Collated neutron probe measurements and derived soil moisture data, UK, 1966-2013: Supporting Information

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1. Summary of the dataset

An archive of neutron probe soil moisture data for hundreds of UK locations has been collated following a data recovery process. The UK Soil Moisture Databank (UKSMD) currently provides neutron probe soil moisture observations for 428 locations. These observations are available for periods of between 1 and 20 years from 1966 to 2013. Between them these data provide:

- Neutron probe readings (number of neutrons) and Volumetric soil moisture content (m^3 m^{-3}) at a range of soil depths;
- Profile moisture content (m^3 m^{-3}) to a range of soil depths;
- Metadata;
- Relevant publications for individual datasets.

The neutron probe tube sites are linked to a British National Grid reference and latitude/longitude.

2. Dataset structure

The UKSMD consists of the four files, 2 containing soil moisture data, and 2 metadata files (also summarised in Table 1):

- **Volumetric_soil_moisture_UKSMD.csv**: Time-series of neutron probe count rate, R, and volumetric soil moisture, θ (m^3 water/m^3 soil), at a range of soil depths (28Mb)
- **Profile_moisture_content_UKSMD.csv**: Time-series of depth-integrated profile moisture content, PMC. Provided as depth of water (m) to a specific depth of soil, and as m^3 water/m^3 soil (28Mb)
- **Tube_metdata_UKSMD.csv**: Tube name, location, dates, depths, vegetation, land-use, soil-type, geology (144kb)
- **Site_publications_UKSMD.csv**: Published papers and reports associated with each area or site, and a URL where available (26kb)

Further details and formats of each metadata and data file are presented in Tables 2 and 3. All files are provided in .csv (comma-separated variable) format, that can be easily imported into a spreadsheet, or read by software written in languages such as R, Python or Fortran.

3. Data production methods

The UKSMD (UK Soil Moisture Databank) consists of collated neutron probe (NP) observations from 1966 to 2013 recovered from fragile magnetic tapes and from disparate spreadsheets and databases. These originally-separate datasets have now been consolidated into one consistent dataset and are now being made openly available.

Much of the older data (1960s and 1970s) formed part of a national soil moisture database, “The Soil Moisture Databank (SMDB)”, (Gardner, 1981), which was previously considered lost, but data for 99 locations has since been recovered from old tapes, reassembled, and quality assessed. An additional archive of more-recent neutron probe data for a further 329 locations up to the year 2013 has been retrieved from disparate spreadsheets and databases across UKCEH. All associated data, from the raw digitised neutron probe measurements to volumetric soil moisture data have been quality controlled and converted to standard (SI) units.

3.1 The data recovery process

The older SMDB data (Gardner, 1981) from the 1960s, 70s and early 1980s were originally processed and stored safely on a NERC Univac 1108, and copies of the original datasets supplied by multiple organisations were retained on magnetic tapes. Regrettably, during migration of computer systems in the 1980s and losses of key staff, all the SMDB soil moisture data on the Univac were considered lost. When the lost magnetic tapes were rediscovered by the authors in 2009, they were not in the best condition, but a considerable volume of data was recovered and transferred to modern networked storage systems. The recovered data generally consisted of NP counts and profile moisture content (PMC) values (depth integrated volumetric water content), rather than volumetric soil moisture values, those these were later re-derived from the NP counts (section 3.2.2).

Other soil moisture data from the 1970s to 2013 were recovered during an extensive data audit across UKCEH. This audit identified and catalogued hundreds of soil moisture datasets, which had been generated in support of a wide range of science projects over many years. Six of these datasets were associated with the NERC funded Lowland Catchment Research (LOCAR) Programme (http://catchments.nerc.ac.uk/about/), for which several other hydrological and meteorological datasets (Leach et al., 2015a,b) have already been published (https://catalogue.ceh.ac.uk/documents/db9f6ef9-9512-4f39-aca3-3c55f51a7487). The NP readings and soil moisture values for individual sites were found on disparate spreadsheets and two different databases (Oracle and SWIPS), prior to being combined with the older Soil Moisture Databank (SMDB) data. These (generally more recent) data consisted of NP counts and volumetric soil moisture values; PMC values were only available for a few sites.

To achieve a soil moisture dataset that was as consistent as possible over the period from 1966 to 2013, NP-derived moisture values from both the SMDB and other archived data were compiled in 3 ways: as NP counts (section 3.2.1), volumetric soil moisture (section 3.2.2), and profile moisture content (section 3.2.3). The resulting combined dataset (section 4) now provides in-situ neutron probe soil moisture data from 441 tube locations in 45 study areas across England, Wales and Scotland.

