Soil Bulk Density Data (FIFE)

Summary:

Soil bulk density is defined as the ratio of the mass of dry solids to the bulk volume of the soil occupied by those dry solids. Bulk density of the soil is an important site characterization parameter since it changes for a given soil. It varies with structural condition of the soil, particularly that related to packing.

The Soil Bulk Density Data Set contains bulk density of the soil based on dry weight at two depths, 0-10 cm and 10-20 cm. Samples were collected at 31 different locations within the FIFE study area during the growing season of 1987. Samples were collected primarily in the northwest quadrant of the study area but at least one sitegrid is located in each of the quadrants of the study area.

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1. Data Set Overview:

Data Set Identification:

Soil Bulk Density Data (FIFE).

Data Set Introduction:

The Soil Bulk Density Data Set contains bulk density of the soil based on dry weight at two depths, 0-10 cm and 10-20 cm. Samples were collected at 31 different locations within the FIFE study area during the growing season of 1987.

Objective/Purpose:

Obtain and calculate measures of soil bulk density.

Summary of Parameters:

Soil density at a specific depth.

Discussion:

Bulk density of the soil based on dry weight is available in this data set at two depths, 0-10 cm and 10-20 cm. Samples were collected at 31 different locations within the FIFE study area during the growing season of 1987 (April - October). Samples were collected primarily in the northwest quadrant of the study area but at least one sitegrid is located in each of the quadrants of the study area. Bulk density of the soil is an important site characterization parameter since it changes for a given soil. It varies with structural condition of the soil, particularly that related to packing.

Related Data Sets:

- Gravimetric Soil Moisture.

FIS Data Base Table Name:

SOIL_BULK_DENSITY_DATA.

2. Investigator(s):

Investigator(s) Name and Title:

Staff Science.

Title of Investigation:

Staff Science Soils Data Acquisition Program.

Contact Information:

Contact 1:
Dr. Alan K. Nelson

NASA Goddard Sp. Fl. Ctr.
Greenbelt, MD
(301)286-9783
nelson@pldsg3.gsfc.nasa.gov

Requested Form of Acknowledgment.

The Bulk Soil Density data were produced by the Evapotranspiration Laboratory, Kansas State University staff. The dedicated efforts of Dr. A.K. Nelson in preparing these data is particularly appreciated.

3. Theory of Measurements:

Soil bulk density is defined as the ratio of the mass of dry solids to the bulk volume of the soil occupied by those dry solids. The bulk volume includes the volume of the solids and the pore space. Bulk density is needed for converting water percentage by weight to content by volume, for calculating porosity and void ratio when the particle density is known, and for estimating the weight of a volume of soil too large to weigh conveniently.

4. Equipment:

Sensor/Instrument Description:

Two different cylindrical metal samplers were used for collecting soil samples to determine soil moisture. The larger (4.86 cm diameter) volumetric sampler was deemed to sufficiently maintain the structure of its samples of soil that the volume of the sampler could be assumed to be the volume of the samples collected with that sampler. A smaller, circa 2-cm diameter sampler (used in rocky soils and when the soils were too dry to penetrate with the volumetric sampler) was deemed to be inappropriate for bulk density measurements because the structure of the collected sample was not maintained and the volume of the sampler was not necessarily the same as the volume of the collected sample.

At several stations, where the soils were very rocky or gravely, measurements specifically for bulk density were collected one, two, or three times during the FIFE study. Such sampling required a trowel, plastic bags to line the excavated hole, water to pour into the plastic bag, and a graduated cylinder to determine the volume of water in the bag.

Other apparatus include soil containers with tight-fitting lids, a drying oven with means for controlling the temperature from 100 to 110 degrees Celsius and a balance for weighing the samples.

Collection Environment:

Ground.

Source/Platform:

Ground.

Source/Platform Mission Objectives:

Determination of soil bulk density.

Key Variables:

Dry weight bulk density at two depths.

Principles of Operation:

Soil bulk density is defined as the ratio of the dry wet weight of soil, to the volume of the soil.

Sensor/Instrument Measurement Geometry:

Samples were obtained with a 4.86-cm diameter soil sampler.

