SEPA
Scottish Environment
Protection Agency

Soil compliance monitoring annual report 2008

Soil is one of Scotland's greatest natural assets. It performs many vital social, economic and environmental functions, including providing the basis for food and forestry production, controlling and regulating water flow and quality, storing carbon, supporting valued habitats and providing a platform for building. It is therefore essential that good soil quality is maintained so that these functions can continue. Soil quality is typically defined as the capacity of a specific kind of soil to function within natural or managed ecosystem boundaries, to sustain biological productivity, to maintain environmental quality and to promote plant and animal health.

In 2001, SEPA published a *State of the Environment: Soil Quality* report, which recognised the importance of soil and the functions it provides. It identified the main pressures on soils and recognised that there was a lack of data available on these pressures and resulting impacts on soil quality. One of the main pressures identified was the application of organic materials to land, either under a paragraph 7 exemption from the Waste Management Licensing Regulations 1994, or under the Sludge (Use in Agriculture) Regulations 1989.

Organic materials can be applied to land to provide agricultural benefit, for example to supply nutrients to promote crop growth, or organic matter to improve workability and water retention in the soil. However, it is important to ensure that nutrients are not allowed to build up to levels which can become damaging, not just to the soil, but also to the water and air environments. Other potential contaminants, such as copper and zinc, must also be prevented from accumulating and becoming toxic to plants, soil organisms and ultimately to humans via the food chain.

In order to monitor the effects of applying organic materials on soil quality, a soil compliance monitoring strategy was developed for SEPA regulated activities that have an effect on soil. This monitoring allows us to audit compliance with the soil limit values set out in the Sludge (Use in Agriculture) Regulations 1989. The soil compliance monitoring strategy is covered in the SEPA corporate plan under the long-term environmental outcome to achieve "improved land quality and healthier soils". This outcome requires SEPA to report on soil compliance monitoring on an annual basis: this report summarises results from sampling and analysis carried out under the SEPA soil compliance monitoring strategy in 2008.

Methods

Soils were sampled from 71 fields and 16 farms following the SEPA soil sampling method (SEPA, 2008). Samples were taken from fields across Scotland to which a variety of organic materials were applied for agricultural benefit, including sewage sludge, distillery waste, vegetable processing waste and off-specification compost* (Figure 1). To put this into context, 13 out of about 550 fields receiving sewage sludge from Scottish Water were sampled. One representative soil sample was taken from each field and analysed by Scottish Agricultural College or Macaulay Institute laboratories for the following soil quality indicators:

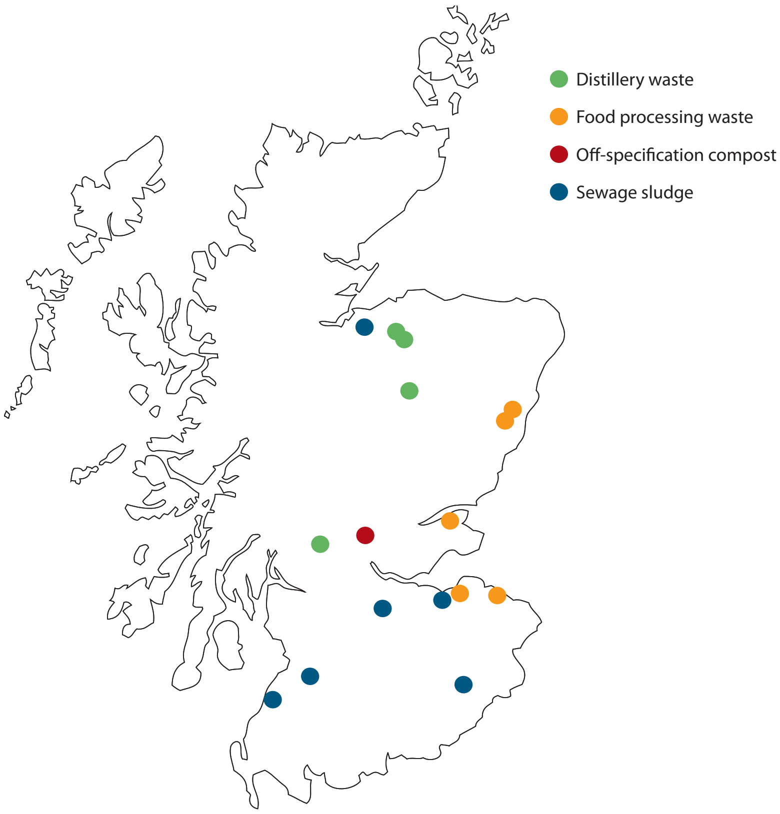
- pH;
- organic carbon;
- total nitrogen;
- extractable phosphorous;
- potassium and magnesium;
- total cadmium;
- chromium;
- copper;
- lead;
- nickel;
- zinc;
- mercury;
- microbial biomass carbon.