3.2 Soil moisture estimation from NP measurements

3.2.1 Neutron probe readings

In-situ measurements of soil moisture are undertaken by lowering neutron probes into access tubes installed deep in the soil. Once in place, the NP access tubes allow for repeat measurements to be made by a trained operator at the same location at any time (Bell, 1976, 1987). The user typically lowers a neutron probe into the tube to a particular depth, where the probe emitted neutrons into the surrounding soil and counted how many returned following collisions with hydrogen (water) in the soil. The resulting neutron probe count rate, R, in a particular soil is dependent upon the soil chemistry, which is assumed constant, and the soil density and water content, which are variable. Readings made by the probe at a particular depth are assumed to apply to a sphere of soil (typically with radius 0.2 to 0.3 metres) surrounding the neutron probe.

3.2.2 Volumetric soil moisture

A value of **volumetric soil moisture** can be derived from the NP reading, where the volumetric soil moisture, θ, represents the volume of water per volume of wet soil, and generally $0 \leq \theta \leq 1$. To estimate θ from a NP reading R, a calibration equation is required, which usually takes the form

$$\theta = a \, \frac{R}{Rw} + b,$$

where R_w is the neutron probe count rate in water ("water count"), and a and b are calibration parameters. The neutron probe user can conduct a field calibration to determine a and b, but if that is not available, a calibration procedure such as the Institute of Hydrology (Wallingford) neutron probe calibration (Bell, 1976) is used.

Neutron probe readings in the upper 20 cm of the soil profile are often underestimates, due to the escape of neutrons out of the soil (Grant 1975). In practice, unless a site-specific calibration takes account of this issue, readings for depths of less than 15 to 20 cm are deleted, and the reading at the next depth down is assumed to apply to the whole of the zone above.

For the dataset provided here, values of R, R_w and θ (together) have been recovered for approximately 73% of observations, and θ has been recovered for approximately 78% of observations. Where original values of R and R_w were recovered but θ was missing, θ was calculated using the above Wallingford Probe calculation equation or the probe calibration equation provided in the SMDB report for that site (Gardener, 1981), assuming the recorded soil-type could be applied at all soil depths. This assumption will result in greater uncertainty in the recently calculated values of θ, than there would have been if the original soil–depth profile and accompanying θ values were available. For some sites (particularly SMDB sites), original values of R, R_w and θ could not be recovered, but depth-integrated profile soil moisture values were available instead (Section 3.2.3).

3.2.3 Depth-integrated profile moisture content

Neutron probes generally provide count rates over a range of depths, for example, readings are often made every 0.1m in the top metre of soil and less frequently in the soil below. Values of the depth-integrated and soil-layer soil moisture contents can be determined using the approach of Bell (1976). Individual NP measurements of count rates are converted to fractional moisture content values, θ_i, at a range of depths, z_i, in the soil (section 3.2.2).

- To derive a soil-layer moisture content (M_i) in layer i, normally expressed as depth of water (m), the moisture content, θ_i, is multiplied by a layer factor, F_i, to give the water content of that layer, $M_i = \theta_i F_i$. The layer factor is usually assumed to be the distance between the half intervals on either side of the measuring depth. Thus a reading made at depth z_i can be assumed to apply to a section of soil with a depth range of $z_i - \Delta z_i/2 \leq z \leq z_i + \Delta z_{i+1}/2$, where $\Delta z_i = (z_i - z_{i-1})$ is the distance between neutron probe readings above and at z_i.
- The depth-integrated profile moisture content, PMC (mm water in a soil of depth z_n mm) from the surface to a particular depth of soil z_n, is given by the sum of the layer M_i values over the depth of soil z_n. A user might require a value for the total volume of water contained in a specific depth profile such as the top metre of soil, or over the maximum depth of soil.

Where the authors have recreated missing PMC values, they have assumed that the first measurement θ_1 at depth z_1 is applied to a layer extending up to the soil surface, and PMC is estimated to a depth of z_m mm as follows:

$$PMC = \theta_1 \frac{\Delta z_1}{2} + \theta_n \frac{\Delta z_n}{2} + \sum_{i=1}^{n-1} \theta_i \; \frac{(\Delta z_i + \Delta z_{i+1})}{2} \text{ mm of water.}$$

Here, the probe reading at depth z_n applies to an interval $\frac{\Delta z_n}{2}$ above and below the measurement, so only half of the reading is required for a profile moisture content that extends to z_n mm.