Manufacturer of Sensor/Instrument:

Soiltest, Inc.
2205 Lee Street
Evanston, IL 60202.

Calibration:

Not applicable.

Specifications:

None available.

Tolerance:

Not applicable.

Frequency of Calibration:

Not available.

Other Calibration Information:

Not available.

5. Data Acquisition Methods:

A cylindrical metal sampler was pressed or driven into the soil to the desired depth and carefully removed to preserve a known volume of sample as it existed in situ. Samples were taken from the 0-5 cm and 5-10 cm depths. The total sample (approximately 100-150 grams) was put into a tin sample can and sealed with plastic electrical tape. Each sample can was identified by the sample site ID code. After sampling, the cans were opened and weighed to obtain the wet weight. Open cans were placed in ovens at 105 degrees Celsius for a minimum of 24 hours for drying, then they were weighed again to obtain the dry weight.

Bulk density measurements were also made (in gravely soils) in the field using a fixed ring to establish a datum and a water displacement method. A plastic bag was inserted into the cavity of the ring. A graduated cylinder was filled with water and the volume recorded. Water was then poured into the plastic bag until the cavity of the ring was filled to level. The volume of water remaining in the graduated cylinder was recorded. The bag with the water in it was carefully removed, taking care not to spill the water or rip the bag. Soil was excavated from the ring cavity to a depth of 5 cm and placed into the sample can(s). All loose soil was removed from the cavity. The bag (with the initial volume of water) was replaced into the cavity and additional water was added until the cavity of the ring was again filled to level. The volume of water remaining in the graduated cylinder was again recorded. The difference between the two recorded graduated cylinder readings is the volume of the soil sample. The bag was again removed, soil excavated to a depth of 10 cm, the bag re-placed and re-filled, and a measure of the volume of the sample between the 5-cm and 10-cm depths calculated. The soil samples were then dried in an oven at 105 degrees C for 24 hours. The dried samples were then weighed and the weight of the can was subtracted to get the dry soil weight.

6. Observations:

Data Notes:

Not available.

Field Notes:

None.

7. Data Description:

Spatial Characteristics:

The FIFE study area, with areal extent of 15 km by 15 km, is located south of the Tuttle Reservoir and Kansas River, and about 10 km from Manhattan, Kansas, USA. The northwest corner of the area has UTM coordinates of 4,334,000 Northing and 705,000 Easting in UTM Zone 14.

Spatial Coverage:

Soil bulk density data were collected at the following locations within the FIFE study area:

SITEGRID	STN_ID	NORTHING	EASTING	LATITUDE	LONGITUDE	ELEV
2731-SBD	1	4328625	711102	39 04 59	-96 33 34	446
1916-SBD	2	4330296	708270	39 05 56	-96 35 30	340
2428-SBD	3	4329265	710635	39 05 20	-96 33 53	415
2731-SBD	4	4328678	711110	39 05 01	-96 33 34	446
2123-SBD	5	4329866	709506	39 05 41	-96 34 39	405
2132-SBD	6	4329774	711336	39 05 36	-96 33 23	405
3221-SBD	7	4327682	709112	39 04 30	-96 34 58	410
3129-SBD	8	4327702	710711	39 04 30	-96 33 51	430
3921-SBD	9	4326116	709185	39 03 39	-96 34 57	415
3414-SBD	10	4327286	707854	39 04 19	-96 35 51	410
4439-SBD	11	4325219	712795	39 03 07	-96 32 27	445
2915-SBD	12	4328167	708028	39 04 47	-96 35 42	415
6735-SBD	13	4320652	712073	39 00 40	-96 33 03	385
2516-SBD	14	4328956	708102	39 05 12	-96 35 38	405
5926-SBD	15	4322227	710270	39 01 32	-96 34 16	370
4609-SBD	17	4324766	706700	39 02 58	-96 36 41	398
6912-SBD	19	4320178	707307	39 00 29	-96 36 21	385
6340-SBD	20	4321484	713000	39 01 06	-96 32 23	410
8639-SBD	21	4316771	712827	38 58 33	-96 32 36	440
6469-SBD	23	4321189	718752	39 00 51	-96 28 25	440
4168-SBD	25	4325704	718646	39 03 18	-96 28 24	438
1563-SBD	27	4331067	717658	39 06 12	-96 28 59	350
6943-SBD	28	4320147	713500	39 00 22	-96 32 04	415
0847-SBD	29	4332344	714439	39 06 57	-96 31 11	418
2139-SBD	31	4329843	712789	39 05 37	-96 32 23	385
3479-SBD	34	4327134	720890	39 04 02	-96 26 49	420
2655-SBD	36	4328787	716070	39 05 00	-96 30 07	367
1478-SBD	38	4331216	720603	39 06 15	-96 26 56	350
1246-SBD	40	4331666	714212	39 06 35	-96 31 21	365
1445-SBD	42	4331160	714090	39 06 19	-96 31 27	400
2043-SBD	44	4330003	713536	39 05 42	-96 31 51	415

