

CONTENTS

Chapter 1 The National Soil Inventory.....	2
1.1 Introduction.....	2
1.2 Site location.....	2
1.3 Site recording.....	3
1.4 Sampling.....	3
1.5 Sample treatment.....	4
1.6 Chemical Analysis.....	4
1.6.1 <2 mm soil.....	5
1.6.2 <150 micrometre soil.....	5
1.7 The way forward.....	5

Table 1.1 Listing of potential attributes for each NSI site.

Chapter 1 The National Soil Inventory

1.1 Introduction

The concept of a National Soil Inventory (NSI) arose in 1976 from a recommendation of the Soil Science Committee of the Joint Consultative Organisation for Research and Development in Agriculture, that '*the Soil Survey of England and Wales should urgently consider arranging for the determination of the total content and extractable amount of biologically important trace elements in soil samples representing their principal soil series*'. (JCO, 1978). Behind this lay observations, made over many years, of both toxicity and deficiency of some elements in some soils in England and Wales, and affecting both grazing animals and arable crops (see, for example, MAFF, 1980). However, there had been no overall assessment of these problems in relation to the national distribution of soil types and differences in their properties. The necessary field work for the NSI was carried out between 1978 and 1983, as part of the National Soil Map Project, which yielded a 1:250 000 scale soil map of England and Wales (Mackney *et al.*, 1983).

An Inventory is a list of things at a place. For the NSI to be an unbiased estimate of the distribution of types of land and their properties, strict protocols were applied to site location and description, soil sampling strategy, and soil profile description. This was very unlike the practice of 'free' soil survey which is commonly used to produce conventional soil maps (Avery, 1987). Considerable effort also went into quality control of pre-treatment and analysis of the samples, data recording, error trapping and construction of the database, because of the number of samples and the magnitude of the subsequent analytical programme (Loveland, 1990; McGrath & Loveland, 1992).

1.2 Site location

For financial reasons, the number of samples was restricted to those falling at the intersects of a 5-km orthogonal grid. The sampling grid was offset 1 km north and east of the origin of the Ordnance Survey National Grid, so that sampling points did not fall on the joins of printed map sheets. If the sampling point fell on anything other than land, e.g. on a road, building, water-body etc., then the sampling point was moved 100 m north of the grid node. If that failed to locate suitable soil, then the point was moved 100 m west *from the originally intended point*. This process was repeated in steps of 100 m and 200 m from the grid node, in the order north, east,

south and west. If no suitable soil was found after this procedure, then the site was abandoned for sampling purposes, although the land-use at the original sampling point was recorded so that the inventory was complete and to make clear the reason for the deviation. If a new sampling point was found, then the standard procedure for description and sampling was followed at that point (see below). In this way, an unbiased record of the occurrence of various forms of land-use was maintained.

The principal interest was in agricultural land. No attempt was made to devise a sampling strategy to cover urban areas adequately. It was expected that the 5-km grid would yield about 6200 sites within England and Wales. In the event, 6127 sites were visited, and 5691 soil samples were collected.

1.3 Site recording

The soil profile was described in a pit dug to 80 cm (or less if rock was encountered) at each sampling point, using standard terminology (Hodgson, 1974). Soil examination to greater depths, e.g. to investigate the soil parent material, was made by screw auger. The site characteristics, vegetation, land-use, slope, aspect and so on were also described according to a comprehensive, but prescribed, system. A fuller description is given in Loveland (1990). All the information was recorded on a standard proforma. This was designed in conjunction with a computer program so that the fields on the form were automatically encoded as the data were entered from a keyboard. Up to 127 attributes, including analytical data (see below), were recorded or measured for each site. The NSI database thus contains *c.* 725000 items of information and became part of the soil information system known as LandIS (Proctor *et al.*, 1998). The site, and the soil samples from it, were identified by the 10-figure National Grid reference of the centre of the sampling grid. As well as being unique, this grid-reference located the site to within 10m on the ground, i.e. to an accuracy which would place any return visit within the original soil sampling sub-grid (see below). This grid reference is also the key to tracing all the information within LandIS for that site. The soil at each site was classified according to Clayden & Hollis (1984). The components of the NSI dataset held within LandIS are shown in Table 1.1.