In the UKSMD, the depths of soil to which PMC values are provided can vary. For many sites PMC is provided from the surface to the maximum depth of the soil measurements, but for others, it is provided from the surface to specific depths of soil. Generally, the depths for which PMC values are provided are those selected by the original project team to answer a specific scientific question, and for some sites, they provided PMC values at multiple depths. For sites where PMC values were not available or not derived by the original project team, the authors have derived PMC down to the maximum measurement depth using the approach outlined above.

4. Dataset format and availability

4.1 Dataset format

The UK Soil Moisture Databank consists of the four files, 2 containing soil moisture data, and 2 metadata files (Table 1). One of the metadata tables (**Site_publications_UKSMD.csv**) provides a link to published references, reports and related datasets where available, and users of the UKSMD are encouraged to acknowledge the original research that provided these data, particularly if ongoing research focusses on particular sites. The second metadata table (**Tube_metdata_UKSMD.csv**) provides details of the NP tube location, including available information such as soil-type, altitude (m) and vegetation. The vegetation and soil-type are given in the format provided by the original observer, and they do not necessarily follow a particular set of categories. Vegetation for example, can be provided as a crop type, a type of woodland, percentage land cover, or a mix of vegetation types. To help the user identify broad categories of vegetation, post-processing has categorised VEGETATION as one of six main types: Arable, Grass, Grass/Woodland, Heathland, Orchard, or Woodland, in the LANDCOVER column in the **Tube_metadata_UKSMD.csv** metadata table.

Table 1: Summary of metadata and data files contained in the UK Soil Moisture Databank

File type	Files provided	Details	Units
Metadata	Tube_metdata_UKSMD.csv	Tube information: name, location, dates, depths, vegetation, land-use, soil-type, geology	n/a
	Site_publications_UKSMD.csv	List of published papers and reports associated with each area or site, together with a URL if available	n/a
Data	Volumetric_soil_moisture_UKSMD.csv	Time-series of neutron probe count rate, *R*, and volumetric soil moisture, θ, at a range of soil depths	R (no units), θ (m^3 water/m^3 soil)
	Profile_moisture_content_UKSMD.csv	Time-series of depth-integrated profile moisture content, PMC. Provided in two ways, PMC1 is m water in soil of depth z_n m, and PMC2 is expressed as m^3 water/m^3 soil	Kg m^{-2} (m) water stored in a soil of depth z_n m, and (m^3 water/m^3 soil)

Further details and formats of each metadata and data file are presented in tables 2 and 3. The files are provided in .csv (comma separated variable) format, that can be easily imported into a spreadsheet, or read by software written in languages such as R, Python or Fortran.

Table 2: Summary of metadata files contained in the UK Soil Moisture Databank

Metadata Table name	Column names	Description of data
Tube_metadata_UKSMD.csv	TUBE_ID	ID of the neutron probe access tube
	TUBE_NAME	Name or number of the neutron probe access tube
	AREA_ID	ID of the geographic area (5 characters)
	AREA_NAME	Name of the geographic area
	SITE_ID	ID of the site within the geographic area
	SITE_NAME	Name of the site within the geographic area
	EASTING, NORTHING	Great Britain (GB) national grid-co-ordinates (m)
	LATITUDE, LONGITUDE	Latitude and Longitude
	TUBE_START_DATE, TUBE_END_DATE	Start and end dates of measurements
	DEPTH_SPECIFIC, DEPTH - INTEGRATED	Whether soil-moisture data are available at different depths (Y/N), or are depth-integrated (Y/N)
	MAX_DEPTH	Maximum depth for which a measurement has been made (m)
	ALTITUDE	m AOD
	VEGETATION	As supplied by the original observer
	LAND_USE	Arable, Grass, Grass/Woodland, Heathland, Orchard, or Woodland
	SOIL_TYPE	Descriptive text supplied by the observer, or extracted from papers/reports
	GEOLOGY	Descriptive text supplied by the observer, or extracted from papers/reports
	CALIBRATION_COMMENT	The calibration equation used to calculate soil moisture, where available
	TUBE_COMMENT	Additional notes about the source of any recently reconstructed metadata
Site_publications_UKSMD.csv	AREA_ID	The main ID for the geographical area
	SITE_ID	Only provided if the reference refers to a specific site
	REFERENCE	References to papers and reports relating to the site
	URL/DOI	Provides a digital link to the paper if available online
	REFERENCE_COMMENT	Any comment on the reference

