ROTHAMSTED RESEARCH

Biotechnology and Biological Sciences Research Council

North Wyke Farm Platform

Fine Resolution (15-minute) Soil Moisture Station Data






User Guide

Version 1.0

The North Wyke Farm Platform: Fine Resolution (15-minute) Soil Moisture Station Data

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Description: The North Wyke Farm Platform (NWFP) was established in 2010 to study and improve grassland livestock production at the farm-scale. The NWFP uses a combination of environmental sensors, routine field and lab-based measurements, and detailed management records to monitor livestock and crop production, emissions to water, emissions to air, soil health, and biodiversity. The rich NWFP datasets help researchers to evaluate the effectiveness of different grassland (and arable) farming systems, which in turn, contributes to the development of sustainable, resilient and net zero land management strategies. This document serves as a user guide to the soil moisture station (SMS) data (soil moisture and soil temperature sensors, rain gauge for precipitation) captured at a 15-minute temporal resolution. The guide gives details of the instrumentation, sensor calibration and data collection and is associated with other dedicated user guides that detail the design, establishment and development of the NWFP, field events, and the quality control process of datasets.

Site: North Wyke, Okehampton, Devon, UK. Geographic location: 50.76944, -3.90138; 50°46’10” N, 3°54’05” W.

Funding: Rothamsted Research receives strategic funding from the UK Biotechnology and Biological Sciences Research Council (BBSRC). The NWFP has been supported by grants BB/J004308/1, BBS/E/C/000J0100 and is currently supported by grant BBS/E/RH/23NB0008 (2023-28).

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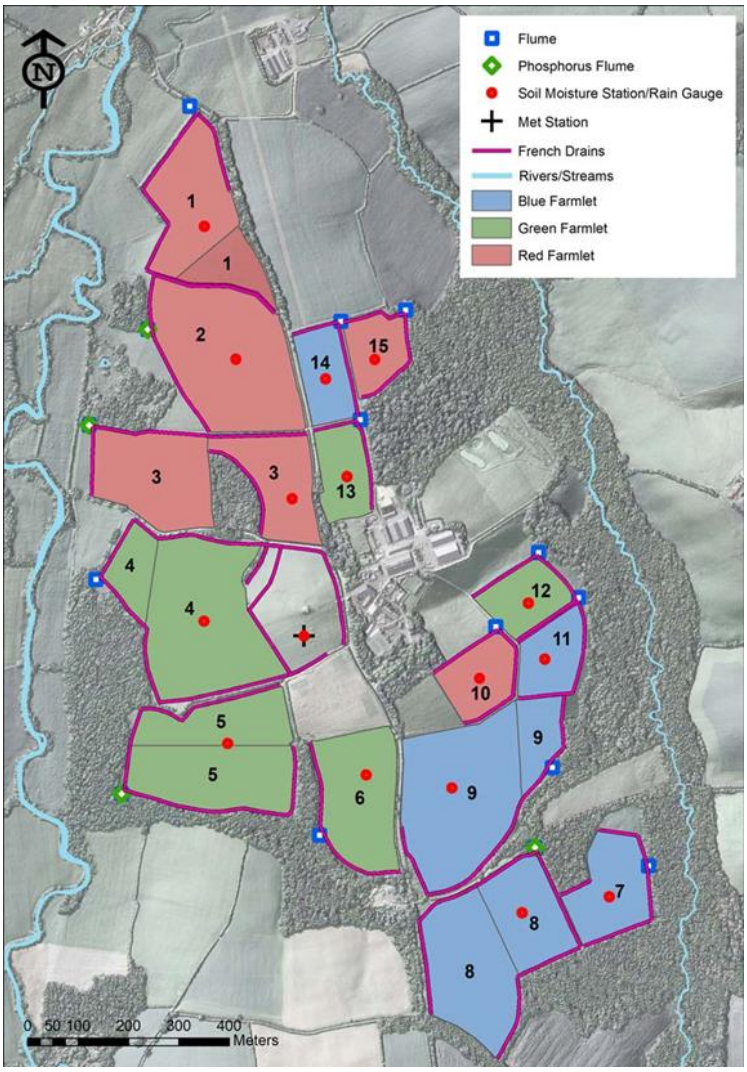
1 Introduction

