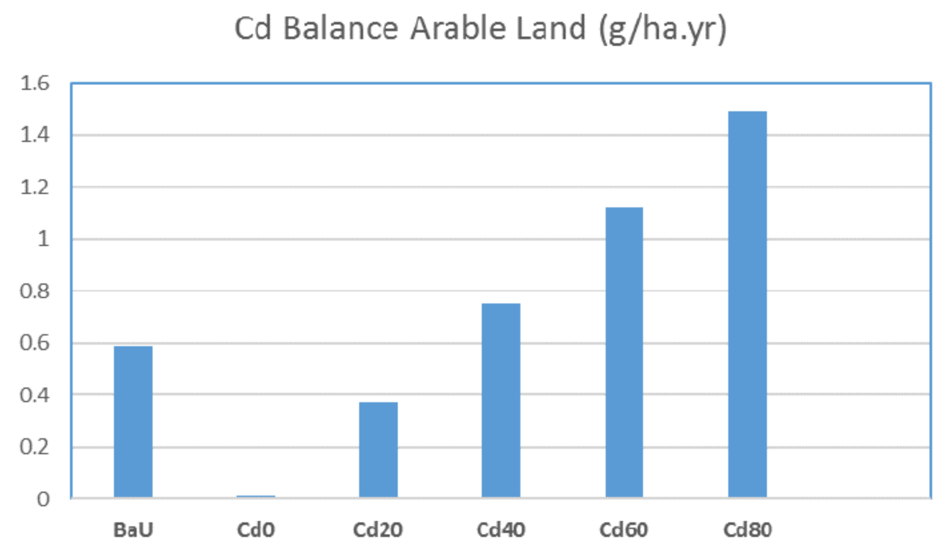

Cd input
(g/ha/yr)
0 - 0.5
0.5 - 1
1 - 1.5
1.5 - 2
2 - 5
> 5
Cd leaching
(g/ha/yr)
0 - 0.25
0.25 - 0.5
0.5 - 1
1 - 2
2 - 4
> 4
Cd uptake
(g/ha/yr)
0 - 0.25
0.25 - 0.5
0.5 - 0.75
0.75 - 1
1 - 2
> 2
Cd
accumulation
(g/ha/yr)
< -2.5
-2.5 - -1
-1 - 0
0 - 1
1 - 2.5
> 2.5

Impact of Scenario





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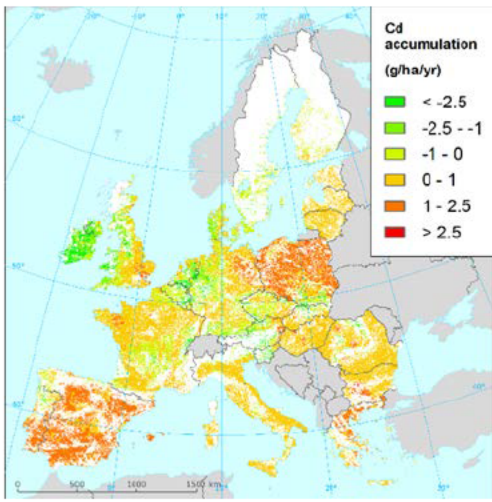
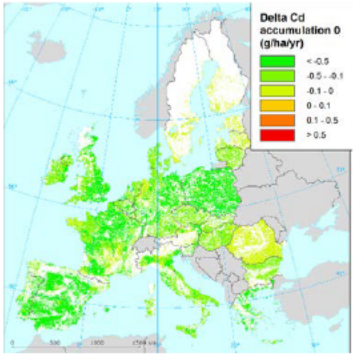
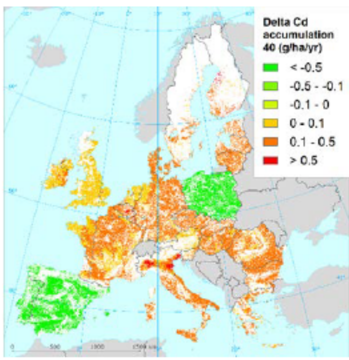
Changes in Accumulation