Table 3: Summary of soil moisture data files contained in the UK Soil Moisture Databank

Data Table name	Column names	Description of data
Volumetric_soil_moisture_ UKSMD.csv	DATE_TIME	Date and time: DD/MM/YYYY HH:MM
	TUBE_ID	The ID of the neutron probe access tube
	AREA_ID	ID of the geographic area (5 characters)
	RW	The neutron probe count rate in water, or "water count". (number of neutrons)
	DEPTH	Measurement depth (m)
	COUNT	Raw count data (number of neutrons)
	VOLUMETRIC SOIL_MOISTURE	Volumetric soil moisture, θ, (m^3 m^{-3}), generally $0 \leq \theta \leq 1$.
	COMMENT	"c" denotes θ values calculated during data recovery
	QUALITY1	QUALITY1 =1 for values >1.0, else QUALITY1=0
	QUALITY2	QUALITY2 =1 for jumps/spikes, else QUALITY2=0
Profile_moisture_content_ UKSMD.csv	DATE_TIME	Date and time: DD/MM/YYYY HH:MM
	TUBE_ID	The ID of the neutron probe access tube
	DEPTH	Depth of soil profile over which PMC is estimated (m)
	PMC1	Profile Soil Moisture Content, PMC1: the vertical integral of soil moisture from the surface down to DEPTH (provided as m water).

	PMC2	Profile Soil Moisture Content, PMC2: the vertical integral of soil moisture from the surface down to DEPTH (provided as m^3/m^3 water).
	COMMENT	"c" denotes PMC values calculated during data recovery
	QUALITY1	QUALITY1 =1 for values >1.0, else QUALITY1=0
	QUALITY2	QUALITY2 =1 for jumps/spikes, else QUALITY2=0

4.1 Soil-moisture data availability

Data for 45 geographic areas containing readings at 112 sites and 428 NP tube locations are now available, in 3 different forms:

- **Raw count**: neutron probe readings, R, and water count, R_w, at a range of depths (section 3.2.1)
- **Volumetric Soil Moisture**: θ, at a range of depths (m^3 water/m^3 soil, and $0 \leq \theta \leq 1$), (section 3.2.2),
- **Depth-integrated Profile Moisture Content (PMC)**: provided as m water stored in soil to a depth of z_n m, and as m^3 water/m^3 soil (section 3.2.3).

Figure 1 presents a map of the UK showing the locations of all the NP tubes and the area name (AREA_ID) and highlighting the approximate number of years of data that are available. To date no NP observations have been recovered for Northern Ireland. Notable datasets include 8 years of data from the Tern catchment (SMDBH), and 7 sites with NP observations spanning 10 or more years of data (shown with larger yellow dots), including 13 continuous years of data for tube sites in Hodnet Heath (HODHE) and Driby in Lincolnshire (LINCS).

