Critical loading of trace elements on agricultural land in Canada

1																	18
1 H 1.008																	2 He 4.003
3 Li 6.941																	10 Ne 20.18
11 Na 22.99	24.31	3	4	5	6	7	8	9	10	11							18 Ar 39.95
19 K 39.10	20 Ca 40.08	21 Sc 49.96	22 Ti 47.88	23 V 50.94	24 Cr 52.00	25 Mn 54.94	26 Fe 55.85	27 Co 58.93	28 Ni 58.69	29 Cu 63.55	65.39	69.72	72.61	74.92	78.96	79.90	36 Kr 83.80
37 Rb 85.47					42 Mo 95.94	43 Tc 98.91	44 Ru 101.1	45 Rh 102.9	46 Pd 106.4	47 Ag 107.9	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe 131.3
55 Cs 132.9					74 W 183.8	75 Re 186.2	76 Os 190.2	77 Ir 192.2	78 Pt 195.1	79 Au 197.0							
87 Fr 223					106 Sg 263.1	107 Bh 264.1	108 Hs 265.1	109 Mt 268	110 Uun 269	111 Uuu 272							
					60 Nd 144.2	61 Pm 146.9	62 Sm 150.4	63 Eu 152.0	64 Gd 157.3	65 Tb 158.9							
					92 U 238.0	93 Np 237.0	94 Pu 244.1	95 Am 243.1	96 Cm 247.1	97 Bk 247.1							

Critical loading of trace elements on agricultural land in Canada – Kd survey and sensitivity analysis