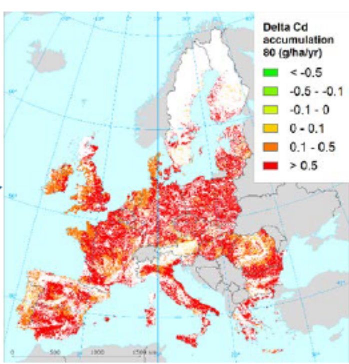
Cd-0



Cd-40



Cd-80



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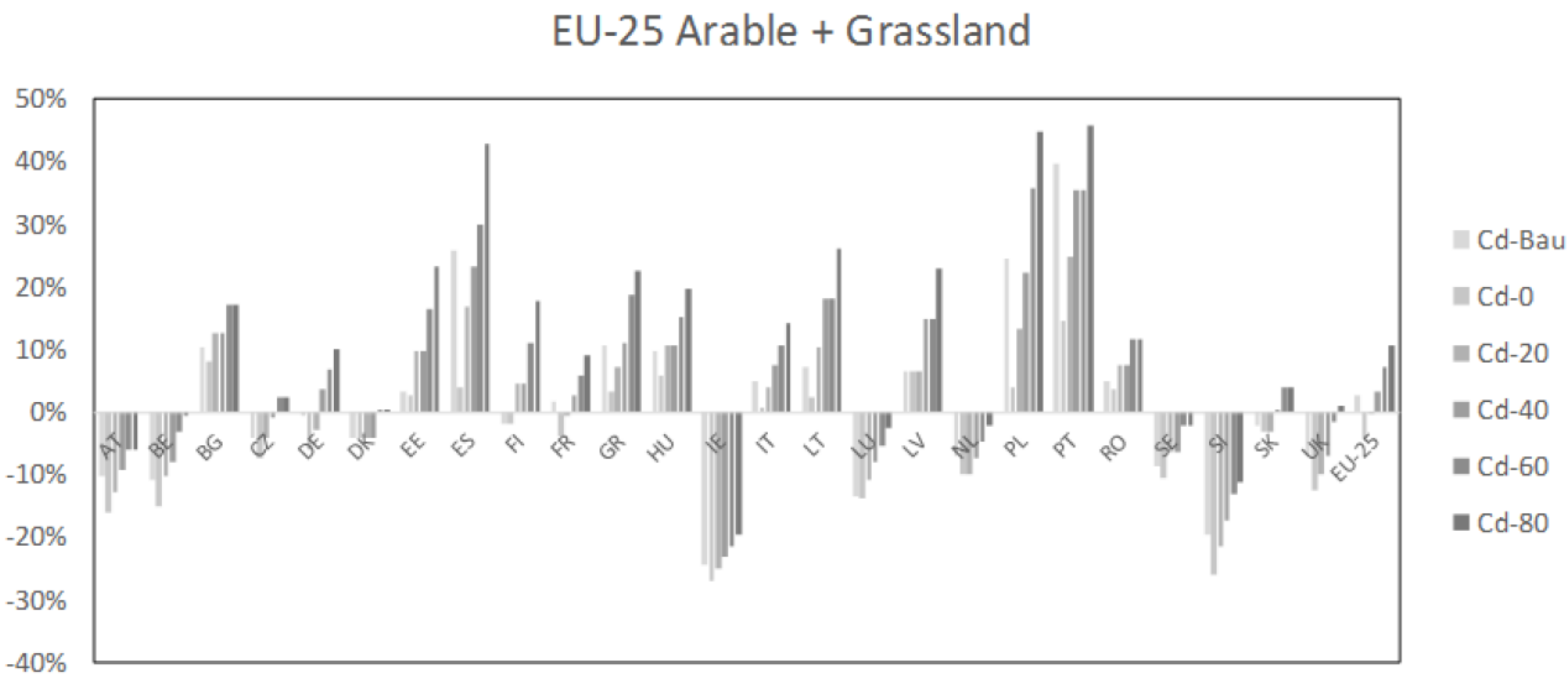
Results dynamic calculations

	Relative change in soil Cd levels at t=100 years from now		
Scenario	All Agricultural land	Arable	Grassland
BaU	2.4%	6.4%	-7.2%
Cd-0	-4.4%	0.2%	-15.6%
Cd-20	-0.1%	4.2%	-10.7%
Cd-40	4.1%	8.1%	-5.8%
Cd-60	8.3%	12.1%	-1.0%
Cd-80	12.5%	16.0%	3.8%