In addition, further samples were collected and analysed in-house for the following soil quality indicators:

- Bulk density
- Earthworms

*Off-specification compost is composted material which has failed to achieve the required standard (PAS100) for it to be legally sold as a product.

Figure 1 Locations of farms sampled in 2008 and organic material types applied



Results

Mean, median, maximum and minimum values for bulk density, chemical soil quality indicator parameters and microbial biomass carbon are shown in Table 1.

Table 1 Mean, median and ranges for each parameter measured (except earthworms)

Parameter	Unit	Mean	Median	Minimum	Maximum	N
Bulk density	g cm^{-3}	1.2	1.2	0.9	1.4	36
pH		6.1	6.0	4.9	7.7	71
P*	mg l^{-1}	22.6♦	10.6	1.8	>160	71
K*	mg l^{-1}	172	134	31.2	797	71
Mg*	mg l^{-1}	158	161	26.2	368	71
C_{org}‡	%	3.5	3.2	1.1	7.7	71
C†	%	3.4	3.2	1.2	7.4	71
N†	%	0.25	0.25	0.06	0.50	71
C:N		14	13	9	23	71
Cd†	mg kg^{-1}	0.23	0.18	0.10	0.50	71
Cr†	mg kg^{-1}	31.1	28.2	10.0	99.1	71
Cu†	mg kg^{-1}	16.6	14.4	5.8	37.2	71
Hg†	mg kg^{-1}	<0.45	<0.45	<0.45	<0.45	71
Ni†	mg kg^{-1}	22.7	22.5	4.0	73.7	71
Pb†	mg kg^{-1}	30.9	21.8	8.5	101.3	71
Zn†	mg kg^{-1}	78.2	68.6	14.8	175.0	71
C_{mic}~	µg g^{-1}	550	440	207	1556	71
C_{mic}:C_{org}	%	1.7	1.6	0.6	3.8	71

*extractable, ‡organic carbon, †total, ~microbial biomass carbon
♦calculated on the basis that values >160 mg l^{-1} are 160 mg l^{-1}

Table 2 shows results for earthworms.

Table 2 Mean, median and ranges for earthworm parameters measured

Parameter	Unit	Mean	Median	Minimum	Maximum	N
Species no.		4.6	5.0	0	9	45
Total abundance	Ind m^{-2}	308	280	0	1202	45
Adult abundance	Ind m^{-2}	79	69	0	320	45
Total biomass	g m^{-2}	97	87	0	357	45
Adult biomass	g m^{-2}	52	39	0	273	45

Both sets of results show that soil quality was generally good. In nearly all fields sampled, soil nutrient concentrations were not excessive, and at the single farm in which excessive phosphorus concentrations were found, this was not thought to be due to the application of organic materials. There was no cause for concern regarding concentrations of copper, zinc or any of the other metals analysed in the sampled soils.