Steve Sheppard

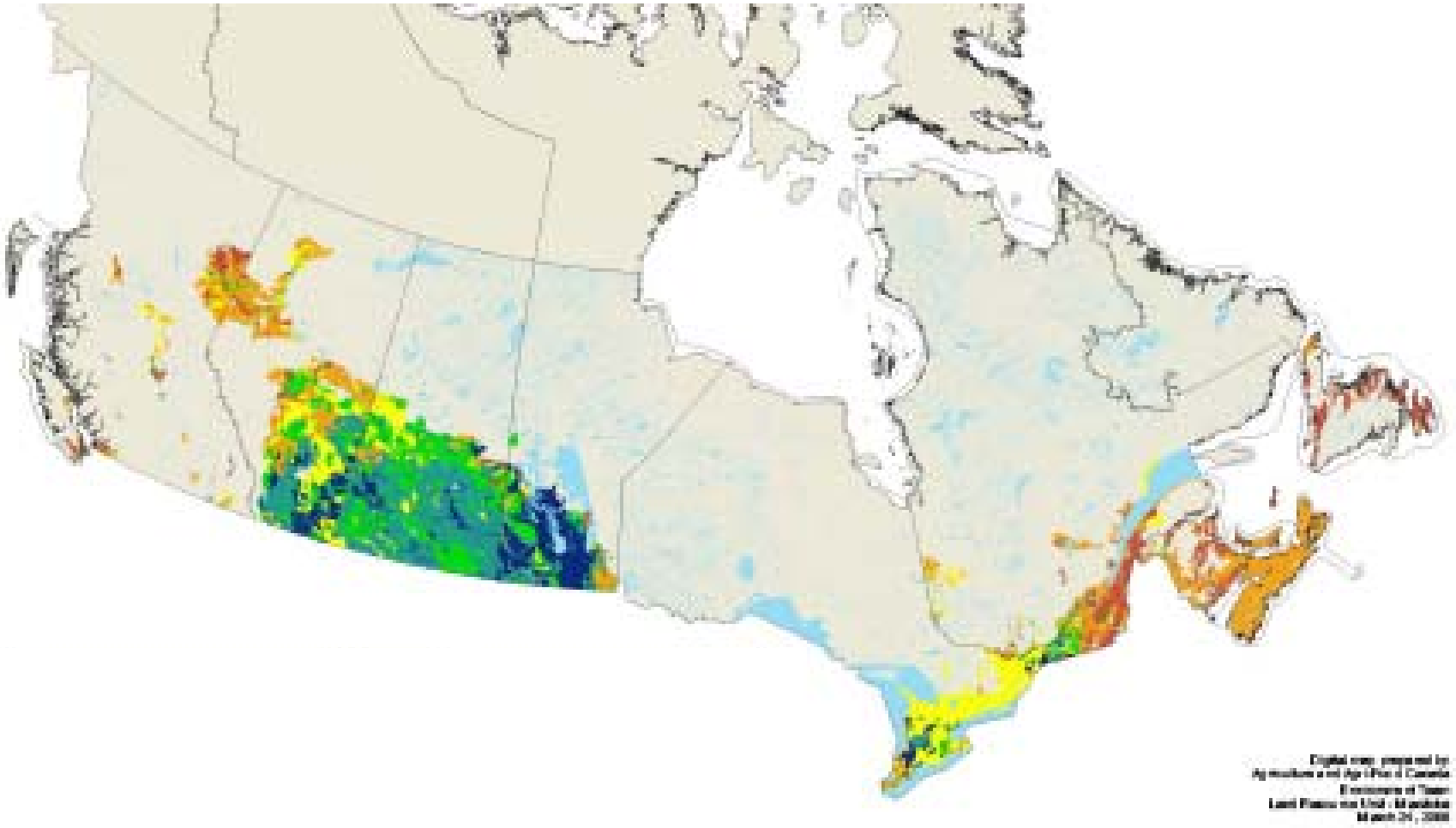
Marsha Sheppard

ECOMatters Inc., Pinawa, Manitoba, Canada, sheppard@ecomatters.com

Cindy Grant

Agriculture and Agri-Food Canada, Brandon, Manitoba, Canada, cgrant@agr.gc.ca

Agricultural land in Canada



Program context

- NAHARP (National Agri-Environmental Health Analysis and Reporting Program)
  - About 21 indicators
  - Trace element critical loads is one
  - Final reporting ~2008

Sheppard, M.I., Sheppard, S.C. and Grant, C. 2006. Critical load approach for a trace element risk indicator for agricultural soils in Canada. Can. J. Soil Science (in press).

Where we are now - inputs

- fertilizers (e.g., Cd in P fertilizer)
- animal supplements (Cu, Zn, As, etc)
- atmosphere (rainfall chemistry)
- sewage sludge
- could add irrigation

Fertilizer inputs

- Spatially distributed crop acreages
- National sales records
- Survey of retail agronomists to obtain materials and typical rates of application