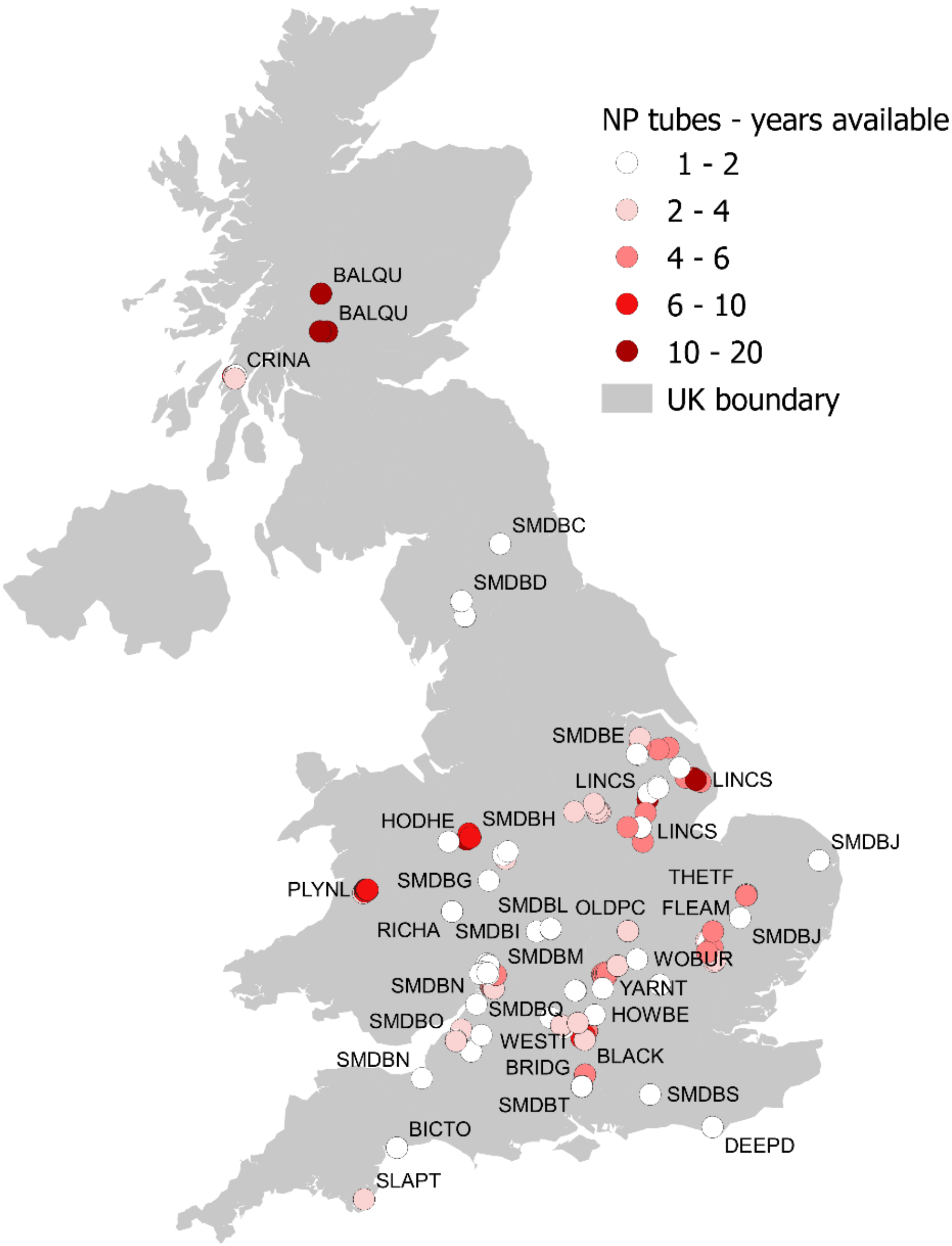

Figure 1: Map of the UK mainland showing the NP tube locations where soil moisture was measured (filled circles) labelled with the AREA_ID. The shading of the filled circles indicates the approximate number of years for which data are available at that location.

Table 4. List of geographic areas for which NP soil moisture observations are available and the number of sites and tubes associated with each area.

AREA_ID	AREA_NAME	number of sites	number of tubes	AREA_ID	AREA_NAME	number of sites	number of tubes
BALQU	Balquidder	4	23	SMDBE	Shardlow, Lincolnshire	5	6
BECHE	Beche Park	1	5	SMDBF	Doverbeck, Nottingham	10	10
BICTO	Bicton College	1	17	SMDBG	Aston, Birmingham	1	4
BLACK	Blackwood Beech Forest	3	19	SMDBH	Tern catchment, Shrewsbury	1	4
BRIDG	Bridget's Farm	3	17	SMDBI	Crewe/Stratford-on-Avon	3	5
CRINA	Crinan	1	22	SMDBJ	Norfolk	1	2
DEEPD	Deep Dean	1	13	SMDBK	Warwickshire, NVRS	1	6
FLEAM	Fleam Dyke	1	11	SMDBL	Warwickshire, NVRS	1	2
FRILS	Frilsham Meadow	1	4	SMDBM	Gloucestershire	6	12
GREND	Grendon	6	41	SMDBN	Gloucestershire	16	16
GRIMS	Grimsbury Wood	1	4	SMDBO	Long Ashton, Bristol	1	1
HIGHF	Highfield Farm	1	4	SMDBP	Long Ashton, Bristol	1	8
HODHE	Hodnet Heath	1	2	SMDBQ	Oxford University Farm, Wytham	1	9
HOWBE	Howberry Farm	2	9	SMDBR	Compton Beauchamp, Wantage	1	1
KNOWL	Knowle Farm	1	4	SMDBS	Jealott's Hill, West Sussex	1	2
LINCS	Lincolnshire	6	19	SMDBT	Southern England (IH)	4	4
OLDPC	Old Pond Close	2	10	SWANB	Swanbourne	1	4
PLYNL	Plynlimon	4	30	THETF	Thetford Forest	2	17
RICHA	Richard's Castle	1	5	WARRN	Warren Farm	3	7
ROTHD	Rothamsted	2	6	WESTI	West Ilsley	1	8
SLAPT	Slapton	2	20	WOBUR	Woburn Experimental Farm	2	4
SMDBC	Hexham Moors	1	2	YARNT	Yarnton	2	4
SMDBD	Lancaster	1	5				