This document provides a guide to the instrumentation used to capture the soil moisture, soil temperature and rainfall data produced at a 15-minute temporal resolution at soil moisture stations (SMS) located centrally on each of the catchments on the NWFP (Figure 1). Information on the site characteristics, design and development of the NWFP, and the quality control (QC) system for the data can be found in the following User Guide documents available on the NWFP website:

- NWFP_UG_Design_Develop.pdf
- NWFP_UG_QC.pdf

Figure 1. Map of NWFP showing systems as of 2015-2019 (first system change period [1]).



[1] *Green farmlet = permanent pasture, Blue farmlet = high sugar grass/clover; Red farmlet = high sugar grass, and later converted to arable in autumn 2019 (start of second system change period). In November 2017, phosphorus was measured at catchment or flume 3 in addition to flumes 2,5, & 8. From autumn 2023 onwards phosphorus will be measured on all catchments. Numbers represent catchment number. Note some catchments consist of multiple fields.*

2 Instrumentation

2.1 Monitoring Soil Moisture, Soil Temperature and Rainfall

An SMS is sited in each of the 15 catchments, consisting of an RTU [A723 addIT Series 4] a combination soil moisture and temperature probe (SM1) and a rain gauge (RG1) all supplied by Adcon, OTT HydroMet GmbH, Vienna, Austria (Figure 2) the specifications of which are described in Appendix A .

Figure 2. Soil moisture station with tipping bucket rain gauge.

The SM1 probe measures soil moisture using capacitance at depths of 10 cm, 20 cm and 30 cm and soil temperature at 15 cm. However, only soil moisture data at 10 cm are available on the data portal as data at the lower depths were deemed unreliable for this soil series.

The SM1 is connected to the RTU via an SDI 12 interface and the raw data are converted to soil moisture using a lookup table developed from testing the sensor output in $1m^3$ blocks of North Wyke soil under a range of different soil moisture conditions. Data from the tipping bucket rain gauge are collected by the RTU's integrated pulse counter at a resolution of 0.2 mm per tip. The original SMS for Catchment 4 was located within the meteorological instruments compound. However, the change in area of Catchment 4 on 13/08/2013 (detailed in the user guide entitled 'NWFP_UG_Design_Develop.pdf') resulted in the SMS being located outside the catchment. A new SMS station was installed in the new Catchment 4 on 04/02/2015.

To provide a reliable dataset, the Catchment 4 data on the data portal start when the new SMS was installed on 04/02/2015. The rainfall data have been included in the MET data and are available for download via the portal.

During June - November 2015 all the A51760 model Adcon soil moisture sensors installed in 2011 were replaced with the A51730 model.

In addition to the soil moisture sensors mentioned above, the NWFP is one of the sites in the UK Centre for Ecology & Hydrology (CEH) Cosmic-ray soil moisture monitoring (COSMOS-UK) network, and an instrument was installed on the NWFP on Catchment 2 on 10/10/2014.

More information on the COSMOS-UK network can be found here:
https://cosmos.ceh.ac.uk/

The near real-time data for the NWFP are freely available here:
https://cosmos.ceh.ac.uk/sites/NWYKE

3 Sensor Calibration and Data Harmonisation

Many sensor calibrations or harmonisations directly relate to the QC of the 15-minute data, the details of which can be found in the User Guide to the QC system entitled 'NWFP_UG_QC.pdf'.