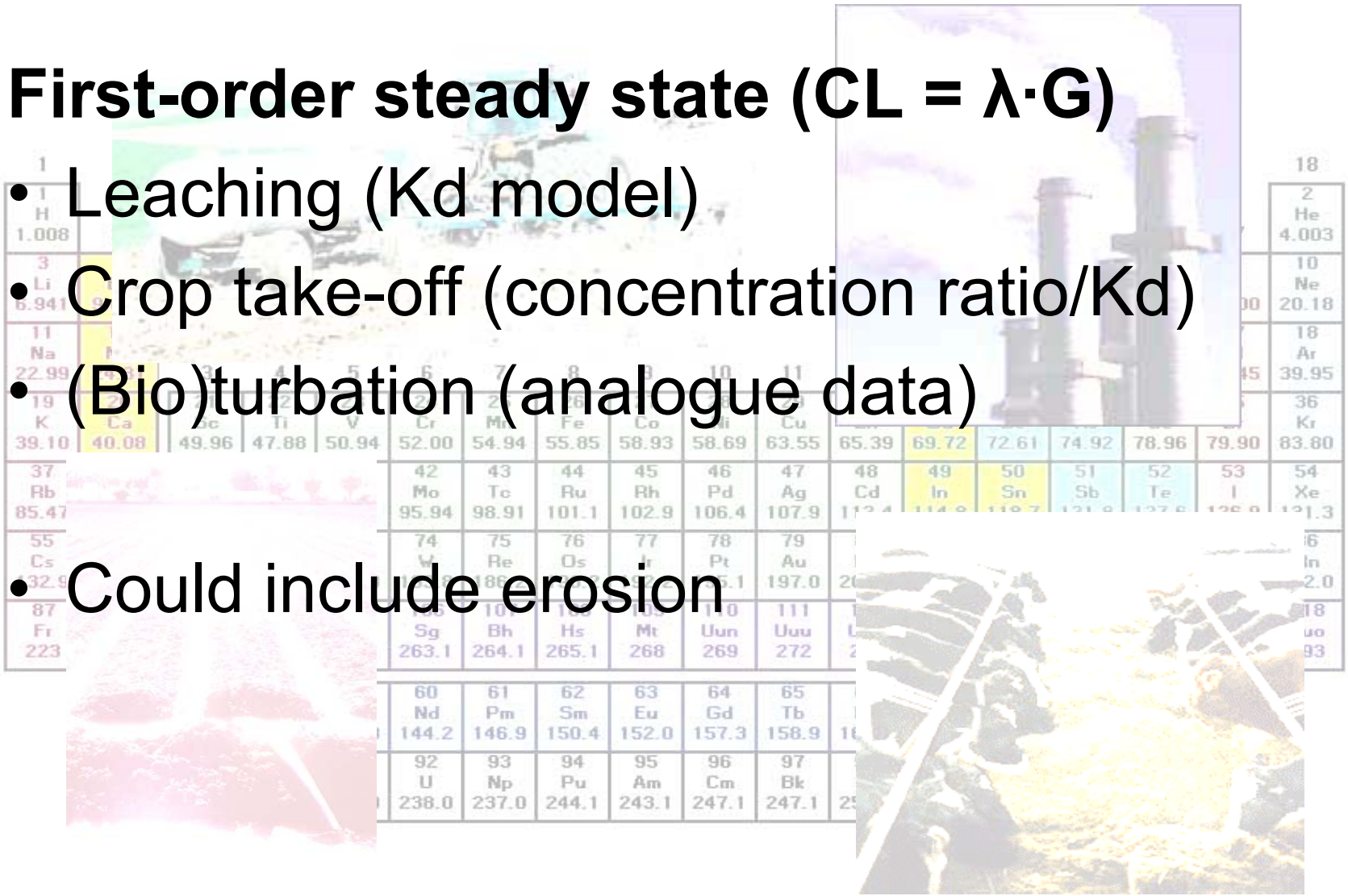
Animal supplements

- Feed supplements
  - nutritional needs (Zn, Mn)
  - hormesis (Cu in pigs)
- Pharmaceuticals
  - e.g., Roxarsone (As)
- Other
  - hoof dips (Cu)

Where we are now - losses

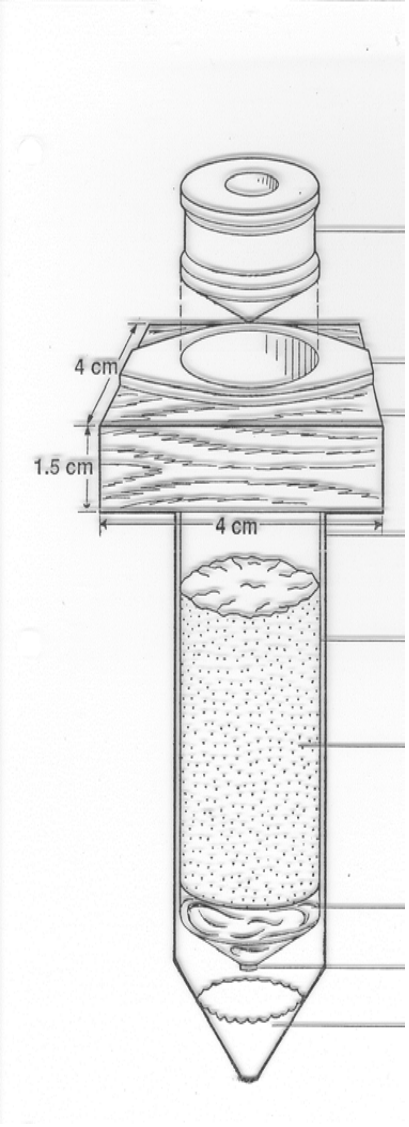
First-order steady state (CL = λ·G)

