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THE RELATION BETWEEN COST AND UTILITY IN SOIL SURVEY

V. THE COST-EFFECTIVENESS OF DIFFERENT SOIL SURVEY PROCEDURES

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Summary

The paper presents the final conclusions of this study. For the three areas surveyed it compares the costs and utilities of different procedures for producing soil maps at scales of 1 : 20 000–1 : 70 000, using the criteria for utility discussed in Part IV. In particular it compares the utilities of different maps produced at the same cost, or the costs of producing different maps of equal utility, and the ratios of utility/cost for different survey procedures at different map scales.

Within the limits of the approximations made and in areas presenting survey problems comparable to the area of lowland Britain surveyed, series maps by grid survey seem likely to give better value for money than series maps by free survey, at map scales greater than 1 : 50 000 in most landscapes and at all scales in some landscapes. There is a ceiling to the utility of general purpose maps of soil series, which is already nearly achieved at map scales of 1 : 25 000–1 : 20 000, and is surpassed only by single property maps by grid survey, at larger scales and at considerably higher cost.

Introduction

THE efficacy of different procedures of soil survey, and their costs, are both affected by many factors. So the relations between them are complex, and there have been few attempts to elucidate these.

This is the last of a series of five papers on a preliminary study to compare the cost-effectiveness of soil-survey procedures appropriate to map scales between 1 : 20 000 and 1 : 70 000.

Part III (p. 381) presented the direct costs of producing soil maps for each of three contrasting areas by different survey procedures at a number of map scales. On the assumption that the purpose of a soil map is to equip its user to make useful statements about soil properties at any site of interest, Part IV (p. 466) presented criteria by which to assess the utility of a soil map. It presented the values of several of the criteria proposed, for the same maps.

Thus Parts III and IV compare the costs or utilities of soil maps at the same scales, produced by different survey procedures. In practice, the choice of procedure for a given survey is most likely to be influenced by which produces the map of greatest utility for a given cost, or at minimum cost for given utility, or which achieves the optimum ratio of utility to cost. The relative advantages of different procedures probably vary with map scale.

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Aim

So this paper compares the utilities of soil maps by different procedures at the same cost, the costs of maps of comparable utility by different procedures, and the ratio of utility/cost for different procedures at a range of map scales. Utility is assessed as in Part IV.

This study

The trial area has been described in Part I (p. 360). Three 'special areas' represented contrasting landscapes within the trial area. General purpose (series) and single-property soil maps of the three areas were produced at a number of scales by free- and grid-survey procedures.

Part II (p. 368) investigated the nature of the soil boundaries being mapped, and concluded that:

In areas 1 and 3 the different soil bodies were large enough to be mapped at the scales being compared (i.e. the soil boundaries were 'coherent' at the scale of mapping); in area 2 the soil varied considerably over short distances, and the map scales were not large enough to resolve the whole survey area into coherent soil bodies.

In areas 2 and 3 most soil boundaries mapped by free survey at 1:63 360 needed revision in the light of the extra observations made for the 1:25 000 map—possibly their external expression was inconsistent; in area 1 some boundaries had sufficient external expression to be mapped correctly at the low density of soil observations appropriate to free survey at 1:63 360.

In areas 2 and 3 cross-country access was relatively easy, most soils could be augered easily, and many could be distinguished on the features of their upper horizons; these conditions did not apply to many of the soils in area 1.

The costs and utilities of different survey procedures in any area depend on the survey problems it presents. More by chance than by design, the three special areas seem to have comprised the main combinations of circumstances likely to be encountered in lowland Britain.

Results

Estimates of the proportions of series mapping units

The proportions of the mapping units on each series map have been compared with their proportions on the corresponding Best Possible Map (Part I), and the per cent success of each map calculated from the extent of its agreement with BPM (Part IV). Per cent agreement with BPM is admittedly a crude criterion of success. It assumes that the boundaries on each BPM are not biased towards either the free- or the grid-observations on which jointly it is based.

Table 1 presents the per cent success, and survey costs (Part III), of series maps by free and grid survey in each special area. The costs of grid survey are for non-graduate staff. Fig. 1 presents the mean values for the six maps, and for the costs of grid survey by both professional and non-professional staff. It suggests that grid survey gives better

value for money than free survey; the contrast might be less marked if both were judged by independent ground check rather than against BPM.