Spatial Coverage Map:

Not available.

Spatial Resolution:

These are averages for replicate measurements of 25 samples, 5 samples taken at each of 5 locations within a sitegrid. These samples were taken at the center of the station and at the North, South, East and West corners of each station, approximately 30 meters from the center. The horizontal resolution with this sampling regime is therefore about 60 meters. At one station (11) samples were taken anywhere from 60 - 150 meters from the center of the site giving a resolution of 120 to 300 meters.

Vertical resolution varied with depth. It was 5 cm from 0 - 10 of depth and 10 cm from 10 - 20 of depth.

Projection:

Not available.

Grid Description:

Not available.

Temporal Characteristics:

Temporal Coverage:

Soil samples were collected from late spring through the fall of 1987, during the four Intensive Field Campaigns (IFC). The campaigns ran during the growing season (April - Oct.), each ran for approximately two weeks.

Temporal Coverage Map:

Not available.

Temporal Resolution:

All soil-moisture samples with a dry weight of greater than 65 grams were used to calculate the bulk density for each location within the FIFE study area (see the *Calculations Section*).

Data Characteristics:

The SQL definition for this table is found in the SOILDENS.TDF file located on the CD-ROM Volume 1.

Parameter/Variable Name

Parameter/Variable Description **Range** **Units** **Source**

SITEGRID_ID
This is a FIS grid location code.
Site grid codes (SSEE-III) give
the south (SS) and the east (EE)
cell number in a 100 x 100 array of

```
200 m square cells.  The last 3
characters (III) are an instrument
identifier.
```

```
STATION_ID
The station ID designating the
location of the observations.
```

```
DEPTH
The depth at which the                                  [mm]
measurements were taken.
```

```
NUM_OBS
The number of observations used
to calculate the SOIL_DENSITY and
SOIL_DENSITY_SDEV at this depth.
```

```
SOIL_BULK_DENSITY
The Soil Bulk Density at this                           [grams]
depth.                                                  [cm^-3]
```

```
SOIL_BULK_DENSITY_SDEV
The standard deviation of the                           [grams]
Soil Bulk Density at this depth.                        [cm^-3]
```

```
FIFE_DATA_CRTFCN_CODE
The FIFE Certification Code for           *
the data, in the following format:
CPI (Certified by PI), CPI-???
(CPI - questionable data).
```

```
LAST_REVISION_DATE
data, in the format (DD-MMM-YY).
```

Footnote:

Valid levels

The primary certification codes are: EXM Example or Test data (not for release). PRE Preliminary (unchecked, use at your own risk). CPI Checked by Principal Investigator (reviewed for quality) CGR Checked by a group and reconciled (data comparisons and cross-checks).

The certification code modifiers are: PRE-NFP Preliminary - Not for publication, at the request of investigator. CPI-MRG PAMS data that are "merged" from two separate receiving stations to eliminate transmission errors. CPI-??? Investigator thinks data item may be questionable.