- Leaching (Kd model)
- Crop take-off (concentration ratio/Kd)
- (Bio)turbation (analogue data)
- Could include erosion



Survey of Kd across Canada

- 112 soils to date, ~54 elements
- Field-capacity or saturated pore-water extracted by centrifuge
- Strong acid or strong acid+HF to obtain totals
- Indigenous versus spiked elements



Kd results

- ‘pedotransfer’ functions for 15 elements
  - Residual GSD remains 4-fold
- log Kd values correlated with cation (K):

  Al, Ca, Cs, Cu, Ga, In, Mg, Mo, Na, Nb, Ni, Pb, Rb, Sb, Sn, Sr, Tl, U, V, Zn, Zr
- log Kd values correlated Ce/Rare Earths:

  As, Ba, Be, Cd, Co, Cr, Cu, Dy, Er, Eu, Fe, Ga, Gd, Ge, Hf, Ho, In, La, Li, Lu, Mn, Nb, Nd, Ni, Pb, Pr, Rb, Sb, Se, Sm, Sn, Sr, Tb, Th, Tl, Tm, U, V, W, Y, Yb, Zn, Zr

$$\log Kd_{Cd} = 1.8 + 0.21 \cdot (\text{soil pH})$$

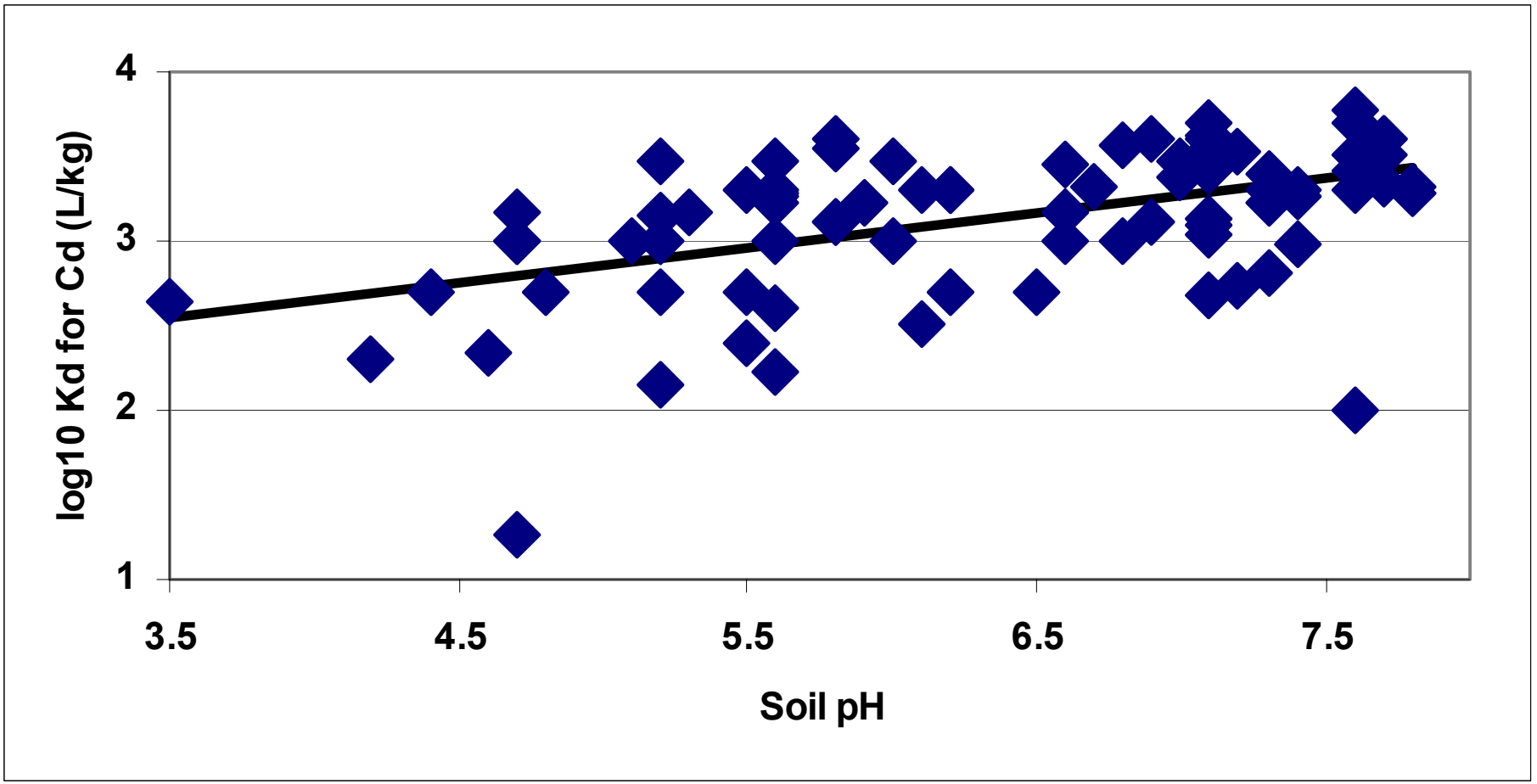
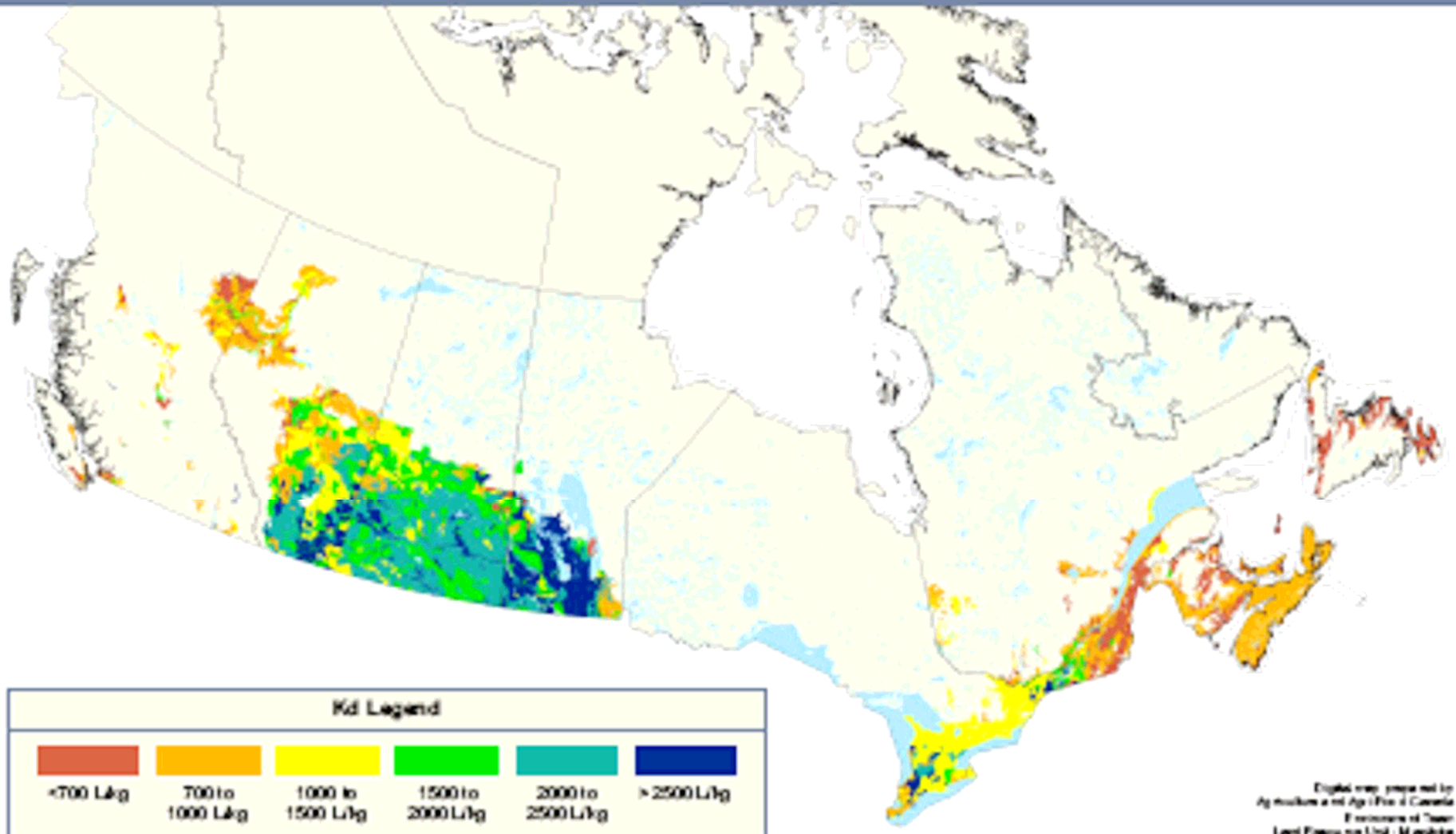
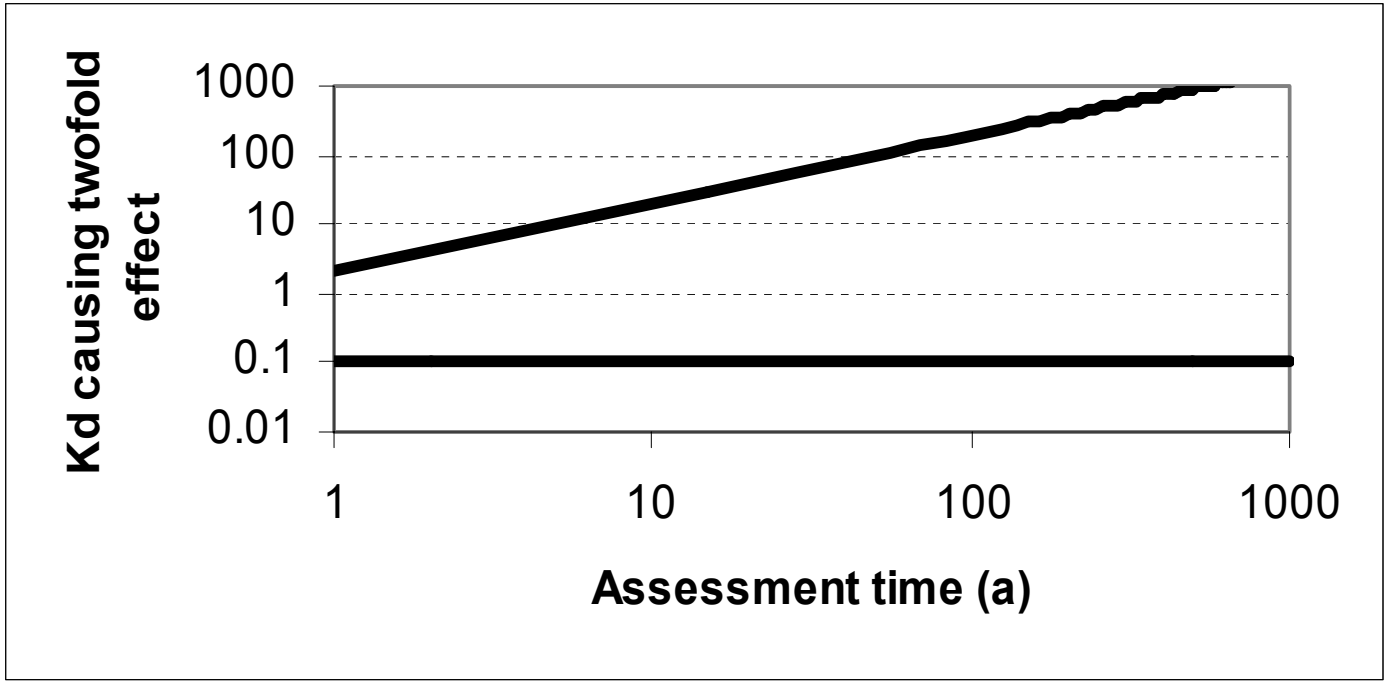