Effects of organic material application on soil quality

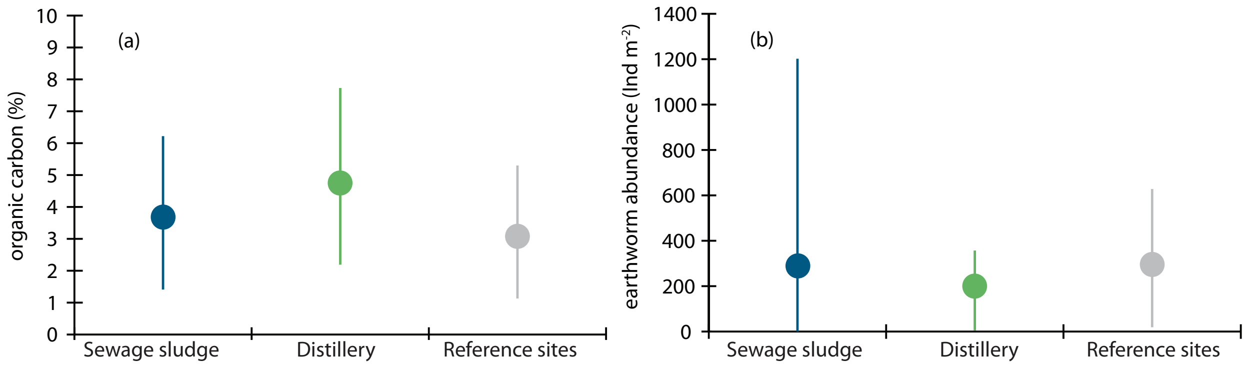
In order to investigate the effect of applying organic materials on soil quality, Scotland-wide results from soil quality indicators were averaged on the basis of type of material applied to fields. In addition, results from fields that had organic materials applied were compared on a farm by farm basis with reference fields where no organic materials were applied.

Examples of results from these analyses are shown in figures 2–4. These figures show organic carbon concentration and earthworm abundance in fields receiving sewage sludge and distillery waste in comparison with reference fields. Higher organic carbon concentration is favourable to soil quality because it increases water and nutrient holding capacities, improves soil structure and reduces vulnerability to erosion, all of which are beneficial to agriculture. Higher earthworm abundance will also benefit agriculture through improving soil structure and encouraging nutrient turnover.

Figure 2a demonstrates that, on a Scotland-wide basis, organic carbon concentrations were on average higher in soils receiving both distillery waste and sewage sludge than in reference fields. In contrast, earthworm abundance was typically lower in fields receiving distillery waste than in reference fields, with relatively little difference seen between fields receiving sludge applications and reference fields (Figure 2b).

However, Figure 2 also illustrates that there are extensive overlaps in the range of values of the soil quality indicators between fields receiving either sewage sludge or distillery waste and reference fields, suggesting that differences between values for soil quality indicators in fields receiving sewage sludge, distillery waste and the reference fields were not significant. These overlaps reflect the huge variability of natural factors such as geology and human influences (eg land use) which mask the influence of the application of organic materials on soil quality.

Figure 2 (a) Organic carbon and (b) earthworm abundance in soils to which sewage sludge or distillery waste was applied along with the reference sites for comparison. The symbol is the mean value, the bar shows the range of values measured.



It is possible to reduce the influence of differences in natural variability and farming practise which affect soil quality indicator values by comparing results from fields receiving organic materials with reference fields at individual farms. Doing so helps to identify some effects of organic material spreading on soil quality.

Organic carbon concentrations were higher in fields where sewage sludge or distillery waste was applied than in reference fields at the majority of farms (Figure 3a and 4a). Similar results were found from sampling at farms receiving sewage sludge in 2007. These results indicate that applying organic materials may be effective in building up soil organic carbon concentrations.

Sewage sludge application may also positively affect soil plant and animal life, since fields receiving sewage sludge generally contained more earthworms than reference fields (Figure 3b). In contrast, distillery waste applications seem to have a negative effect on earthworms, with abundance substantially reduced in fields receiving distillery waste in comparison with reference fields (Figure 4b). However, further sampling is needed to investigate if this is a general effect or just coincidence.

Figure 3 (a) Organic carbon and (b) earthworm abundance in fields receiving sewage sludge and reference fields with the same land use at four farms. The bar shows standard deviation. Note that no earthworm data is available for farm PE.

