Data Article

Data on spatial and temporal modelling of soil water storage in the Guinea savannah zone of Northern Ghana

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A B S T R A C T
In this article, we present the space-time variability of soil moisture (SM) and soil water storage (SWS) from key agricultural benchmark soil types measured across the Guinea savannah zone of Ghana (n ≈ 2,000 measurements) in a single cropping season (Nketia et al., 2022). From 36 locations, SM measurements were obtained with a PR2/60 moisture probe calibrated for a 0–100 cm soil depth interval (at six depths). We further introduce a new pedotransfer model that was developed in deriving the SWS for the same depth interval of 0–100 cm. Assessing information on the space-time variability of SM and SWS is essential for agricultural intensification efforts, especially in semi-arid landscapes of sub-Saharan Africa (SSA), where there is the need and the potential to increase food-crop production. This dataset spans the main topographic units of the Guinea savannah zone and covers dominant vegetation types and land uses of the region, which is similar to most parts of West Africa. The comprehensive dataset and the customized machine learning models can be used to support crop production with respect to water management and optimized agricultural resource al-
location in the Guinea savannah landscapes of Ghana and other parts of SSA.

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**Specifications Table**

| Subject | Agricultural Sciences. |
|---------|------------------------|
| Specific subject area | Soil science for sustainable agriculture, food security and soil water management. |
| Type of data | Tables, Figures, and 'R' data files. |
| How data were acquired | Station measurements of soil moisture (SM) using a probe. |
| Data format | Raw, analyzed. |
| Description of data collection | *In situ* SM content was taken at 36 locations across key agricultural benchmark soil locations using a calibrated Delta-T PR2/60 moisture probe at 0–100 cm soil depth (subdivided into six depths) in the Guinea savannah landscapes of Ghana. Sampling locations were stratified using a hybrid model, which coupled a global weighted principal component algorithm and a cost-constrained conditioned Latin hypercube algorithm. |
| Data source location | • Region: Northern Ghana (Tamale region), Guinea savannah agroecological zone.  
• Country: Ghana.  
• 36 Geographical Position System (GPS) coordinates of the measurement locations are included in the article. |
| Data accessibility | Data available within the article and also hosted on an open-access cloud repository:  
• Repository name: Zenodo  
• Data identification number (doi): 10.5281/zenodo.6447871  
• Direct URL to data: https://zenodo.org/record/6447871#.YlQpc8hByHs. |
| Related research article | K.A. Nketia, S.B. Asabere, A. Ramcharan, S. Herbold, S. Erasmi, D. Sauer, Spatio-temporal mapping of soil water storage in a semi-arid landscape of Northern Ghana–A multi-tasked ensemble machine-learning approach, Geoderma. 410 (2022) 115,691. https://doi.org/10.1016/j.geoderma.2021.115691 |

**Value of the Data**

- The data provides information on space-time SM and SWS over 0–100 cm soil depth for key agricultural benchmark soils of the Guinea savannah zone of Ghana.
- It provides useable information on the 4D SWS distribution of the Guinea savannah region of Ghana, which can support farmers in estimating where, when, how much, and for how long SWS is available for cultivation [1].
- The data is useful for soil and agronomic research into crop yield production limited by water stress, such as modelling scenarios of water management for dry-season farming.

1. **Data Description**

The data presented in this paper illustrates the space-time variability of soil moisture (SM) and soil water storage (SWS) of 36 stratified locations of the Guinea savannah zone of Ghana (n ≈ 2000). **Fig. 1** shows the study area and locations from where *in situ* SM measurement were collected, covering a 170 × 190 km area across seven key agricultural benchmark soil types.
Table 1 shows site characteristics and their associated GPS coordinates for the 36 measurement locations. Fig. 2 illustrates how the in situ SM measurements and soil sampling at each measurement location was conducted. We modelled vertical variation in SWS for the 36 locations, using a set of pedotransfer algorithms, converting the in situ measured SM at standard depths (i.e., 10, 20, 30, 40, 60, and 100 cm) into six depth intervals (i.e., 0–5, 5–15, 15–30, 30–40, 40–60, and 60–100 cm) as per GlobalSoilMap specifications [2]. The data file called ‘Code_C1.R’ (https://zenodo.org/record/6447871#.YlQpc8hByHs) shows the fully commented systematic SWS modelling framework used in deriving SWS data within this article.

Fig. 3 depicts a soil catena showing the soil types of the study area along which measurements were undertaken. The dataset can also be grouped based on the seven key benchmark soil types covering the three topographical units of the study area (Fig. 3) [4]. The upper slope is covered by Eutric Plinthosols (Kpelesawgu series in the local Ghanaian soil classification system). Soils on middle to lower slopes include Gleyic Planosols (Lima series), Petric Plinthosols (Changnalili series) and Chromic Lixisols (Kumayili series), and soils on toe slopes are Gleyic Fluvisols (Dagare series), Plinthic Lixisols (Siare series) and Fluvic Gleysols (Volta series).