Results changes Cd in soil at country level



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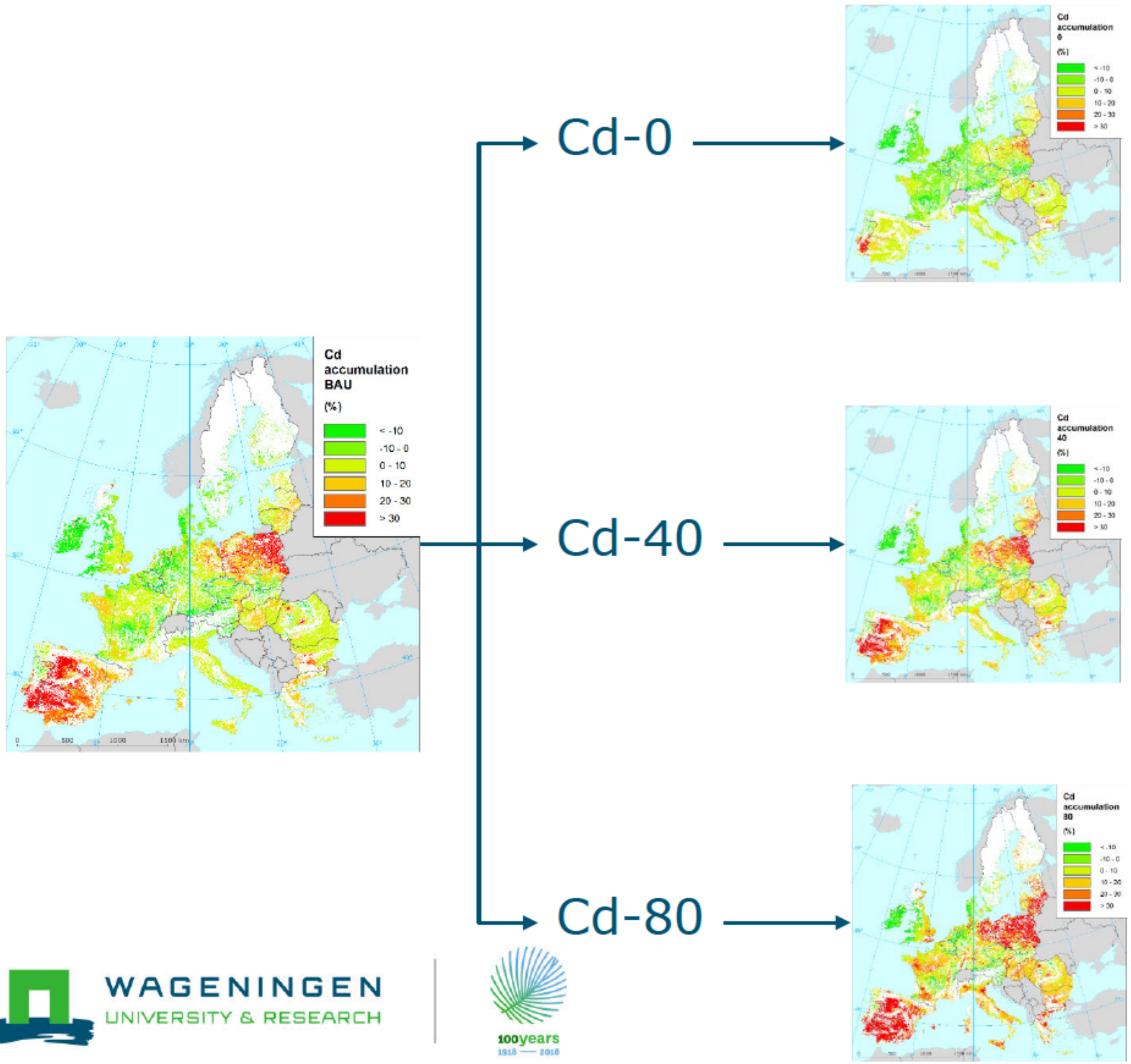
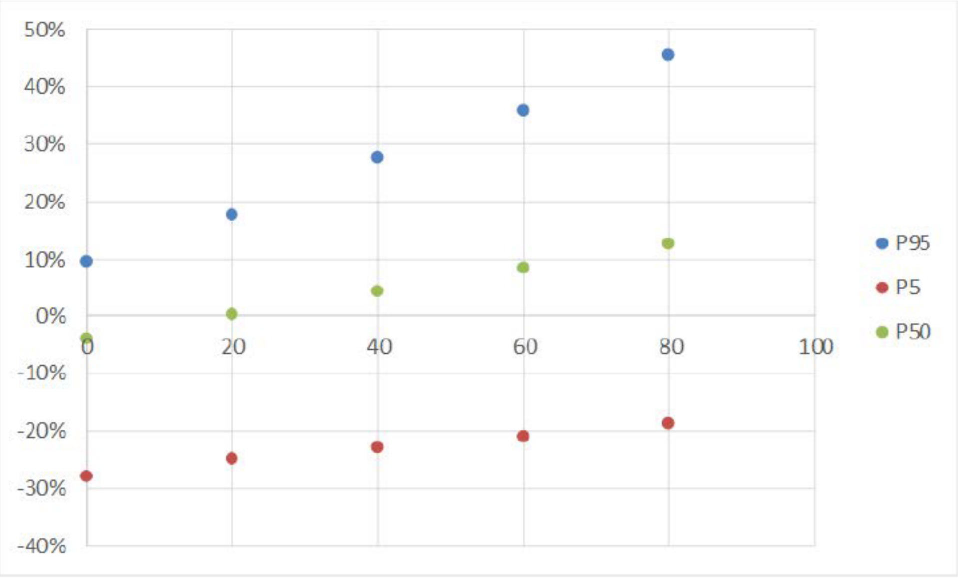
Regional (relative) changes in soil Cd