TABLE I

The costs of soil surveys and their percentage success at estimating the proportions of soil series

			Area 1		Area 2		Area 3	
		Surveyor	Cost £/km²	Percentage success	Cost £/km²	Percentage success	Cost £/km²	Percentage success
Free survey	25SS	SO[2]	30·3	98	17·2	93	11·7	91
	63SS	SO	4·8	75	3·3	83	2·7	50
Grid survey	100/100	SA[3]	14·0	98	10·0	96	6·4	96
	140/140	SA	7·8	95	5·4	96	3·7	95
	100/300 [1] 300/100	SA	5·8	94·5	4·1	88·5	2·6	96
	300/300	SA	2·2	94	2·2	89	1·5	97

[1] 100/300SS and 300/100SS are averaged.
[2] SO = Scientific Officer (graduate).
[3] SA = Scientific Assistant.

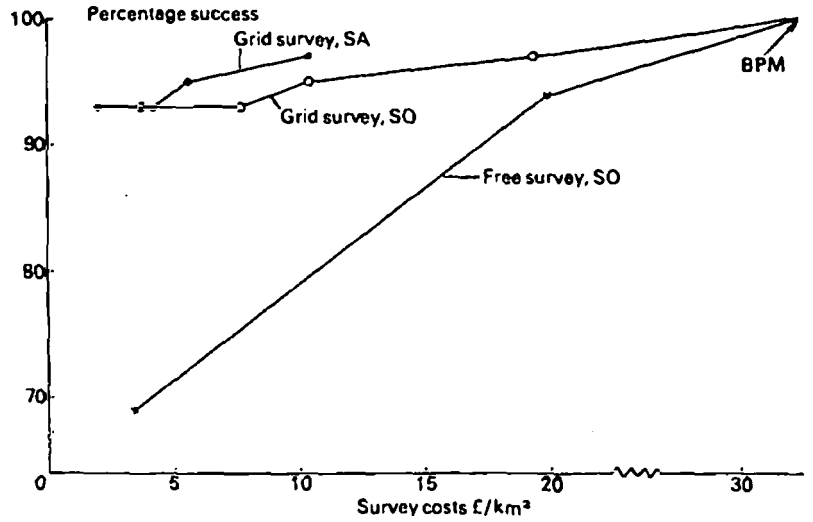

FIG. 1. The per cent success of series maps by grid or free survey and by graduate (SO) and non-graduate staff (SA) in estimating the *proportions* of series mapping units. Success estimated on agreement with the best map of each area, and averaged.

The 'purity' of series mapping units

The purity of the mapping units on a soil map is the percentage of unbiased check sites at which the map correctly predicts the profile class. Part IV gives the purities of the series maps of the three special areas. Here we compare the percentage of sites correctly predicted with the aid of a soil map, with the percentage which would have been predicted correctly by chance alone, had the proportions of the profile classes been known. The proportions are taken from BPM: errors in BPM affect all

the values for each area equally. So Fig. 2 relates the increases in purity (Part IV) attributable to the soil maps, to the costs of the maps (Part III). Since 100/100SS,[1] the series grid map of largest scale, was based on every grid observation, none remained to check its purity; so there are no points on Fig. 2 for series grid maps at cost or scale comparable to the most detailed series map by free survey (25SS).[1] Values for 100/300SS and 300/100SS have been averaged.

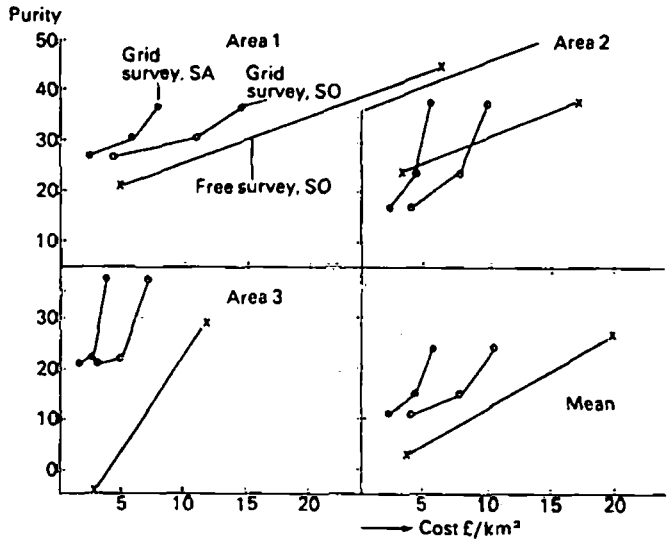

FIG. 2. The *purities* of series mapping units, as the fraction of sites at which series maps by grid and free survey predicted the profile class correctly, compared with the fraction which could have been correctly predicted by chance alone had the proportions of the series been known.