1.4 Sampling

Soil sampling was restricted to the uppermost 15 cm of *mineral* soil (or less if rock intervened), or of peat, as appropriate, i.e. litter layers were not sampled, as they were

regarded as ephemeral. The actual sampling depth was recorded. Twenty-five cores of soil were taken at the nodes of a 4m grid within a 20 m x 20 m square centred on the OS 5-km grid-point. The cores were taken with a screw-type, mild-steel auger, to avoid contamination from traces of elements such as chromium and manganese present in stainless, plated or similar special steels. The cores of soil were bulked and mixed well in the field, double-bagged in food-grade polythene bags, and a waterproof and rot-proof label ('Synteape') placed between the bags. The target sample mass was 450 g of air-dried soil. In organic or other loosely-packed layers, it was often necessary to take many more than 25 auger cores. In such cases, the interval of the sub-sampling grid decreased in 1 m steps (e.g. 3 m x 3 m) and the whole grid resampled. This procedure was repeated until sufficient soil was judged to have been taken.

1.5 Sample treatment

Field-moist samples of soil were refrigerated (to 4°C) on the day of sampling, and transported to the Soil Survey laboratory within the following 2 weeks. On receipt, each sample was allocated a unique sample number, cross-referenced to the National Grid reference of the site. Samples were spread out on sheets of 'Kraft' paper to air-dry, after which each was split into two equal portions. One of these was kept as a reference sample, without further treatment, in case of contamination or loss during subsequent analysis. The other sample was milled in a mild-steel roller-mill (Waters & Sweetman, 1955) to pass a 2-mm aperture sieve. Preliminary work had shown that no detectable contamination of the samples arose from this procedure. A 150g sub-sample of this milled soil was obtained using a rotary splitter, and transferred to the ADAS laboratories for determination of some properties (see below). A further 25g sub-sample was taken from the <2mm air-dry sample by coning and quartering, and ground to <150 micrometres in an all-agate planetary ball mill. This sample was used for the determination of elements extracted by *aqua regia* (details below).

1.6 Chemical Analysis

The following determinations were made, either in the laboratories of the Agricultural Development and Advisory Services (ADAS), then an arm of MAFF, the laboratory of the then Soil Survey of England and Wales at Rothamsted Experimental Station

(SSEW), or the laboratories of the then Department of Soils and Plant Nutrition, Rothamsted Experimental Station (RES).

1.6.1 <2 mm soil

pH (ADAS): by means of a combination electrode and pH meter in a 1:2.5 soil-water suspension (MAFF, 1986).

Organic carbon (SSEW): by dichromate oxidation (Kalembasa & Jenkinson, 1973).

Particle-size distribution (SSEW): the pipette method following destruction of organic matter with hydrogen peroxide. This determination was not made for samples with an organic carbon content estimated to be >18%, as these are classified as organic soils, in which the contribution of mineral matter to their behaviour is regarded as small (Avery, 1980a).

'Available' K, Mg (ADAS): extraction with 1M ammonium nitrate solution followed by measurement by flame photometry (MAFF, 1986).

'Available' P (ADAS): extraction with 0.5 M sodium bicarbonate solution followed by measurement as the blue phospho-molybdate complex (MAFF, 1986).

'Extractable' Cd, Co, Cu, Pb, Ni, Zn: extraction with 0.05 M ammonium-EDTA solution at pH 7.0 (MAFF, 1986) (ADAS), followed by determination using Inductively Coupled Plasma - Atomic Emission Spectrometry ICP-AES (RES) (McGrath & Cunliffe, 1985).

1.6.2 <150 micrometre soil

Concentrations of Al, Ba, Cd, Ca, Cr, Co, Cu, Fe, Pb, Mg, Mn, Ni, P, K, Na, Sr and Zn extracted by *aqua regia*, and determined by ICP-AES (RES) (McGrath & Cunliffe, 1985).

Throughout the analysis, there was a programme of stringent quality control, further details of which, and the analytical approach, and the handling of the analytical data, are given by McGrath & Loveland (1992).

1.7 The way forward

Summary statistics and maps for many of the variables were published in the Soil Geochemical Atlas of England and Wales (McGrath & Loveland, 1992). From time to time, the data have been interrogated in relation to matters of environmental

protection, e.g. the disposal of sewage sludge. However, there has been no comprehensive mathematical analysis of the NSI dataset, especially from a geostatistical standpoint. Thus, it was not known how the variables related to each other geographically, or to altitude, to rainfall, to land-use patterns and so on. More urgently, there was no understanding as to whether all or part of the dataset could be used to form the basis of a soil monitoring scheme, e.g. would a 10-km grid or a 20-km give an acceptable number and distribution of soil sampling sites which would yield sufficient data to underpin a robust soil monitoring network. This clearly has enormous significance in terms of the resources required to repeat all or part of the necessary site visits, soil sampling and analysis. The work described in this report was framed against this background, namely the need to understand the spatial relationships within the NSI data (the geostatistics), and the application of that part of the work to the design of a soil monitoring network for England and Wales. The NSI data were extracted from LandIS, and transferred to the University of Reading under the terms of the so-called 'LandIS Agreement' between MAFF and SSLRC. The description of the file contents is as given in the LandIS Reference Site Manual, produced under MAFF Project SR0105.