3.1 Soil Moisture Stations

To harmonise the data collected from two different firmware of the soil moisture probes (Section 2.1), new conversion formulae were generated under experimental conditions and used to recalculate the data. The experiment was conducted as follows. A 1 m^3 soil-block of Hallsworth series soil, as found on the NWFP, was extracted, and moved undercover. The 2 firmware versions of the soil moisture probes were installed in the block. The soil-block was saturated above field capacity and then allowed to dry naturally over a 6-month period. During this time, fortnightly measurements were taken from the probes and simultaneously a soil sample was removed from the block to coincide with the measurement depth(s). The soil sample was oven dried to measure the actual moisture content. Data from the probes and the oven dried samples were plotted against each other and fitted with a linear regression. No clear relationship was found for either the 20 cm or 30 cm depth results and thus these data from the probes were deemed unreliable for this soil series. Consequently, the 20 cm and the 30 cm soil moisture data have been removed from the Data Portal, and only the 10 cm data remain. The formulae for the conversion from scaled frequency unit (SFU) output from the probes to soil moisture are given in Appendix B.

3.2 Rain Gauges

Rain gauges (RGs) are checked monthly in the field for basic functionality, and periodically under laboratory conditions since 02/04/2014. A known quantity (500 ml) of water is dripped through them and the number of tips counted. If there is any difference between the expected and observed number of tips, a correction factor is generated which can be applied to the data. The decision was made not to correct the data, as the frequency of the checks made it difficult to determine the actual behaviour of the instruments in the field. However, the results

of the checks are provided in Appendix C and downloaded RG values could potentially be improved if multiplied by the corresponding catchment-specific correction factor.

3.3 Data Telemetry and Acquisition

Central to the NWFP experiment is the communication network that provides continuous data transfer from the in situ soil moisture, soil temperature and tipping bucket raingauges. At present the NWFP, the telemetry network collects data every 15 minutes.

Data transfer from the soil moisture station sensors is via remote telemetry units (RTUs) [Adcon, OTT HydroMet GmbH, Vienna, Austria], which collect in-field data at configured intervals and transmit via UHF radio. Other telemetry components supplied by Adcon, OTT HydroMet GmbH include:

1. A centrally located base-station (A850 Gateway) which manages the RTU network, receiving the data as well as having the capability to send commands back to the RTUs if required.
2. Software (addVantage Pro), which collects, stores, processes, and displays the data via its integrated web server.

Raw data are collected from loggers in the field (Adcon RTUs via UHF radio) every 15 minutes and hosted by Adcon addVANTAGE pro software, allowing for visualisation (Figure 3), data processing, automated control, event alarming and data export/distribution. An extension running within the software automatically creates and exports weekly CSV files for each parameter for archive and subsequent QC procedures.

Figure 3. Example of graphical display by the addVantage Pro software of soil moisture, soil temperature and rainfall data for one of the catchments.

4 Sensor Downtime Log

A log of all sensor downtime issues is maintained in MS Access where input forms and restricted fields are used to ensure that the correct and required data is recorded. The information includes details on the location, the sensor, the start and end times the sensor was not functioning correctly, information about the problem and the required QC action (e.g., set recorded data as missing or add a 'unreliable' flag to the data). Exports from this worksheet are automatically used as part of the QC process. The sensor downtime log also serves as a useful reference when trouble shooting current sensor issues.

5 Data Portal

The NWFP Data Portal (https://nwfp.rothamsted.ac.uk/) allows accessibility to the core NWFP datasets to not only Rothamsted Research but also the wider research community. The data are open access and free to download but users are required to register their interest.

For information on the latest version of the 15-minute datasets and the changes since the last version, please refer to the User Guide entitled 'NWFP_UG_QC.pdf' available on the NWFP website:

http://resources.rothamsted.ac.uk/farm-platform-national-capability/data-portal-guides-and-information.

In addition, the website offers a wealth of online, and regularly updated information to complement the data.

6 Citing the Data

If you choose to use any of datasets provided by the NWFP in a publication, please cite:

- *Orr, R. J., Murray, P. J., Eyles, C. J., Blackwell, M. S. A., Cardenas, L. M., Collins, A. L., Dungait, J. A. J., Goulding, K. W. T., Griffith, B. A., Gurr, S. J., Harris, P., Hawkins, J. M. B., Misselbrook, T. H., Rawlings, C., Shepherd, A., Sint, H., Takahashi, T., Tozer, K. N., Whitmore, A. P., Wu, L. and Lee, M. R. F. (2016). The North Wyke Farm Platform: effect of temperate grassland farming systems on soil moisture contents, runoff and associated water quality dynamics. European Journal of Soil Science, 67, 4, 374-385. (doi:10.1111/ejss.12350).*