Sample Data Record:

SITEGRID_ID	STATION_ID	DEPTH	NUM_OBS	SOIL_BULK_DENSITY
1563-SBD	27	25	5	1.27
1563-SBD	27	75	5	1.17
4168-SBD	25	25	145	1.04
4168-SBD	25	75	145	1.12

SOIL_BULK_DENSITY_SDEV	FIFE_DATA_CRTFCN_CODE	LAST_REVISION_DATE
.25	CPI	05-NOV-93
.13	CPI	05-NOV-93
.14	CPI	05-NOV-93
.16	CPI	05-NOV-93

8. Data Organization:

Data Granularity:

The horizontal resolution is about 60 meters. At one station the resolution was between 120 to 300 meters. Vertical resolution varied with depth. It was 5 cm from 0 - 10 of depth and 10 cm from 10 - 20 of depth. All soil-moisture samples with a dry weight of greater than 65 grams were used to calculate the bulk density for each location within the FIFE study area

A general description of data granularity as it applies to the IMS appears in the EOSDIS Glossary.

Data Format:

The CD-ROM file format consists of numerical and character fields of varying length separated by commas. The character fields are enclosed with a single apostrophe. There are no spaces between the fields. Each file begins with five header records. Header records contain the following information: Record 1 Name of this file, its table name, number of records in this file, path and name of the document that describes the data in this file, and name of principal investigator for these data. Record 2 Path and filename of the previous data set, and path and filename of the next data set. (Path and filenames for files that contain another set of data taken at the same site on the same day.) Record 3 Path and filename of the previous site, and path and filename of the next site. (Path and filenames for files of the same data set taken on the same day for the previous and next sites (sequentially numbered by SITEGRID_ID)). Record 4 Path and filename of the previous date, and path and filename of the next date. (Path and filenames for files of the same data set taken at the same site for the previous and next date.) Record 5 Column names for the data within the file, delimited by commas. Record 6 Data records begin.

Each field represents one of the attributes listed in the chart in the *Data Characteristics Section* and described in detail in the TDF file. These fields are in the same order as in the chart.

9. Data Manipulations:

Formulae:

Derivation Techniques and Algorithms:

Bulk densities were calculated in the following manner: Any dry gravimetric soil samples collected during the summer of 1987, which weighed more than 65 grams, were assumed to have been collected with the volumetric sampler (i.e., volume = 92.92 cubic centimeters). The bulk density for each of these samples was calculated according to the following formula:

Bulk Density = (Dry weight of sample in grams) / 92.92

A mean of all bulk density determinations at a given site-depth was calculated. The number of determinations and the standard deviation of the mean bulk density are also reported.

Data Processing Sequence:

Processing Steps:

See the *Calculations Section*.

Processing Changes:

None.

Calculations:

Special Corrections/Adjustments:

The soil at Stations 7, 27, and 31 (Sitegrid IDs 3221, 1563 and 2139, respectively) proved too rocky to use the volumetric soil probe. These stations were sampled on two or three different occasions through the summer by hand. The volume of the sample was determined by lining the hole with a plastic bag and measuring the volume of water needed to fill the bag to the level of the surrounding surface. The bulk densities were then calculated using the following formula:

Bulk Density = (Dry weight of sample in grams) / (volume of the sample in milliliters)

Calculated Variables:

Bulk Density.

Graphs and Plots:

None.

10. Errors:

Sources of Error:

In general, the soil samples used for calculating bulk density were in fact collected for the purposes of gravimetric water content. Thus, there will be some errors due to a non-volumetric sample: if driven too deep, the corer would compact the soil giving a too-high estimate of bulk density; while if not driven to the hilt, the soil sample would not fill the corer giving a too-low estimate of the bulk density. Compression may occur in dry soils if they are very loose. In dry or hard soils, hammering the sampler into the soil often shatters the sample, and the structure of the soil in situ is destroyed during sampling. Ironically, those bulk density measurements calculated on only two or three samples would be most accurate in methodology (plastic-bag technique rather than soil corer) but were only undertaken at sites where the variability of the soils could lead to large errors in the estimate of a mean bulk density.

Quality Assessment:

Data Validation by Source:

None.

