

# ECOSYSTEM SERVICES, AGRICULTURE AND TRACE METALS

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# Argoecosystem services

- **Ecosystem services** - the goods and services provided by ecosystems that are required for human well being, but which do not have a direct market value.
- **For example**
- nutrient cycling
- the provision of habitat (e.g. for harvestable species or beneficial predators)
- biocontrol
- production (e.g. food)

(De Groot, 1992; De Groot et al., 2000; Kibblewhite et al., 2008)

# Trace metals

- Some essential for life – required as enzyme cofactors
- 10% of enzymes require Zn, 1 % Cu
- Some have no biological function – Cd, Hg, Pb
- Some have very limited biological function – Ni required by 1 enzyme
- ALL can be toxic when a threshold concentration is reached

# Trace metals

Metals enter agroecosystems:

- From the atmosphere – smelting emissions, mining dust, burning fossil fuels & volcanoes
- From mining activities
- From agricultural materials
  - Phosphate fertiliser
  - Liming agents
  - Animal manures
  - Sewage sludge

## Trace metal concentrations (mg kg<sup>-1</sup>) in sludges and in the soils of England and Wales

metal	10 %ile		Median		90 %ile	
	Soil	Sludge	Soil	Sludge	Soil	Sludge
<b>Cd</b>	<b>0.2</b>	<b>0.8</b>	<b>0.7</b>	<b>1.6</b>	<b>1.4</b>	<b>3.4</b>
<b>Cr</b>	<b>15</b>	<b>12</b>	<b>39</b>	<b>24</b>	<b>64</b>	<b>158</b>
<b>Cu</b>	<b>9</b>	<b>192</b>	<b>18</b>	<b>373</b>	<b>37</b>	<b>758</b>
<b>Pb</b>	<b>20</b>	<b>40</b>	<b>40</b>	<b>99</b>	<b>131</b>	<b>288</b>
<b>Ni</b>	<b>7</b>	<b>11</b>	<b>23</b>	<b>20</b>	<b>42</b>	<b>65</b>
<b>Zn</b>	<b>38</b>	<b>347</b>	<b>82</b>	<b>559</b>	<b>147</b>	<b>1076</b>

# A hidden problem

- Woburn market garden experiment (Giller et al. 1998) – sewage sludge applied between 1942 and 1961
- Clover seeded for first time since 1942 in 1985
- Clover was stunted and chlorotic (yellow)
- Yield 60 % lower than control
- Due to a lack of N fixation by *Rhizobium*
- *Rhizobium* suffered toxicity due to metal contaminated organic matter

# Protection of agroecosystems

- Potential harm to crop production recognised, e.g. phytotoxicity
- Therefore, regulation:
  - Council Directive 86/278/EEC of 12 June 1986 on the protection of the environment, and in particular of the soil, when sewage sludge is used in agriculture
  - UK law – The sludge (use in agriculture) regulations, Statutory instrument N0. 1263
  - US - 40 CFR Part 503 – Standards for the use or disposal of sewage sludge

**Comparison of the maximum concentration of trace metals (mg kg<sup>-1</sup>) allowed to accumulate in agricultural soils as a result of sewage sludge application in the EU, US and UK (McGrath *et al.*, 1994).**

	<b>Cd</b>	<b>Cu</b>	<b>Ni</b>	<b>Pb</b>	<b>Zn</b>	<b>Hg</b>
<b>EU</b>	<b>1-3</b>	<b>50-140</b>	<b>30-75</b>	<b>50-300</b>	<b>150-300</b>	<b>1-1.5</b>
<b>UK</b>	<b>3</b>	<b>135</b>	<b>75</b>	<b>300</b>	<b>300</b>	<b>1</b>
<b>USA</b>	<b>20</b>	<b>750</b>	<b>210</b>	<b>150</b>	<b>1400</b>	<b>8</b>



- The aim of the regulations is to prevent the input of trace metals reaching levels that may cause phytotoxicity to crops, or that may cause harm to human and animal health

- Nothing about ecosystem services –

**Not thought of back then**

- But some services are covered –  
e.g. production

# The Bradshaw report

- Review of the rules for sewage sludge application to agricultural land; soil fertility aspects of potentially toxic elements\*
- Concluded that current UK limit on Zn in UK for all but alkaline (>7.0) soils was too high
- *Rhizobium* spp. affected at 300 mg kg<sup>-1</sup>, but 200 mg kg<sup>-1</sup> should protect them
- Concern expressed about deleterious effects of mycorrhizal fungi – but no appropriate studies conducted!

\* -MAFF/DoE, 1993. *Review of the rules for sewage sludge application to agricultural land; soil fertility aspects of potentially toxic elements (PB156)*, HMSO, London.

# The Bradshaw report

- New advisory limit of 200 mg kg<sup>-1</sup> for soil with a pH between 5.0 – 7.0 set
- Not within the committee's remit to assess controls on metal concentrations for other waste materials!
- Recommended further consideration to contribution of animal wastes!

\* -MAFF/DoE, 1993. *Review of the rules for sewage sludge application to agricultural land; soil fertility aspects of potentially toxic elements (PB156)*, HMSO, London.

Time taken (yrs) for organic fertiliser applications to raise an average UK rural soil to the Cu limit.

	Mean conc. fertiliser		High conc. fertiliser	
	180 kg N ha <sup>-1</sup>	250 kg N ha <sup>-1</sup>	180 kg N ha <sup>-1</sup>	250 kg N ha <sup>-1</sup>
Sewage sludge	153	110	115	83
Diary slurry	1527	1100	270	195
Dairy manure	1261	908	847	610
Pig slurry	546	394	238	171
Pig manure	147	106	71	51
Layer manure	1619	1167	1403	1011
Broiler manure	1018	733	569	410

Time taken (yrs) for organic fertiliser applications to raise an average UK rural soil to the UK code of practice limit for Zn.

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	180 kg N ha <sup>-1</sup>	250 kg N ha <sup>-1</sup>	180 kg N ha <sup>-1</sup>	250 kg N ha <sup>-1</sup>
Sewage sludge	112	81	83	60
Diary slurry	473	340	136	98
Dairy manure	321	231	206	149
Pig slurry	346	250	80	57
Pig manure	133	96	80	58
Layer manure	237	171	172	124
Broiler manure	271	195	216	156

# Conclusion

- Soil fertility can be negatively effected by metals from sources from other than sludge
- i.e. the ecosystem service of nutrient provision can be negatively affected by disruption of important plant symbionts
- No legal regulation to prevent this!

# But, there is more...

- Korthals et al. (2000) found that some nematode genera (*Thonus*, *Alaimus* & *Aporcelaimellus*) affected at low Cu and Zn concentrations
- Disappeared from experimental mesocosms at soil concentrations above 50 mg kg<sup>-1</sup>
- Effect on ecosystem function and therefore ecosystem services not know
- But, nematodes important in biological control, predation of microorganisms & detritus breakdown
- But also parasites of plants and animals

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**American soils may be at greater risk!**



# But, there is more...

## **Food chain transfer:**

- Only domestic animals and humans considered in legislation
- What about biocontrol agents like ladybirds, other beetles, lacewing larvae and hoverfly larvae?
- Aphids biomagnify Cd and Zn
- Ladybirds and beetles accumulate Zn (Winder et al., 1999; Green et al. 2010)
- Lacewing larvae biomagnify Cd (Green et al. 2006)
- Are they Safe?
- **Who knows!!!**