It would not seem that free survey has much advantage over grid survey, except possibly for low-cost maps at scales less than 1 : 50 000 where it may achieve a purity 20 per cent better than no map (area 2).

Uniformity of soil properties within mapped soil units

In so far as the main purpose of a soil map is to equip someone to make useful statements about the soil at all points of interest, the most important criterion of its utility is the uniformity of soil properties of practical significance within mapping units.

Part IV presented Relative Variance (RV) to compare the uniformity of mapping units with the uniformity of the landscape at large, and (1 − RV) to assess how much of the total variability of any soil property is described by the mapping units.

Here we compare the values of (1 − RV) achieved by series maps by free and grid survey, and also by single-property maps by grid survey. The values for the 100/300 and 300/100 series maps are averaged; there are no values for the 100/100 single property or series maps, since there

[1] See footnote (p. 469) on the symbols used to describe the maps being compared.

were no data to check them which had not already been used to compile them. (1—RV) has been calculated for a range of soil properties, which include some that might have been affected by management and some that probably have not; some that might be supposed to be associated with external soil features and some that are probably not. In area 1, values of (1—RV) are given for OM, CEC, available Mg and K, both for single-property grid maps of these properties, and for the same properties between the iso-lines of topsoil clay single-property maps.

We compare the survey costs of free series maps by a graduate surveyor (scientific officer) and grid series maps by a non-professional (scientific assistant) surveyor. We assume that a series map (free or grid) may be expected to provide useful information about eight soil properties, so that the cost of a series map may be divided by eight, when it is compared with a single-property map. This arbitrary figure biases comparisons in favour of series which are weakly associated with soil properties, and against series which are strongly associated with soil properties, or with the external soil features on which they may be mapped in free survey. The costs of series maps do not include the cost of characterizing series units by sampling and analysis. We have assumed that one set of soil samples, or grid observations, has provided material for eight single-property maps, so we have shared the cost of field work, but not of analyses, between eight single-property maps. We assume that the field work for single-property maps was done by non-professional staff, and the analyses by the cheapest possible procedure (Part III). The costs of soil maps by air-photograph interpretation (a.p.i.) are based upon crude approximations (Part III).

Fig. 3 illustrates the values of (1—RV) achieved by different survey procedures at given cost, and the costs of survey by different procedures to achieve given values of (1—RV).

In detail, the results depend on the different survey problems of the three areas and on the degree of association between soil properties and mapping units. In general, series maps by free survey are superior to series maps by grid survey at the same cost only if the maps are at small scale (low cost), and if (1—RV) relates to a soil property (e.g. clay content in area 1) which has reasonably clear external expression itself or is associated with a property which has clear external expression. Series maps by grid survey have the advantage in areas where soils, or soil properties, are not strongly associated with obvious contrasts in external expression. Unfortunately, for reasons already given, we have no values of (1—RV) for grid surveys at scales as large as the most expensive and detailed free survey. However, the 100/100 grid maps can be seen to cost less than corresponding maps by free survey, and their extrapolated values of (1—RV) are higher.

Single-property maps by grid survey can achieve higher values of (1—RV) than series maps, but usually at high cost; at comparable lower costs they tend to achieve lower values of (1—RV) than either grid- or free-series surveys. These comparisons are slightly biased in favour of series surveys, because the cost of characterizing the series is not included.