Figure 2. Estimated solid/liquid partition coefficients (Kd) for Cd in all agricultural soil in Canada.



When is Kd important?



At 10 years, anything with Kd>20 L/kg does not move

At 300 years, need to know Kd up to 1000 L/kg

Sensitivity analysis – loss terms

- As, Cd, Cu, Pb, Se, Zn
- Variation
  - set to represent measurement uncertainty and national-scale spatial variation
- Results:
  - Bioturbation usually the dominant loss
  - Leaching sometimes up to 98% of loss
  - Crop take-off always <40% of loss
  - Volatilization important for Se

Median (and maximum) contributions to loss

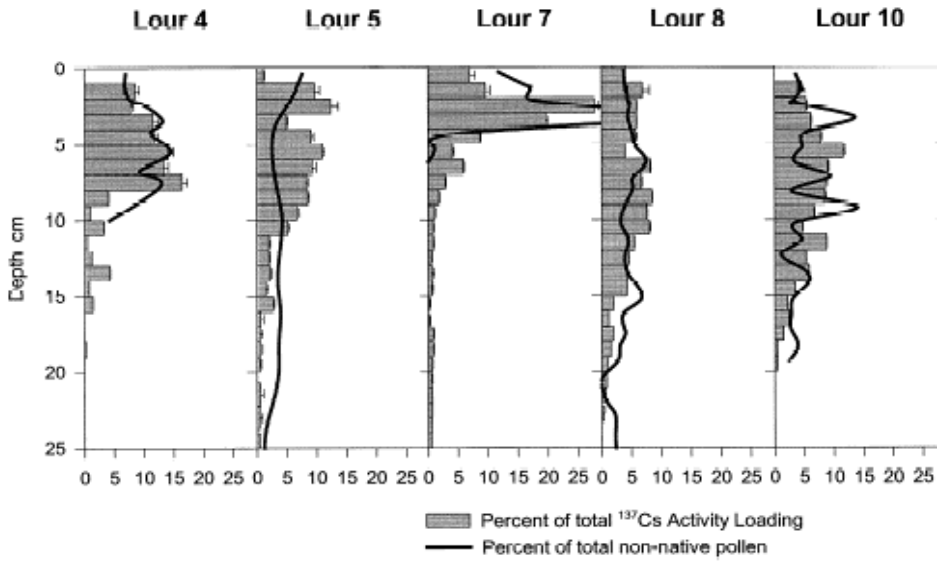
(as % of total loss rate)

	As	Cd	Cu	Pb	Se	Zn
Leaching	**10** (95)	**5** (93)	**6** (94)	**0** (56)	**3** (95)	**18** (98)
Crop take-off	**0** (1)	**0** (16)	**1** (25)	**0** (2)	**0** (1)	**2** (40)
Bioturb.	**90** (100)	**94** (100)	**93** (100)	**100** (100)	**12** (90)	**78** (100)
Volat.					**81** (100)	

Bioturbation loss rate

- Müller-Lemans and van Dorp (1996)
- Cs migration in soil

$\lambda = 0.008$ per annum for top 20 cm



Challenges

- Sewage sludge – ‘hot spots’, spatially stochastic?
- Livestock – can we simply quantify mineral inputs?
- Bioavailability - Kd or free-ion or BLM?
- Losses – what losses are real losses (erosion, bioturbation, particle migration)?
- Which elements to add?

Conclusions and Acknowledgments

- A work in progress, a national ‘report card’

  What fraction of agricultural soil in Canada is at risk from trace element contamination?

- ✓ Funding
  - Agriculture and Agri-Food Canada
  - (Environment Canada)

The End