Table 1.1 Listing of potential attributes for each NSI site (reference to codes in the Table is to Hodgson (1974)).

Attribute	Description
pH	Acidity/alkalinity
CARBON	Organic Carbon (OC) % (by mass)
EXT_P	Extractable Phosphorus concentration (mg/l)
EXT_K	Extractable Potassium concentration (mg/l)
EXT_Mg	Extractable Magnesium concentration (mg/l)
EXT_Zn	Extractable Zinc concentration (mg/l)
EXT_Cu	Extractable Copper concentration (mg/l)
EXT_Ni	Extractable Nickel concentration (mg/l)
EXT_Cd	Extractable Cadmium concentration (mg/l)
EXT_Pb	Extractable Lead concentration (mg/l)
EXT_Co	Extractable Cobalt concentration (mg/l)
EXT_Mn	Extractable Manganese concentration (mg/l)
DTOP	Depth of topsoil (cm)
DGLEY	Depth to gleyed horizon (cm)
DSGLEY	Depth to slightly gleyed horizon (cm)
DSKL	Depth to skeletal horizon (cm)
DROCK	Depth to rock(cm)
DSPL	Depth to slowly permeable layer, i.e. in which there is no downward percolation of water (cm)
COARSE	Indicates presence of coarse textured subsoil Y/N
CALC_PSC_MOD	Texture class modifier for Sand from C%, Z% & OC indicator
CALC_PSC	Texture class from clay%, silt% and carbon indicator
M_ALLUVIUM	Marine alluvium indication Y, N, M (maybe)
DISTURB	Soil disturbed indicator (Y/N)
TOPSOIL_CALC	Topsoil calcareous or not (Y/N)
FLOOD	Susceptibility to flooding indicator (Y/N)
CARBON_IND	Indicates OC>12% in top 25cm (Y/N)
EROSION_RISK	Erosion risk Y, N, I (indeterminate)
AV_STONE_ABUND	Average stone abundance in top 25 cm
AV_STONE_SIZE	Average stone size in top 25 cm
AP_POTS	Profile available water (AP) between suctions -50 and -1500 kPa for potatoes (mm)
AP_WHEAT	Profile available water (AP) between suctions -50 and -1500 kPa for winter wheat (mm)
DHOR_CALC	Bottom depth (cm) in AP calculations, i.e. depth (cm) to impenetrable layer, if present, otherwise lowest depth (cm) recorded for this profile.
EAST_NSI	National Grid reference easting at 5km resolution with 1km offset from true grid
NORTH_NSI	National Grid reference northing at 5km resolution with 1km offset from true grid
PSC_HB97	Calculated particle size class (for modified Field Handbook - 1997 edn).
UPPER_DEPTH	Horizon upper depth in cm (<0 indicated litter layer)