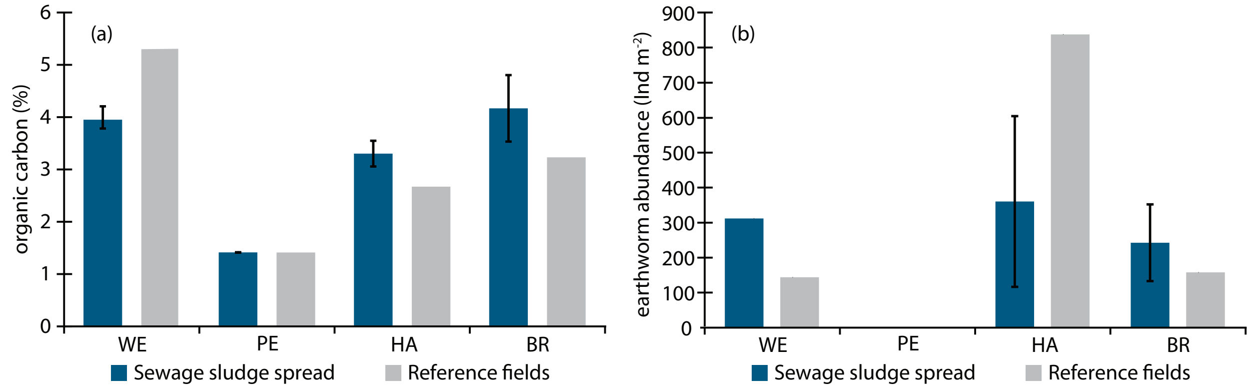
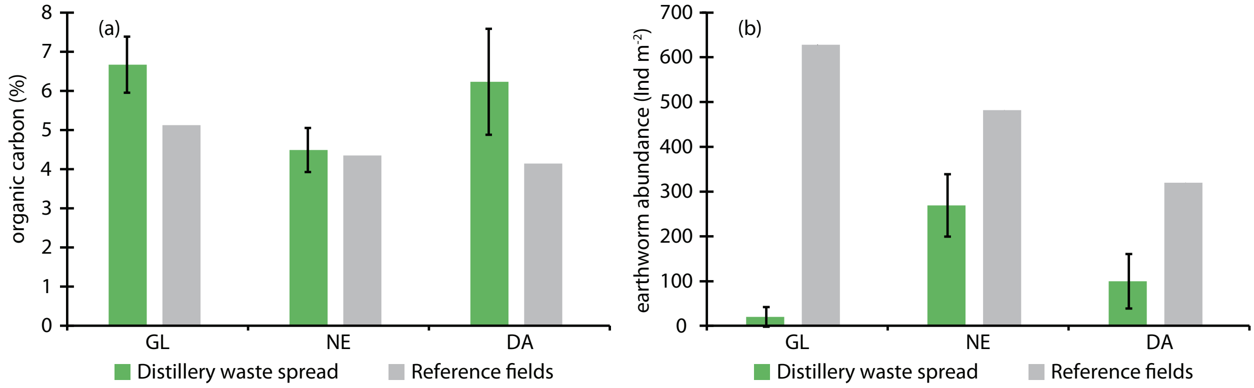


Figure 4 (a) Organic carbon and (b) earthworm abundance in fields receiving distillery waste and reference fields at three farms in north east Scotland. The bar shows standard deviation. Note that the reference field at farms GL and DA have historically received inputs of distillery waste, but no waste has been spread at the reference field at DA since 2003, and at the reference field at GL since 1994.



Compliance with regulations

Fields receiving applications of sewage sludge that were sampled in 2008 were found to be 100% compliant with the Sludge (Use in Agriculture) Regulations 1989. This compares with 97% compliance in 2007.

Conclusion

As in 2007, results from 2008 illustrate that soil quality in the fields sampled was generally good in terms of the indicators analysed. Significant effects from organic material application on soil quality on a Scotland-wide basis could not be discerned from either 2007 or 2008 results. This highlights the fact that soils are naturally very variable and that it will take many years of sampling at the current rate to build up a Scotland-wide picture of the impact on soil quality of applying organic materials to land. However, it was possible to identify some apparent effects of sewage sludge and distillery waste spreading on organic carbon and earthworms at an individual farm level.

Reference

SEPA (2008). Soil sampling method. Procedure ES-NFC-WP-003.

Further details

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