Confidence Level/Accuracy Judgment:

The use of soil-moisture samples in the calculation of bulk density allowed a much greater sample size than any study undertaken just for bulk density. The ravages of collecting 210 samples daily may have lead to some non-representative sampling. However, the soils crew was by-and-large a conscientious group and the large number of samples should dilute the errors introduced by problems encountered during sampling. The samples collected with the plastic-bag technique were meticulously carried out; variability in these small samples sizes is attributable to the variability in the soils.

Measurement Error for Parameters:

No quantitative assessment was made, see the *Confidence Level/Accuracy Judgment Section*.

Additional Quality Assessments:

FIS staff applied a general Quality Assessment (QA) procedure to the data to identify inconsistencies and problems for potential users. As a general procedure, the FIS QA consisted of examining the maximum, minimum, average, and standard deviation for each numerical field in the data table. An attempt was made to find an explanation for unexpected high or low values, values outside of the normal physical range for a variable, or standard deviations that appeared inconsistent with the mean. In some cases, histograms were examined to determine whether outliers were consistent with the shape of the data distribution.

The discrepancies, which were identified, are reported as problems in the *Known Problems with the Data Section*.

Data Verification by Data Center:

The data verification performed by the ORNL DAAC deals with the quality of the data format, media, and readability. The ORNL DAAC does not make an assessment of the quality of the data itself except during the course of performing other QA procedures as described below.

The FIFE data were transferred to the ORNL DAAC via CD-ROM. These CD-ROMs are distributed by the ORNL DAAC unmodified as a set or in individual volumes, as requested. In addition, the DAAC has incorporated each of the 98 FIFE tabular datasets from the CD-ROMs into its online data holdings. Incorporation of these data involved the following steps:

- Copying the entire FIFE Volume 1, maintaining the directory structure on the CD-ROM;
- Using data files, documentation, and SQL code provided on the CD-ROM to create a database in Statistical Analysis System (SAS); and
- Creating transfer files to transfer the SAS metadata database to Sybase tables.

Each distinct type of data (i.e. "data set" on the CD-ROM), is accompanied by a documentation file (i.e., .doc file) and a data format/structure definition file (i.e., .tdf file). The data format files on the CD-ROM are Oracle SQL commands (e.g., "create table") that can be used to set up a relational database table structure. This file provides column/variable names, character/numeric type, length, and format, and labels/comments. These SQL commands were converted to SAS code and were used to create SAS data sets and subsequently to input data files directly from the CD-ROM into a SAS dataset. During this process, file names and directory paths were captured and metadata was extracted to the extent possible electronically. No files were found to be corrupted or unreadable during the conversion process.

Additional Quality Assurance procedures were performed as follows:

- Statistical operations were performed to calculate minimum and maximum values for all numeric fields and to create a listing of all values of the character fields. During this process, it was determined that various conventions were used to represent missing values. (Note: no modifications were made to any data by the DAAC). In most cases, missing value identification conventions were discussed in the accompanying .doc file. Based on a visual check of the minimum and maximum values, no glaring errors or holes were identified that might indicate errors introduced during CD-ROM mastering by the FIFE project or data ingest by the DAAC.
- Some minor inconsistencies and typographical errors were identified in some of the character fields and column labels, however, no modifications were made to the data by the DAAC.
- Some conversions of ASCII data were necessary to move the data from a DOS platform to a UNIX platform. Standard operating system conversion utilities were used (e.g., dos2unix).

- Much of the metadata required for archival is imbedded in the narrative documentation accompanying the data sets and extracted manually by DAAC staff who have read the .doc files provided on the CD-ROM and have hand entered this information into the metadata database maintained by the DAAC. QA procedures have been performed on these metadata to identify and eliminate typographical errors and inconsistencies in naming conventions, to ensure that all required metadata is present, and to ensure the accuracy of file names and paths for retrieval.
- Data requested for distribution to users are checked to verify that files copied from disk to other media remain uncorrupted.

As errors are discovered in the online tabular data by investigators, users, or DAAC staff, corrections are made in cooperation with the principal investigators. These corrections are then distributed to users. CD-ROM data are corrected when re-mastering occurs for replenishment of CD-ROM stock.

11. Notes:

Limitations of the Data:

Not available.

Known Problems with the Data:

None.