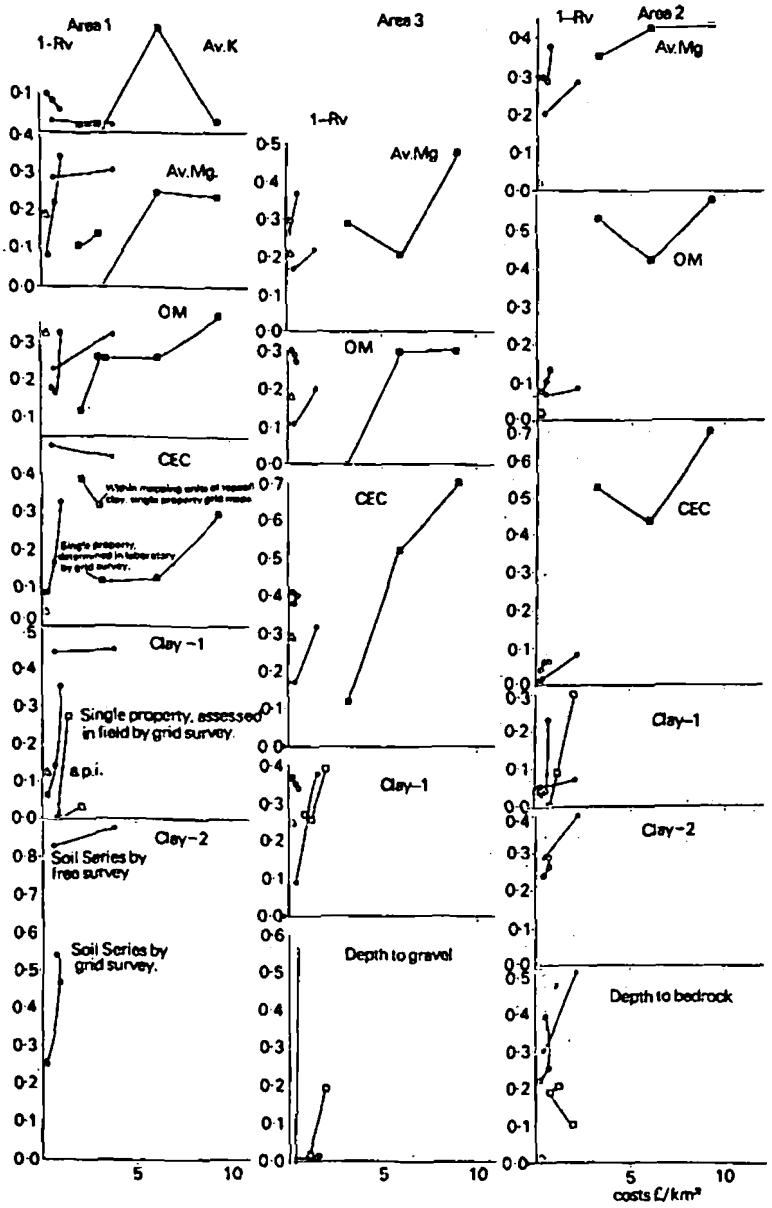

FIG. 3. The success (1 − RV) of soil maps by different survey procedures in describing the variabilities of different soil properties within three areas.

△ surveyed by a.p.i.
●—● soil series maps by free survey
○—○ soil series maps by grid survey
□—□ single properties assessed in the field
■—■ single properties assessed in the laboratory } mapped by grid survey
◪—◪ (1 − RV) for CEC, OM, available K or Mg within the mapping units of the topsoil clay single-property map.

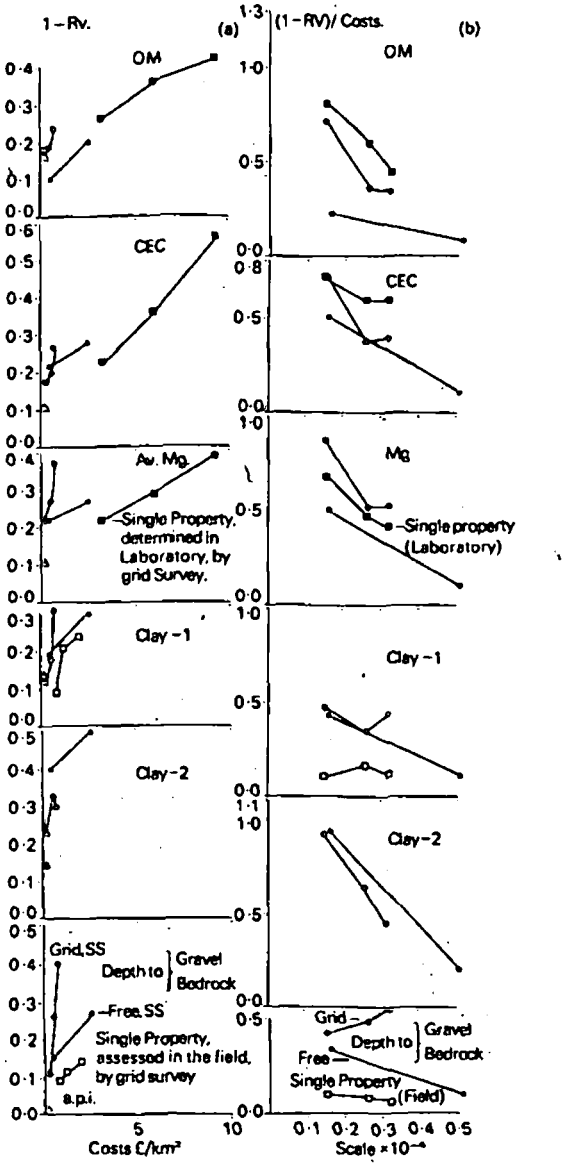

FIG. 4. The relative success of different survey procedures, averaged over three areas, compared in terms of:

(*a*) (1 – RV) at given cost *or* cost for given (1 – RV)
(*b*) (1 – RV)/cost at given scale (see Part I).