The shared dataset reported in the article is stored in an excel file, called ‘File_T1_SM_SWS.xlsx’ (https://zenodo.org/record/6447871#.YlQpc8hByHs). The ‘File_T1_SM_SWS.xlsx’ file contains two spreadsheets, i.e., ‘SM’ for raw SM data, and ‘SWS’ for the calculated SWS data. The variables in each data sheet are specified below:

- Sheet ‘SM’ shows the station IDs of the in situ measurement locations (column 1) and the lower soil depths (in cm) at which SM measurements were taken (column 2). Columns 3 and 4 contain the raw volumetric SM measurements expressed in percentages and their associated measurement dates, respectively. Columns 5 and 6 show WGS84 coordinates of the measurement stations in latitude and longitude, respectively.
Table 1
Site characteristics and GPS coordinates for all sampling locations from the Guinea savannah zone of Ghana.

| Station ID | Latitude [°] | Longitude [°] | Soil type* | Soil association** | WRB classification | Geology | District block |
|------------|-------------|---------------|------------|-------------------|-------------------|---------|----------------|
| **Sites where SM and physical soil properties were determined** | | | | | | | |
| AT01 | 9.38209 | −0.68264 | Lima | Sambu-Pasga | Gleyic Planosols | Shale, Mudstone, Sandstone | Mion |
| AT02 | 9.3898 | −1.02133 | Kpelesawgu | Sambu-Pasga | Eutric Plinthosols | Shale, Mudstone, Sandstone | Tolon |
| AT03 | 9.24358 | −0.62165 | Changnalili | Lima-Volta | Petric Plinthosols | Alluvial sediments | Karaga |
| AT04 | 9.30885 | −0.71828 | Kpelesawgu | Techiman-Tampu | Eutric Plinthosols | Voltain sandstone | Tamale Metro |
| AT05 | 9.40523 | −1.23727 | Changnalili | Kpelesawgu-Changnalili | Petric Plinthosols | Voltain shale | Tolon |
| AT06 | 9.55798 | −0.96041 | Lima | Lima-Volta | Gleyic Planosols | Alluvial sediments | Kumbungu |
| AT07 | 9.55211 | −1.17127 | Lima | Sambu-Pasga | Gleyic Planosols | Shale, Mudstone, Sandstone | Kumbungu |
| AT08 | 9.34742 | −0.75396 | Lima | Techiman-Tampu | Gleyic Planosols | Voltain sandstone | Tamale Metro |
| AT09 | 9.2598 | −0.72064 | Lima | Lima-Volta | Gleyic Planosols | Alluvial sediments | East Gonja |
| AT10 | 9.45722 | −1.29907 | Lima | Kpelesawgu-Changnalili | Gleyic Planosols | Voltain shale | North Gonja |
| **Sites where in situ measurements were taken** | | | | | | | |
| AT11 | 9.63135 | −1.18874 | Lima | Kpelesawgu-Changnalili | Gleyic Planosols | Voltain shale | Kumbungu |
| AT12 | 9.39602 | −0.48972 | Kumayili | Techiman-Tampu | Chromic Lixisols | Voltain sandstone | Tamale Metro |
| AT13 | 9.41191 | −0.23344 | Changnalili | Gushiagu-kasele | Petric Plinthosols | Voltain shale | Karaga |
| AT15 | 9.32232 | −0.81182 | Lima | Lima- Volta | Gleyic Planosols | Alluvial sediments | East Gonja |
| AT16 | 9.08735 | −1.13139 | Siare | Siare-dagare | Plinthic Lixisols | Alluvial sediments | Central Gonja |
| AT17 | 9.80794 | −0.4222 | Lima | Kpelesawgu-Changnalili | Gleyic Planosols | Voltain shale | Karaga |
| AT18 | 9.08612 | −1.03072 | Volta | Kpelesawgu-Changnalili | Fluvic Gleysols | Voltain shale | Central Gonja |
| AT19 | 9.57707 | −0.7718 | Lima | Techiman-Tampu | Gleyic Planosols | Voltain sandstone | Savelugu Nanton |
| AT20 | 9.31643 | −0.25106 | Lima | Sambu-Pasga | Gleyic Planosols | Shale, Mudstone, Sandstone | Mion |
| AT22 | 9.75427 | −0.82686 | Volta | Lima-Volta | Fluvic Gleysols | Alluvial sediments | Kumbungu |