In addition, if using data from the baseline period please cite:

- *Takahashi, T., Harris, P., Blackwell, M. S. A., Cardenas, L. M., Collins, A. L., Dungait, J. A. J., Hawkins, J. M. B., Misselbrook, T. H., McAuliffe, G. A., McFadzean, J. N., Murray, P. J., Orr, R. J., Rivero, M. J., Wu, L. and Lee, M. R. F. (2018). Roles of instrumented farm-scale trials in trade-off assessments of pasture-based ruminant production systems. Animal, 12, 8, 1766-1776. (doi:10.1017/S1751731118000502).*

- *Orr, R. J., Griffith, B. A., Rivero, M. J. and Lee, M. R. F. (2019). Livestock Performance for Sheep and Cattle Grazing Lowland Permanent Pasture: Benchmarking Potential of Forage-Based Systems. 9, 2, 101-118. (doi:10.3390/agronomy9020101).*

For the datasets used, please cite the latest version of the relevant User Guide PDF document(s), listed in the table below, that describe the establishment and development of the NWFP, and the various datasets produced in detail. The link to these can be downloaded from the NWFP website. Note that the User Guide entitled 'NWFP_UG_Design_Develop.pdf' should be cited irrespective of the dataset used.

Data used	Main title of User Guide PDF document
All datasets	NWFP_UG_Design_Develop.pdf
15-minute time-series datasets (water, soil moisture, meteorology)	NWFP_UG_Hydrology&WaterQuality_Data.pdf NWFP_UG_SMS_Data.pdf NWFP_UG_MET_Data.pdf
Greenhouse gases	NWFP_UG_EC_GHG_Data.pdf NWFP_UG_GreenFeed_Data.pdf
Field surveys	NWFP_UG_FieldSurvey_Data.pdf
Livestock	NWFP_UG_Livestock_Data.pdf
Field events	NWFP_UG_FieldEvents_Data.pdf

Also, please include the following sentences in the acknowledgments section:

"The North Wyke Farm Platform is a UK National Capability supported by the Biotechnology and Biological Sciences Research Council (BBS/E/RH/23NB0008)."

"We acknowledge the interests of the Ecological Continuity Trust (ECT), whose national network of LTEs includes the experiment on which this research was conducted."

7 Appendices

Appendix A. Soil properties monitored at each of the fifteen catchments on the NWFP.

Soil Property	Method	Units	Range	Resolution	Accuracy
Precipitation	Tipping bucket	mm	0 – 100 per hour	0.2	0-50: ±1%
Soil Temperature @ 15 cm depth	Thermistor	°C	-55 - 70	0.125	±0.5
Soil Moisture @ 10 cm depth	Capacitance sensor	%	0 - 100	0.1	±2.0

Appendix B. Formulae for conversion from scaled frequency unit (SFU) to soil moisture.

Soil Moisture Sensor	Formulae
SM1 A51730, F/W 6.0	% soil moisture = SFU - 18.80) / 1.808
SM1 A51730, F/W 6.2	% soil moisture = SFU + 12.87) / 1.808

Appendix C. Correction factors[2] calculated for rainfall data (2014-2019).

Catchment Number	Feb 2014	Aug 2015	Feb 2017	Jul 2019
1	1.124	0.980	1.157	1.164
2	1.131	1.136	1.116	1.114
3	1.147	1.179	1.121	1.163
4	1.142	1.106	1.147	1.123
5	1.087	0.988	1.147	1.161
6	1.109	1.131	1.101	1.155
7	1.068	1.073	1.152	1.205
8	1.082	1.042	1.163	1.045
9	1.055	1.111	1.059	1.126
10	1.083	1.109	1.190	1.164
11	1.076	1.073	1.020	1.023
12	1.100	1.101	1.142	1.084
13	1.122	1.064	1.131	1.148
14	1.065	1.055	1.078	1.054
15	1.060	1.073	1.106	1.107

[2] *1 mm raw values*