5. Quality information

5.1 Missing data

All recovered data and metadata have been checked for errors, omissions and consistency, and obvious problems corrected with reference to the original data files, or papers/report where available. In each file missing data are indicated as “-1”. Where available, data are provided in 3 formats: NP readings, R, volumetric soil moisture, θ, and profile moisture content PMC. For sites where data are available in one form but not another, they have been calculated by the authors where possible. These values are identified with a “c” in the COMMENT column.

Where the original metadata (e.g. elevation of the monitoring site) are missing, they have been sourced from other contemporary datasets and a note has been included in the TUBE_COMMENT column of the **Tube_metadata_UKSMD.csv** file. Geographical locations of each NP tube (TUBE-ID) are provided as GB national grid easting and northings and as latitude and longitude. In some cases, the grid-references of closely located tubes are identical. Although there has been an attempt to improve the location information using data in published papers/reports, in some cases there has not been sufficient information to do so, either because this was not recorded at the time of monitoring, or because the authors were unable to link multiple sets of grid-references to individual NP tubes.

5.2 Quality control and uncertainty

Volumetric soil moisture values, θ, are generally expected to lie between 0 and 1. During the quality control process, any negative θ values were removed and recorded as "missing values" (-1). For three areas, BALQU (Balquhidder, Monachyle site), CRINA (Crinan, Knapdale) and PLYNL (Nant Iago and Cyff sites in Plynlimon), some θ values were greater than 1.0. All three of these areas lie in regions with high rainfall and peat-containing soils where high values of soil moisture are expected, particularly in winter, though not necessarily supersaturated soils. Where θ > 1.0 in the VWC file (Volumetric_soil_moisture_UKSMD.csv), and PMC2 > 1.0 in the PMC file (Profile_moisture_content_UKSMD.csv), the quality flag, QUALITY = q1. Given the uncertainty in estimation of absolute values of soil moisture from neutron probe readings (section 3.3.2), a user would be advised to place greatest emphasis in the variation in soil moisture rather than absolute values, and to treat any values of θ > 1 with suspicion.

A visual inspection of time-series of PMC values highlighted various discrepancies, for example, unrealistic jumps in the PMC data. Where possible, any discrepancies were traced back to the original digital data holding, to see where any error might have crept in. Where data were clearly incorrect but could not be corrected because there was no information available to do so, they were removed and recorded as "missing values" (-1). However, in other cases where both VWC and PMC values jump unrealistically, but the values agree with each other and with the original digitised data recorded by the observer, they have been retained. In such cases, the quality flag, QUALITY = q2.

NP-derived estimates of soil moisture are generally considered accurate, repeatable and sensitive to *changes* in soil moisture (Lekshmi et al. 2014, Akhtar et al. 2000), and are thought to provide good estimates of moisture content if calibrated for that purpose (Akhtar et al., 2000). However, several studies have indicated that NP-derived soil moisture estimates are more reliable for measuring changes in soil moisture, than for estimating soil moisture content itself, e.g. Vachaud et al. 1977, Akhtar et al. 2000, and Gardner (1981).

Values of θ and PMC derived by the original monitoring teams are provided whenever possible, as they will have been most familiar with the probe they used and the local soil properties. For data or sites where θ values are not available, and/or the recommended probe-specific calibration has not been undertaken, the requirement (section 3.2.2) to apply a probe calibration equation corresponding to one of three different soil-categories provides a significant source of uncertainty in estimates of θ from neutron probe readings. For example, for a typical water count, R_w, of 1000 and a reading, R, of 500, θ can vary between 0.37 and 0.47, depending on the Wallingford calibration equation selected. This variation in derived θ rises in line with the reading, R, and in very wet soils, e.g. $R \approx R_w$, the uncertainty can exceed 20%, however an expert investigator with a good understanding of the soil and tube site would be expected to identify the most appropriate calibration equation and minimise this potential source of error. For tube sites where neither the original soil moisture estimates nor the NP calibration equation were recovered, the authors have calculated θ values using the Wallingford calibration equation (section 3.3.2) assuming the soil-type listed in the metadata is correct and applies to soil at all depths. For these tubes and datasets, values calculated recently by the authors are labelled with a "c" in the "COMMENT column (Table 3), to alert users that there will be greater uncertainty in the absolute values of θ.