(continued on next page)
## Table 1 (continued)

| Station ID | Latitude [*°] | Longitude [*°] | Soil type** | Soil association** | WRB classification | Geology | District block |
|------------|---------------|----------------|-------------|-------------------|------------------|---------|----------------|
| AT23       | 9.51278       | −0.75376       | Lima        | Lima-Volta        | Gleyic Planosols | Alluvial sediments | Savelugu Nanton |
| AT24       | 9.47611       | −1.13107       | Kumayili    | Sambu-Pasga      | Chromic Lixisols | Shale, Mudstone, | Savelugu Nanton |
| AT25       | 9.38885       | −0.2706        | Kpelesawgu  | Techiman-Tampu   | Eutric Plinthosols | Volcan sandstone  | Tamale Metro   |
| AT26       | 9.53645       | −1.37973       | Dagare      | Sambu-Pasga      | Gleyic Fluvisols  | Shale, Mudstone, | North Gonja    |
| AT27       | 9.52581       | −0.92455       | Lima        | Lima-Volta        | Gleyic Planosols | Alluvial sediments | Kumbungu       |
| AT28       | 9.73252       | −0.47761       | Lima        | Sambu-Pasga      | Gleyic Planosols | Alluvial sediments | Karaga          |
| AT29       | 9.15954       | −1.42628       | Lima        | Techiman-Tampu   | Gleyic Planosols | Volcan sandstone  | Central Gonja  |
| AT30       | 9.40799       | −0.45041       | Lima        | Lima-Volta        | Gleyic Planosols | Alluvial sediments | Mion            |

### Sites where in situ measurements were taken

| AT31       | 9.07524       | −0.54386       | Lima        | Sambu-Pasga      | Gleyic Planosols | Shale, Mudstone, | East Gonja      |
| AT32       | 9.32838       | −0.93585       | Lima        | Lima-Volta       | Gleyic Planosols | Alluvial sediments | Central Gonja  |
| AT33       | 9.60072       | −0.84122       | Kumayili    | Mimi-Techiman    | Chromic Lixisols | Volcan sandstone  | North Gonja     |
| AT34       | 9.59978       | −0.63474       | Lima        | Kpelesawgu-Changnalili | Gleyic Planosols | Volcan shale | Savelugu Nanton |
| AT35       | 9.38973       | −0.33578       | Lima        | Lima-Volta       | Gleyic Planosols | Alluvial sediments | Mion            |
| AT36       | 9.49393       | −0.69697       | Lima        | Lima-Volta       | Gleyic Planosols | Alluvial sediments | Karaga          |
| AT37       | 9.47358       | −0.84833       | Lima        | Techiman-Tampu   | Gleyic Planosols | Volcan sandstone  | Sagnerigu       |
| AT38       | 9.20374       | −0.97482       | Volta       | Kpelesawgu-Changnalili | Fluvic Gleysols | Volcan shale | Central Gonja   |

### Sites for plant available water content

| Wet 1      | 9.65884       | −0.57731       | Lima        | Lima-Volta       | Gleyic Planosols | Alluvial sediments | Karaga          |
| Wet 2      | 9.40714       | −0.98608       | Kpelesawgu  | Sambu-Pasga     | Eutric Plinthosols | Shale, Mudstone, | Tolon           |

** according to the Ghanaian soil classification system.
Fig. 2. In situ SM measurement and undisturbed soil sampling. (A)–(C) Installation of access tubes for the PR2/60 moisture probes (Delta-T Devices) down to a depth of 100 cm. (D) 3D representation of a soil profile with installed access tube and PR2/60 moisture probe. (E)–(F) Soil sampling with a stainless-steel cylinder at specific soil depths.

- In sheet ‘SWS’, also station IDs of the measurement locations (column 1) and their corresponding dates of measurement (column 2) are presented. Columns 3 and 4 contain the upper and lower soil depth, respectively, (both in cm), for which SM measurements were taken. Columns 5 and 6 contain the benchmark soil types (in the Ghanaian local system) and their equivalent FAO World Reference Base classification, respectively. Columns 7 and 8 show soil thickness (in cm) and its corresponding calculated SWS (expressed by an absolute value in mm), respectively. Column 9 shows the topographic units along which the seven key benchmark soil types occur.
Fig. 3. Soil types along the three topographical units. Chart not drawn to scale. Modified from Nketia et al. [1].

The data covers soils under different vegetation types such as Borassus palm (*Borassus aethiopum*), Senegal mahogany (*Khaya senegalensis*), shea tree (*Vitellaria paradoxa*) and natural grassland (*Pennisetum purpureum*), and soils under various types of land use, including dryland farming, irrigated vegetable cultivation and pastures.

2. Experimental Design, Materials and Methods

2.1. In situ SM measurements

The 36 measurement locations were stratified following an unbiased approach that coupled the global weighted principal component algorithm with a cost-constrained conditioned Latin hypercube algorithm [3]. With this approach, it was possible to account for the maximum local spatial structures of the study area, while selecting optimized locations that highly influenced SM variability.