Changes of Cd in soil at EU level (NUTS3 data)



Comparion with Smolders, 2017

Input source	Smolders (2017)	Integrator (arable soils only)		
		Min EU-27	Average EU27	Max EU-27
Manure/biosolids/lime	0.2	0.09	0.34	1.10
Mineral fertiliser	0.7	0.01	0.64	1.08
Atmospheric deposition	0.3	0.16	0.42	0.91
Plant uptake	0.2	0.05	0.26	1.52
Partial balance (no leaching)	+1.0	+0.30	+1.14	+2.15

Predicted relative changes in soil Smolders vs Integrator

	Relative change in soil Cd (in % compared to current Cd levels in soil)			
	Smolders	Integrator		
Scenario	EU-average	All soils	Arable	Grassland
Business as Usual	-16	2.4%	6.4%	-7.2%
Cd-0	Not included	-4.4%	0.2%	-15.6%
Cd-20	-21	-0.1%	4.2%	-10.7%
Cd-40	-13	4.1%	8.1%	-5.8%
Cd-60	-5	8.3%	12.1%	-1.0%
Cd-80	+3	12.5%	16.0%	3.8%

Main difference in leaching approach

- $K_f = [Cd_{soil}]/[Cd_{solution}]^n$

Smolders: n=1 (linear sorption model)

Römkens et al. 2005: n≠1 (non-linear sorption model)

Linear Model: higher predicted levels of Cd in solution in low-Cd/low OM/low pH soils

Soil Properties used		Ratio of predicted Cd solution concentrations (Linear Kf/non-linear model)		
%SOM	pH	Cd_{soil} = 0.2	Cd_{soil} = 0.5	Cd_{soil} = 1.0
2	5	2.0	4.0	6.8
5	5	1.1	2.2	3.8
10	5	0.7	1.4	2.4
30	5	0.4	0.7	1.2
2	6	1.5	3.1	5.3
5	6	0.9	1.7	3.0
10	6	0.6	1.1	1.9
30	6	0.3	0.6	1.0
2	7	1.2	2.5	4.2
5	7	0.7	1.4	2.3
10	7	0.4	0.9	1.5
30	7	0.2	0.4	0.7

Range in predicted leaching losses at NUTS3 level

	Leaching flux Arable soils (g ha^{-1} yr^{-1})				Leaching flux Grassland soils (g ha^{-1} yr^{-1})			
	INT	INT_S	INT	INT_S	INT	INT_S	INT	INT_S
Percentile	t=0	t=0	t=100	t=100	t=0	t=0	t=100	t=100
1	0.01	0.06	0.01	0.08	0.01	0.06	0.02	0.08
5	0.03	0.15	0.03	0.18	0.03	0.21	0.05	0.25
25	0.16	1.0	0.19	1.0	0.22	1.3	0.27	0.96
50	**0.43**	**2.5**	**0.48**	**2.2**	**0.58**	**3.3**	**0.60**	**1.5**
75	1.0	5.5	1.0	3.7	1.3	7.4	1.2	2.1
95	2.8	14.8	2.5	6.2	3.8	19.3	2.2	3.1
99	*5.4*	*27.6*	*4.2*	*8.1*	*6.6*	*31.9*	*3.0*	*4.1*

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Conclusions

- 45% (88 ton yr^{-1}) of all inputs of Cd to agricultural soils is from mineral fertilisers
- Removal of Cd from soil largely occurs through leaching (73%, equivalent to 108 ton yr^{-1}) and crop removal only contributes to 27% (39 ton yr^{-1})
- Present Cd balances in arable land are positive but negative for pasture soils,
- For arable soils, accumulation occurs at all proposed levels of Cd (Cd-20 to Cd-60),

Conclusions II

- A stand-still level for Cd in arable soils at t=100 years at zero inputs from fertilizer
- Regional variation in Cd balances is large with accumulation prevailing in the Mediterranean areas and Poland.
- Leaching is the main reason for the pronounced difference between model results presented by Smolders (2017) and those generated in the present study.
- Linear Kd model by definition leads to higher predicted leaching concentrations

The real issue.....

- How do such small changes of Cd in soil affect quality of food and exposure?
  - Differences between Smolders and Integrator become less relevant
  - Changes in soil Cd are such that Cd in crops does not decrease substantially

  But......

  - Stand still (Cd in soil) at least guarantees that levels of Cd in food do not rise any further

Thank you

Q & A