6. How to use the data

- Users of the UKSMD data are encouraged to acknowledge the original research studies that provided the soil-moisture measurements, particularly if research focuses on a particular site, or set of sites. To assist users, several publication references and URLs are provided in the

Site_publications_UKSMD.csv file, and Table A.1 presents an overview of the scientific studies to which these data originally contributed.

- If observations of volumetric soil-moisture at specific depths are required, the **Volumetric_soil_moisture_UKSMD.csv** file provides time-series of neutron probe count rate, R, and volumetric soil moisture, θ (m^3 water/m^3 soil), at various soil depths. Alternatively, if depth-average values of soil-moisture are preferred, for example to support comparisons across soils with varying depths, the **Profile_moisture_montent_UKSMD.csv** file provides time-series of depth-integrated profile moisture content, PMC (m^3 water/m^3 soil), from the soil surface to a specified soil-depth.
- Note that several studies have indicated that NP-derived soil moisture estimates are more reliable for measuring *changes* in soil moisture, than for estimating absolute values (section 5.2 provides more details).
- Quality flags "q1" and "q2" indicate suspect data, and analyses using UKSMD data could potentially be repeated with and without the suspect data values to assess sensitivity.
- Soil-moisture for sites associated with the LOCAR project (BECHE, FRILS, HIGHF, WARRN, WESTI), can be used alongside LOCAR meteorological data (Leach et al., 2015a,b).
- UKSMD data can also be used to assess or improve the performance (for example via data assimilation) of hydrological, agricultural, or land-surface models, where an independent measurement of soil-moisture at a range of soil depths is required. In combination with other soil-moisture datasets, such as the International Soil Moisture Network (ISMN, https://ismn.geo.tuwien.ac.at/en/, Dorigo et al., 2021), the Global Soil Moisture Databank (Robock et al. 2000), and COSMOS-UK (Evans et al., 2016), UKSMD data can support international studies into soil moisture variability.
- The UKSMD in-situ NP soil moisture measurements could potentially support assessments of remotely-sensed (EO) soil moisture products, though it is important to note that NP measurements are considered unreliable in the top 10cm of soil for which satellite and cosmic-ray sensor observations are generally provided.
- The UKSMD provides soil–moisture observations for UK sites with a range of soil-types, geological conditions and land-covers. Some of the monitoring was undertaken for pairs or spatial networks of NP tubes, supporting studies into the sensitivity of soil-moisture measurements to vegetation and to specific tube location. Soil moisture is a major driver of (greenhouse gas) nitrous oxide emissions (Butterbach-Bahl et al., 2013) and the UKSMD historical observations may prove valuable in supporting historical emissions assessments.
- The UKSMD NP observations span a 47-year period from 1966 to 2013 and include the prolonged and severe drought of 1976 which affected much of the UK (Rodda and Marsh, 2011). Many of the older SMDB data contained in the UKSMD were lost in the early 1980s and can now contribute to contemporary analyses into drought development and recovery.

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Appendix 1

Table A1: An overview of the data sources used in the UKSMD and the scientific studies to which they contributed. Further references and DOIs are provided in the **Site_publications_UKSMD.csv** file.