SM measurements were taken in 36 soil profiles, located on the three main soil topographic units: upper, middle-lower, and toe slopes (Fig. 3). At each location, an access tube was installed (Fig. 2A−C), where SM was measured at six standard depths within the 0−100 cm depth (i.e., 10, 20, 30, 40, 60, and 100 cm) using a calibrated moisture probe (PR2/60, Delta-T Devices) (Fig. 2D). One of the objectives of work reported in the associated paper of this data article, Nketia et al. [1] was to estimate SM from Sentinel-1 data. Thus, the SM measurements were timed to coincide with the overpass of the Sentinel-1 satellite at a temporal resolution of 12 days for ten time-steps covering the whole dry season (i.e., February–June). Thus, in total 2,160 soil measurements were taken.

2.2. SWS modelling framework

An important contribution of this data is the modelled SWS. This part of the data was derived by implementing a pedotransfer algorithm in two main stages as illustrated in Fig. 4. In a first
step, *in situ* SM measurements were vertically discretized into six depth intervals (i.e., 0–5, 5–15, 15–30, 30–40, 40–60, and 60–100 cm) following the *GlobalSoilMap* specifications [2]. In a second step, SWS at each data point was recursively profiled as a function of the measured *in situ* SM, bulk density and the effective soil thickness between two soil layers [1]. By this approach, we accounted for the differential availability of SWS critical to the management of shallow and deep-rooted plants notable to the study area. This approach also allowed us to account for the effect of soil depth on *in situ* SM measurements.

The study area is characterized by an inherent plinthic and petro-plinthic horizon, occurring at 70–100 cm depth [4] and thus restricting water movements between lower and upper soil layers. Because of this situation groundwater movement was not considered in the SWS modelling framework. Thus, we only assumed SWS for the succeeding soil depth (*d*) as a reservoir for the preceding soil depth (d−1) at a time-step (t). For this rationale, observed changes in measured SM of the soil depths is proportional to the change in modelled SWS at a location between a preceding and a succeeding soil depth at a time-step. Eq. (1) defines the SWS model, which is expressed by an absolute value in mm. For each *in situ* SM measurement at each point in time and soil depth, we accounted for the SWS loss or gain at this point with respect to its initial state [5,6]. Well annotated *R* [7] scripts that were used in modelling SWS are presented in the file ‘Code_C1.R’ (available at https://zenodo.org/record/6447871#.YlQpc8hByHs).

\[
SWS_{itd} = 0.1 * f(SM_{itd}, BD_{id}, h_{id})_t + R_t * f(SM_{id}, BD_{id}, h_{id})_{t-1}
\]  

(1)

where input parameters for function (*f*), calculated at a constant factor of 0.1 (from density of water of 1 g cm\(^{-3}\)), were *in situ* SM (*SM_{itd}; %Vol*) at location (*i*), time-step (*t*) and soil depth (*d*), bulk density laboratory data (*BD_{id}; g cm\(^{-3}\)) and respective soil thickness (*h_{id}; cm*). *R*\(_t\) explains the rate of loss or gain in *SM_{itd} between a preceding and subsequent soil depth interval [6], and
Fig. 5. Space-time variability of SWS for benchmark soil types; (A) Kpelesawgu series, (B) Changnalili series, (C) Dagare series, (D) Kumayili series, (E) Lima series, (F) Siare series and (G) Volta series along the various in situ measurement depths. Soil names are in Ghanaian soil classification system. Statistical measures (range – length of whiskers and medians – vertical bars) indicating the space-time variability of SWS are also shown. RZ-SWS means rootzone soil water storage.

varies from 0 (low loss or gain) to ± 1 (high loss or gain). Fig. 5 illustrates the variability of SWS per each benchmark soil type along the in situ measurement depth intervals.

Ethics Statement

There is no conflict of interest. The data is available to the general public.

Supplementary Material

Full datasets (i.e., Code_C1.R, File_T1_SM_SWS.xlsx and ‘Spatio-temporal variability of SWS.pdf’) are hosted on an open-access repository at https://zenodo.org/record/6447871#.Y1Qpc8hByHs.

CRedit Author Statement

Kwabena Abrefa Nketia: Conceptualization, Data curation, Methodology, Investigation, Visualization, Writing – original draft; Stephen Boahen Asabere: Conceptualization, Methodology, Investigation, Writing – review & editing; Daniela Sauer: Consultation/support in the conceptualization and in the realization of the methodological approach, Writing – review & editing.
Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data Availability

Data on space-time soil moisture and modelled soil water storage, Ghana (Original data) (Zenodo).

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