Usage Guidance:

This data set could be used in conjunction with other soil moisture data to validate the soil moisture values predicted by the airborne remote sensing instruments during FIFE. It could be used with caution in similar prairie landscapes to compare remote sensing derived soil moisture and field measured soil moisture.

Any Other Relevant Information about the Study:

Bulk densities for Station 11 were provided by Sashi Verma, (402) 472-3679.

12. Application of the Data Set:

This data set could be used in conjunction with other soil moisture data to validate the soil moisture values predicted by the airborne remote sensing instruments during FIFE.

13. Future Modifications and Plans:

The FIFE field campaigns were held in 1987 and 1989 and there are no plans for new data collection. Field work continues near the FIFE site at the Long-Term Ecological Research (LTER) Network Konza research site (i.e., LTER continues to monitor the site). The FIFE investigators are continuing to analyze and model the data from the field campaigns to produce new data products.

14. Software:

Software to access the data set is available on the all volumes of the FIFE CD-ROM set. For a detailed description of the available software see the *Software Description Document*.

15. Data Access:

Contact Information:

ORNL DAAC User Services
Oak Ridge National Laboratory

Telephone: (865) 241-3952
FAX: (865) 574-4665

Email: ornldaac@ornl.gov

Data Center Identification:

ORNL Distributed Active Archive Center
Oak Ridge National Laboratory
USA

Telephone: (865) 241-3952
FAX: (865) 574-4665

Email: ornldaac@ornl.gov

Procedures for Obtaining Data:

Users may place requests by telephone, electronic mail, or FAX. Data is also available via the World Wide Web at http://daac.ornl.gov.

Data Center Status/Plans:

FIFE data are available from the ORNL DAAC. Please contact the ORNL DAAC User Services Office for the most current information about these data.

16. Output Products and Availability:

The Soil Bulk Density data are available on FIFE CD-ROM Volume 1. The CD-ROM file name is as follows:

\DATA\SOILPROP\SOILDENS\1987MULT.SDB

17. References:

Satellite/Instrument/Data Processing Documentation.

Gardner, W.H. 1986. Water content. p.635-662. In: A. Klute (ed.) Methods of Soil Analysis. Part 1. Physical and mineralogical methods, 2nd ed. Agronomy Monogr. 9. ASA and SSSA, Madison, WI.

Journal Articles and Study Reports.

Engman, E.T., W. Kustas, T.J. Schmugge, and J.R. Wang. 1987. Relationship among the remotely sensed soil moisture, streamflow, and evapotranspiration. AGU Fall Meeting, San Francisco.

Archive/DBMS Usage Documentation.

Contact the EOS Distributed Active Archive Center (DAAC) at Oak Ridge National Laboratory (ORNL), Oak Ridge, Tennessee (see the *Data Center Identification Section*). Documentation about using the archive and/or online access to the data at the ORNL DAAC is not available at this revision.

18. Glossary of Terms:

A general glossary for the DAAC is located at Glossary.

19. List of Acronyms:

BPI Byte per inch CD-ROM Compact Disk-Read Only Memory DAAC Distributed Active Archive Center EOS-DIS Earth Observing System-Data and Information System FIFE First ISLSCP Field Experiment FIS FIFE Information System ISLSCP International Satellite Land Surface Climatology Project ORNL Oak Ridge National Laboratory URL Uniform Resource Locator UTM Universal Transverse Mercator

A general list of acronyms for the DAAC is available at Acronyms.

20. Document Information:

April 26, 1994 (citation revised on October 15, 2002).

Warning: This document has not been checked by the FIFE Information Scientist for technical or editorial accuracy. There may be inconsistencies with other documents, technical or editorial errors that were inadvertently introduced when the document was compiled, or references to preliminary data that were not included on the final CD-ROM.

Previous versions of this document have been reviewed by the Principal Investigator, the person who transmitted the data to FIS, a FIS staff member, or a FIFE scientist generally familiar with the data.

Document Review Date:

June 26, 1996.

Document ID:

ORNL-FIFE_SOILDENS.

Citation:

Cite this data set as follows:

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Document Curator:

DAAC Staff

Document URL:

http://daac.ornl.gov