The relative advantage of different survey procedures is more apparent in Fig. 4*a* which averages survey costs, and values of (1 – RV), over the three areas, for a range of the more important physical and chemical properties. At low costs (round £0·5 (1969)/km²), free survey produces

more useful maps of soil series than grid survey for 5 out of 6 of the properties investigated; at higher costs grid survey is superior to free survey for all but subsurface clay content, for which (1—RV) is influenced by its very high values in area 1. Soil morphological properties are more economically described by series maps than by single-property maps. For chemical properties determined in the laboratory, single-property maps achieve higher values of (1—RV) than series maps, but only at substantially higher cost.

Fig. 4*b*, based on the same averaged data, compares the ratios of (1—RV)/cost achieved by different survey procedures over arange of map scales.

Discussion

The value of these comparisons depends on the assumptions and approximations made to obtain them (Parts I–IV), and on how far the survey problems of the three special areas are representative of wider areas of lowland Britain.

The estimates of survey costs include only the direct field and laboratory costs of producing the soil map. They include no cartographic, editorial, administrative, or travel expenses, nor the cost of compiling the soil memoir.

As between general purpose (series) or single-property maps, the costs of the latter are based on unusually low charges for soil analyses, but are overestimated on the time taken to draw up map legends, while the costs for series maps are underestimated by the amount of time originally spent drawing up the map legend, and the cost of sampling and characterizing series mapping units. It may be generous to assume that series maps are, in general, used to inform their users about as many as eight soil properties.

The relative advantages of free or grid surveys for mapping series depend on the salary ratio of professional and non-professional staff. As presented here, grid survey is at a disadvantage to the extent that grid-series maps at small scale could have been considerably improved at little extra cost if the soil boundaries had been interpolated with the aid of external soil features. Free survey is at a disadvantage in Fig. 4*b*, since the map scales (Part I) give insufficient credit to the contribution of external soil features in locating soil boundaries (area 1). It is unfortunate that there were no data to determine the utility of grid-series maps at larger scales.

The series map at 1:63 360 is typical of soil maps produced by free survey in England and Wales over the last 25 years. Within the limits of the 1:63 360 soil map, the choice of the trial area was not influenced by soil or relief. Within the limits of the landscapes sampled, the choice of special areas for detailed comparisons of survey procedures was unbiased.

The soil boundaries in the three special areas illustrate some of the common survey problems likely to be encountered in lowland Britain. Lacking information on how frequently different problems are likely to be encountered, we have averaged the costs and utilities of soil maps in

the three areas, in the expectation that the averages are not too dissimilar from the averages which would be obtained from a wider sample of lowland Britain.

The estimates of utility are unbiased, but are liable to sampling errors, which increase as the number of data decrease, i.e. greatest for grid surveys at the largest scales. These have probably caused the apparently erratic fluctuations in utility on Figs. 2 and 3, which are reduced by the averaging of the three areas.

Implications

This was a pioneer study of a complex field, subject to the several sources of error already recapitulated. Its conclusions must be tentative. In so far as:

1. the choice of areas for detailed study was unbiased and offered a reasonable sample of the kinds of survey problems to be encountered in lowland Britain,
2. the proposed criteria for the utility of a soil map succeed in describing the extent to which it equips its user to make useful statements about soils or soil properties,
3. the soil properties, for which values of (1 − RV) are presented, provide a fair sample of the range of soil properties about which statements might be required,
4. the balance of the various errors due to the approximations unavoidable in a preliminary study is too small to reverse the orders of merit apparent in the figures,

then Figs. 1, 2, 4*a*, and 4*b* illustrate the relative advantages of different survey procedures in lowland Britain, and provide some indication of which survey procedure is likely to provide best value for money.

With all these reservations, it would seem that, at scales greater than 1 : 50 000, and at all scales in some landscapes, series maps by grid survey by a technical assistant may give better value for money than series maps by free survey by a graduate surveyor. There is a ceiling to the utility of either, which has almost been reached at map scales as small as 1 : 20 000–1 : 25 000, and can only be surpassed by single property surveys at larger scales and greater cost.

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