LOWER_DEPTH	Horizon lower depth in cm
TEXTURE_MOD	Soil texture class modifier
TEXTURE	Soil texture class (inc. particle size class and peat codes)
VON_POST	von Post no.
NATURE_O	Nature of organic horizon
H_DISCONT	Part of horizon notation for discontinuity/buried horizons
H_UPPER_CASE	Upper case part of horizon notation
H_LOWER_CASE	Lower case part of horizon notation
MATRIX_HUE	Hue code for soil matrix
MATRIX_VALUE	Value for soil matrix
MATRIX_CHROMA	Chroma for soil matrix
PED_SIZE	Size (code) for peds
PED_SHAPE	Ped shape (code)
PED_GRADE	Ped grade (code)
PED_HUE	Hue code for soil peds
PED_VALUE	Value for soil peds
PED_CHROMA	Chroma for soil peds
MOTTLE_HUE	Hue code for soil mottles,
MOTTLE_VALUE	Value for soil mottles
MOTTLE_CHROMA	Chroma for soil mottles
MOTTLE_ABUND	Abundance code for soil mottles
MOTTLE_SIZE	Size code for mottles
S_MOTTLE_HUE	Hue code for soil subsidiary mottles
S_MOTTLE_VALUE	Value for soil subsidiary mottles
S_MOTTLE_CHROMA	Chroma for soil subsidiary mottles
S_MOTTLE_ABUND	Abundance code for subsidiary mottles
S_MOTTLE_SIZE	Size code for subsidiary mottles
CLAY_PC	Clay content (%) estimated in the field
SILT_PC	Silt content (%) estimated in the field
SOIL_WATER	Soil water state (DRY, MOIST or WET)
POROSITY	Porosity (code)
ROOT_NATURE1	Root type (code)
ROOT_NATURE2	Root type (code)
ROOT_NATURE3	Root type (code)
ROOT_ABUND	Root abundance (code)
ROOT_SIZE	Root size (code) Root type (code)
COAT_ABUND	Coat abundance code
BND_DISTINCT	Horizon boundary distinctness code
BND_FORM	Horizon boundary form code
STONE_TYPE	Code for type of stones
STONE_SUBTYPE	Stone subtype
SUB_STONE_TYPE	Code for stone sub-type of stones
SUB_STONE_SUBTYPE	Between 1 and 10
STONE_ABUND	Abundance code for stones
STONE_SIZE	Size code for stones
CARBONATES	Carbonate code
NOD_COMPOSITION1	First composition or type of nodules
NOD_COMPOSITION2	Second composition or type of nodules

NOD_ABUND	Abundance code for nodules
OM	Organic matter status code for mineral horizons
ADAS_TEXTURE	ADAS texture code
SAMPLE_U_DEPTH	Upper depth (cm) of NSI soil sample
SAMPLE_L_DEPTH	Lower depth (cm) of NSI soil sample
OBS_DATE	Date of observation
OBSERVER	Initials of person making observation
SERIES	Soil series code for each series
VARIANT	Code to indicate soil series variant
SUBGROUP	Soil subgroup number.
INACCESS	Inaccessibility code for National Soil Inventory
SOIL_MADE	Made or reclaimed land code
ALT	Altitude (m) above Ordnance Datum (OD) for UK, at a point.
SLOPE	Slope in degrees
ASPECT	Compass point (bearing code e.g. NNE)
SLOPE_FORM	Slope form code
OUTCROP	Rock outcrop (% as a code)
ROCK_TYPE	Code for type of rock
ROCK_SUBTYPE	Code for subtype for rock
SUB_ROCK_TYPE	Code for subsidiary rock
SUB_ROCK_SUBTYPE	Code for subsidiary rock subtype
ROCK_CALC	Calcareous code for ROCK_CODE, C for calcareous, else blank
ERODE1	Erosion code for observed erosion (major)
ERODE2	Erosion code for observed erosion (minor)
LCC	Land-use Capability Class
LAND-USE	Land-use code
UPLAND_VEG	Upland vegetation code
PSC_GROUP	Particle size grouping (1,2,3) for available water (AP) calculations
SS_WK	Soil structure for weak ped grades
SS_MOD	Soil structure for moderate ped grades
SS_ST	Soil structure for strong ped grades
SS_MISS	Soil structure for missing ped grades
CLAY	Clay including CaCO ₃ (%) (<2um)
SILT	Silt content (%), including CaCO ₃ , (0.002 - 0.06mm, 2-60um)
VFSAND	Very fine sand, including CaCO ₃ (0.06 - 0.1 mm, 60-100um)
MFSAND	Moderately fine sand (%), including CaCO ₃ , (100-200um)
MSAND	Medium sand (%), including CaCO ₃ (200 - 600um)
CSAND	Coarse sand, including CaCO ₃ , (%), (600um - 2mm)
P	Total Phosphorus concentration (mg/kg)
K	Total Potassium concentration (%)
Ca	Total Calcium concentration (%)
Mg	Total Magnesium concentration (%)
Na	Total Sodium concentration (mg/kg)
Fe	Total Iron concentration (%)
Al	Total Aluminium concentration (%)
Co	Total Cobalt concentration(mg/kg)
Mn	Total Manganese concentration (mg/kg)
Ba	Total Barium concentration (mg/kg)

Sr	Total Strontium concentration (mg/kg)
Zn	Total Zinc concentration (mg/kg)
Cu	Total concentration of Copper (mg/kg)
Ni	Total Nickel concentration (mg/kg)
Cd	Total Cadmium concentration (mg/kg)
Cr	Total Chromium concentration (mg/kg)
Pb	Total Lead concentration (mg/kg)