Optimising site location for new soil moisture probes across the agricultural areas of the Eyre Peninsula

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Background

The purpose of this study is to determine and demonstrate optimised sites for new soil moisture probes for the EP. If new installations are considered, and to promote development of a burgeoning network, it is important that the new locations be optimised and positioned in 'new' soils not already represented the current spread of probes or where new ones will be placed. Achieving these goals adds to the effectiveness of the current spread of probes by ensuring that probes are strategically installed in the next-most important soils in not currently covered in the region; this will have the effect of maximising the value of investment.

The following describes an optimisation process for siting an arbitrary 8 new probes in the region.

Theory

The methodology applies the principle that soil development is predictable and relates to soil forming distributions of soil forming factors (Jenny, 1941). These factors include landscape relief (the shape of the land surface), parent material (the lithology that the soil has developed from), climate (temperature, rainfall and seasonality), organisms (action of fauna and flora; mixing, decomposing etc.), and time (the maturity of the soil in its current form). GIS datasets depicting soil forming factors are covariates of soil formation, e.g. slope covaries with soil depth because steep slopes are likely to have shallower soils than flat ones, and a relief GIS covaries with soil texture as finer clays are generally received in low lying areas of landscapes. Various soil forming factors exert variable influence according to scale. For example, climate has a greater influence at the regional scale where trends are regional whereas relief dominates influence at the local scale.

This soil forming principle can be exploited to identify optimal location of soil sampling sites using a statistical Latin hypercube (LHS) technique described in Minasny and McBratney (2006). The technique identifies data groupings – or strata – from multiple (coregistered) covariates that are equally similar, and a sampling point is applied for each strata. This means that each sampling point is equally different from each other sampling points, and as covariates are used, each sampling point represents a different soil in the area. Continuing the soil sampling analogy, if one wanted to add new (*x*) sampling points to an existing soil survey that was not optimally planned in the first place (i.e. didn't apply LHS in the design or some other statistical approach), one could pre-decide a number (*n*) of LHS strata, find which existing survey points occupy *n* strata based on their covariate data, and allocate the *x* sampling points according to new strata. This soil sampling optimisation processes is called Hypercube Evaluation of legacy samples (HELS) and described by Carré et al. (2007).

This theory of HELS is schematically represented in Figure 1, which depicts a range of soils represented by colour continuum. In this case n = 20 strata, x = 4 new sampling sites, and there are previously 18 sampling sites in the study area. In these illustration 11 LHS strata are occupied by sampling sites (sometimes more than one), and there are 9 strata with no sites. Using HELS, the empty strata are ranked in importance, and the four new sites allocated to each of the four highest ranked strata. Coordinates are then randomly extracted from each of the four strata to locate the position of these new sampling sites on the ground.

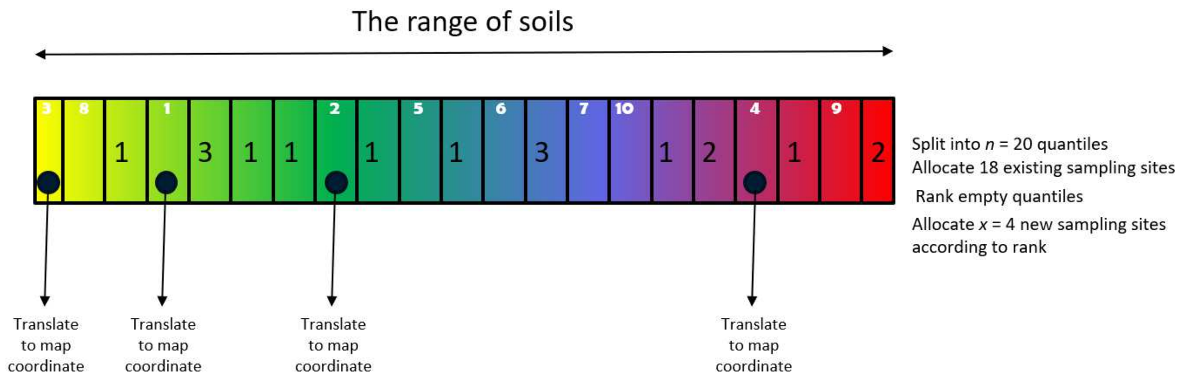

Figure 1. Schema of HELS in operation using an example where 20 strata are selected, there are 18 existing sampling sites, and four new ones are required.

Here the HELS approach for optimally identifying new soil sampling sites to existing sites is demonstrated for the location of new probes on the EP.

Data preparation

The EP dryland farming area was defined according to the South Australian soil landscape unit (SLU) coverage of the EP (Hall et al., 2009). Covariates were gathered from the Soil Landscape Grid of Australia database (SLGA) (Grundy et al., 2015). The SLGA database contains a range of nationally consistent and publicly available GIS format covariate datasets[1]. In this case the 90 m ground resolution products were selected depicting parent material, relief and climate covariates. Principal component analysis (PCA) derivatives 1, 2, and 3 were selected for each of the themes; PCA is a statistical technique used to compress the data from multiple images of similar themes whilst capturing much of the combined variation these contain, and it assists computational efficiency without significant loss of analytical quality (Burrough and McDonnell, 2000). Thus the covariates that were collated for HELS included: SLGA Parent Material PCA 1, 2, and 3; SLGA Relief PCA 1, 2, and 3; SLGA Climate PCA 1, 2, and 3, and; SLU. Finally, the covariates were sub setting according to the dryland cropping area of EP from Australian land use mapping (ACLUMP) (ABARES, 2010) to ensure no other land uses were included.