AREA_ID	AREA_NAME	Purpose of original study
BALQU	Balquidder	Effects of forest management on water resources in Scottish Highlands (Johnson and Whitehead, 1993)
BECHE	Beche Park	Follows on from the LOCAR (LOwland CAtchment Research) initiative (Wheater, Peach, & Binley, 2007).
BICTO	Bicton College	Estimation of groundwater recharge to chalk and sandstone aquifers (Ragab.et al. 1997)
BLACK	Blackwood Beech Forest	Hydrological impacts of hardwood plantation in lowland Britain (Neal et al., 1991)
BRIDG	Bridget's Farm	Recharge of an Upper Chalk aquifer (Wellings, 1984)
CRINA	Crinan	Afforestation on catchment runoff, and later research into water-use by forests (Calder, 1998).
DEEPD	Deep Dean	Processes of water movement through a chalk coombe deposit in SE England (Hodnett and Bell, 1990).
FLEAM	Fleam Dyke	Recharge in an English chalk aquifer (Wellings and Cooper, 1983).
FRILS	Frilsham Meadow	Follows on from the LOCAR (LOwland CAtchment Research) initiative (Wheater, Peach, & Binley, 2007).
GREND	Grendon	The Grendon Underwood field drainage experiment (IH Report No. 65), Beven (1980).
GRIMS	Grimsbury Wood	Follows on from the LOCAR (LOwland CAtchment Research) initiative (Wheater, Peach, & Binley, 2007).
HIGHF	Highfield Farm	Follows on from the LOCAR (LOwland CAtchment Research) initiative (Wheater, Peach, & Binley, 2007).
HODHE	Hodnet Heath	Post Drought Soil Water Recharge (Finch, 1999)
HOWBE	Howberry Farm	Reference transpiration and evaporation study for a riparian grassland site (Finch and Harding 1998)
KNOWL	Knowle Farm	Understanding transpiration from coppiced poplar and willow (Hall et al, 1998).
LINCS	Lincolnshire	Recharge in Lincolnshire: Estimates from soil water measurement (Gardner, 1990)
OLDPC	Old Pond Close	The Hydrological Impacts of Broadleaf Woodland in Lowland Britain (Rosier et al. 1990).
PLYNL	Plynlimon	Long-term variability in the water balances of the Plynlimon catchments (Hudson and Gilman, 1993).
RICHA	Richard's Castle	The Hydrological impacts of energy crop production in the UK (Finch J.W. et al, 2004)
ROTHD	Rothamsted	An objective assessment of soil-moisture deficit models (Calder et al., 1983)
SLAPT	Slapton	A study to determine subsurface hillslope runoff processes (Institute of Hydrology, 1993)
SMDBC	Hexham Moors	The Soil Moisture Databank: Moisture content data from some British soils (Gardner, 1990).
SMDBE	Shardlow, Lincolnshire	The Soil Moisture Databank (Gardner, 1990).
SMDBF	Doverbeck, Nottingham	The Soil Moisture Databank (Gardner, 1990).
SMDBG	Aston, Birmingham	The Soil Moisture Databank (Gardner, 1990).
SMDBH	Tern, Shrewsbury	The Soil Moisture Databank (Gardner, 1990).
SMDBI	Crewe/Stratford-on-Avon	The Soil Moisture Databank (Gardner, 1990).
SMDBJ	Norfolk	The Soil Moisture Databank (Gardner, 1990).

SMDBK	Warwickshire, NVRS	The Soil Moisture Databank (Gardner, 1990).
SMDBL	Warwickshire, NVRS	The Soil Moisture Databank (Gardner, 1990).
SMDBM	Gloucestershire	The Soil Moisture Databank (Gardner, 1990).
SMDBN	Gloucestershire	The Soil Moisture Databank (Gardner, 1990).
SMDBO	Long Ashton, Bristol	The Soil Moisture Databank (Gardner, 1990).
SMDBP	Long Ashton, Bristol	The Soil Moisture Databank (Gardner, 1990).
SMDBQ	Wytham, Oxford	The Soil Moisture Databank (Gardner, 1990).
SMDBR	Compton Beauchamp	The Soil Moisture Databank (Gardner, 1990).
SMDBS	Jealott's Hill, West Sussex	The Soil Moisture Databank (Gardner, 1990).
SMDBT	Southern England (IH)	The Soil Moisture Databank (Gardner, 1990).
SWANB	Swanbourne	Hydrological effects of short rotation energy coppice (Hall et al., 1996)
THETF	Thetford Forest	Water resource implications of the proposed Greenwood Forest (Cooper and Kinniburgh, 1993)
WARRN	Warren/Sheepdrove Farm	The research was part of the LOCAR initiative (Wheater, Peach, & Binley, 2007).
WESTI	West Ilsley (Folly Down)	The research was part of the LOCAR initiative (Wheater, Peach, & Binley, 2007).
WOBUR	Woburn Exp. Farm	The Hydrological impacts of energy crop production in the UK (Finch J.W. et al, 2004)
YARNT	Yarnton	Water Regime of River Meadows: Yarnton Mead Case Study (Gardner, 1991)