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Predicted risk of cobalt deficiency in grazing sheep from a geochemical survey; communicating uncertainty with the IPCC verbal scale.

R M Lark (1), E L Ander (1), M R Cave (1), K V Knights (2), M M Glennon (2), and R P Scanlon (2)

(1) British Geological Survey, Nottingham, United Kingdom (mlark@nerc.ac.uk), (2) Geological Survey of Ireland, Beggars Bush, Haddington Road, Dublin 4, Ireland

Deficiency or excess of certain trace elements in the soil causes problems for agriculture, including disorders of grazing ruminants. Farmers and their advisors in Ireland use index values for the concentration of total soil cobalt and manganese to identify where grazing sheep are at risk of cobalt deficiency.

We used cokriging with topsoil data from a regional geochemical survey across six counties of Ireland to form local cokriging predictions of cobalt and manganese concentrations with an attendant distribution which reflects the joint uncertainty of these predictions. From this distribution we then computed conditional probabilities for different combinations of cobalt and manganese index values, and so for the corresponding inferred risk to sheep of cobalt deficiency and the appropriateness of different management interventions.

The challenge is to communicate these results effectively to an audience comprising, *inter alia*, farmers, agronomists and veterinarians. Numerical probabilities are not generally well-understood by non-specialists. For this reason we presented our results as maps using a verbal scale to communicate the probability that a deficiency is indicated by local soil conditions, or that a particular intervention is indicated. In the light of recent research on the effectiveness of the verbal scale used by the Intergovernmental Panel on Climate Change to communicate probabilistic information we reported the geostatistical predictions as follows.

First, we use the basic IPCC scale with intensifiers, but we also indicate the corresponding probabilities (as percentages) as recommended by Budescu et al. (2009). Second, we make it clear that the source of uncertainty in these predictions is the spatial variability of soil Co and Mn. The outcome under consideration is therefore that a particular soil management scenario would be indicated if the soil properties were known without error, possible uncertainty about the implications of particular soil conditions for the Co status of grazing livestock are excluded. Third, we frame the management outcomes without the use of quantifiers which are potentially ambiguous (Budescu et al., 2009) or which may introduce severity bias (Harris and Corner, 2011). Specifically we did not refer to the 'low' or 'high' risk of a cobalt deficiency indicated for particular combinations of Co and Mn indices. Rather we consider the following possible outcomes:

1. 'Soil Co and Mn indicate a risk of Co deficiency' (the Co and Mn index correspond to any cell in Table 1 not designated 'None').
2. 'Soil Co and Mn indicate that soil treatment at 3 kg ha^{-1} cobalt sulphate is required.'
3. 'Soil Co and Mn indicate that soil treatment at 2 kg ha^{-1} cobalt sulphate is required.'
4. 'Soil Co and Mn indicate that animal treatment is required to avoid Co deficiency.'

Budescu, D.V., Broomell, S., Por, H.-H. 2009. Improving communication of uncertainty in the reports of the Intergovernmental Panel on Climate Change. *Psychological Science*, **20**, 299–308.

Harris, A.J.L., Corner, A. 2011. Communicating environmental risks: clarifying the severity effect in interpretations of verbal probability expressions. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, **37**, 1571–1578.