Application of HELS

The 44 pre-existing soil probe sites (as of August 2020) were applied in HELS and an arbitrary 8 new probe sites were defined. The results of the HELS analysis is presented in Figure 2. As expected, the outcome shows a bias towards the far west of the region with location of 6 of the 8 new probes as it appears from a geographic perspective at least that this region has low representation. It also follows that, from a covariate/soil formation/soil type perspective that the soils of that area are poorly represented. It is not possible to give reason for the location of the two new probe sites in the vicinity of the Cleve township, but users would be confident that these point to gaps in the regional soil types.

[1] https://esoil.io/TERNLandscapes/Public/Products/TERN/Covariates/Mosaics/90m_PCA/

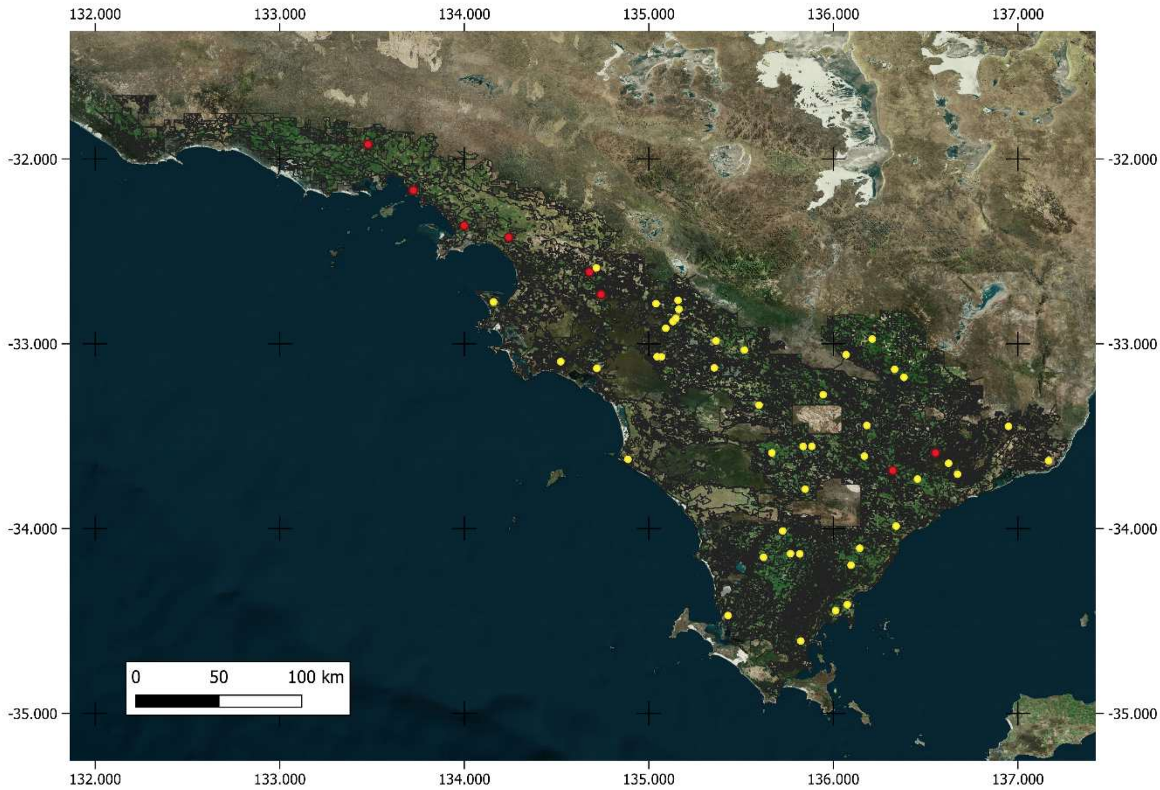

Figure 2. Eyre Peninsula dryland agricultural areas with existing 44 soil moisture probes (yellow dots) and the location of 8 more (red dots) by HELS

Conclusions

The HELS algorithm is designed to locate using statistical means (LHS) the optimal location of new soil sampling sites in the presence of existing sampling sites using soil covariate information relating to soil formation. This study has demonstrated adaption of the technique for new soil moisture probe sites in EP's dryland cropping areas that takes into account the location and soil types already covered by existing probes. For demonstration purposes, 8 probes were added to the existing spread of 44 probes already installed. The statistical methodology ensures that new probes can be added to the existing spread without bias to ensure the new spread is more effective in serving all the farmers on the EP. The method can also be used to priorities new probe deployments in sub regions or farms - covariates are compatible at the farm scale.

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References

ABARES, 2010. Land Use and Land Management Information for Australia: Workplan of the Australian Collaborative Land Use and Management Program, Australian Bureau of Agricultural and Resource Economics

and Sciences, Canberra.

Burrough, P.A., McDonnell, R.A., 2000. Principles of Geographical Information Systems. Oxford University Press Inc., New York, USA.

Carré, F., McBratney, A.B., Minasny, B., 2007. Estimation and potential improvement of the quality of legacy soil samples for digital soil mapping. Geoderma 141(1–2), 1-14.

Grundy, M.J., Rossel, R.A.V., Searle, R.D., Wilson, P.L., Chen, C., Gregory, L.J., 2015. Soil and Landscape Grid of Australia. Soil Research 53(8), 835-844.

Hall, J.A.S., Maschmedt, D.J., Billing, N.B., 2009. The Soils of Southern South Australia. Department of Water, Land and Biodiversity Conservation, Government of South Australia, Adelaide, Australia.

Jenny, H., 1941. Factors of soil formation, a system of quantitative pedology. McGraw-Hill, New York.

Minasny, B., McBratney, A.B., 2006. A conditioned Latin hypercube method for sampling in the presence of ancillary information. Computers & Geosciences 32(9), 1378-1388.

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