USDA-NRCS Field Bulk Density Perspective for Soil Ontology Group

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Bulk density protocols and notes here: BulkDensityRef

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1) If you are a field soil scientist, what is your decision tree for taking a bulk density measurement?

For every soil pit that we send off for laboratory characterization, we collect bulk density samples by layer in triplicate. Ideally these are paraffin-coated (intact) clods. In cohesion-less material we use cylindrical or rectangular (known volume) cores or compliant cavity. For organic materials, the lab has suggested the "brownie method" where a rectangle of "known volume" ($x * y * z$) is cut from a pit face with a sharp knife – this is sometimes less disruptive than the coring tools depending on organic fiber kind and decomposition state.

The KSSL Sample Submission Protocol (PDF) describes how to collect, label and ship samples to Kellog Soil Survey Laboratory in Lincoln, Nebraska. Data generated by our laboratory in Lincoln comprise the bulk of the data in the National Cooperative Soil Survey Characterization (NCSSC) Database.

I will briefly walk through bulk density in NASIS from the perspective of a field soil scientist. I will talk about four tables associated with the NASIS Pedon object: `phdb`, `phfmp`, `phlabresults`, and `phsample`. The following summary tables are generated by querying the metadata tables in a local instance of the NASIS database. The source code is in the *.Rmd*.

TablePhysicalName	TableDescription
phdb	This table records individual bulk density measurements taken for a particular pedon and its horizons.
phfmp	The Pedon Horizon Field Measured Property table contains the results of field or office conducted soil property analyses that apply to an individual horizon, that cannot be stored elsewhere in the database as separate data elements in other tables. Analy
phlabresults	This table records the results of analytical tests of soil chemical and physical properties.
phsample	The Pedon Horizon Sample table describes the relationship between a soil horizon description and other types of data that may be in the database that relate to that specific horizon, i.e. laboratory analysis results.

Routine soil description

Most of my soil descriptions in NASIS do *not* have bulk density measurements.

For specific projects I have collected bulk density samples more frequently. For instance, low bulk density is partially diagnostic for Andisols, Andic Soil Properties and Andic subgroups (volcanic soils). Bulk density measurements on uncharacterized pedons were used to demonstrate the *extent* of concepts that had been fully laboratory characterized at several other locations. The data collected may be stored in NASIS, but are not in NCSSC database because the profiles were not being fully characterized, and the samples were not sent to the Lincoln lab.

I record these measurements within the NASIS *Pedon Horizon Bulk Density* `phdb` table. A single record in that table is about the equivalent of 1 rep of `Bulk Density, Core, <2 mm fraction, Field Moist` or `db_fmstc` in the NCSSC `analyte` table.

Note that the `phdb` table has columns to store data for sieving out coarse fragments and accounting for their volume, determining moisture content and also calculated values of mass per volume field-moist, oven-dry (whole soil) and oven-dry (sieved).

phdb Table

TablePhysicalName	ColumnPhysicalName	ColumnDescription
phdb	phiidref	An internal ID (integer) that is part (or all) of a key that uniquely identifies a record in another table. Also known as part (or all) of a “foreign key”. In cases where the _iid_ref is used as part of a lookup (choice list) into another table, NASIS u
phdb	seqnum	Sequential number of the feature being described.
phdb	obsgrsoimoist	The measured amount of water in the soil layer, expressed as a weight percentage.
phdb	recuseriidref	The key of the NASIS user who last updated the corresponding record.
phdb	recwlupdated	The date and time the corresponding record was last updated.
phdb	datacollector	The name of the person collecting the measurements or observations.
phdb	bddepthtop	The depth to the top of the layer from which the bulk density sample was taken.
phdb	bddepthbottom	The depth to the bottom of the layer from which the bulk density sample was taken.
phdb	totalsamplewtfm	The field moist weight of the total sample.
phdb	totalsamplewtairdry	The air dry weight of the total sample.

phdb	coarsefragwtairdry	The air dry weight of coarse fragments in the sample.
phdb	subsamplewtairdry	The air dry weight of the subsample.
phdb	subsamplewtod	The oven dry weight of the subsample.
phdb	bdmethod	The method used to obtain the bulk density sample.
phdb	samplevolfieldmoist	The field moist volume of the total sample.
phdb	bdovendrywhole	The oven dry weight of the whole soil per unit field oven dry volume of soil exclusive of the desiccation cracks.
phdb	bdovendryfineearth	The oven dry weight of the less than 2 mm soil material per unit field oven dry volume of soil exclusive of the desiccation cracks.
phdb	obsgravsoilmoistfe	The measured amount of water in the less than 2 mm fraction of the soil, expressed as a weight percentage.
phdb	phbulkdensityiid	An internal ID (integer) that is part (or all) of a key that uniquely identifies a record. Also known as part (or all) of the “primary key”. This value is managed by NASIS and cannot be edited.
phdb	coarsefragwtfm	The field moist weight of coarse fragments in the sample.
phdb	coarsefragdensity	The particle density of the coarse fragments in the sample.
phdb	coarsefragvolmeasured	The field measured volume of coarse fragments in the sample.
phdb	bdsatiated	The oven dry weight of the less than 2 mm soil material per unit volume of soil at a water tension of 0 bar.
phdb	obsgrsoimoist_s	Indicates if the non-null value in the corresponding column was manually entered (M), calculated (C), or if its source is unknown (P). A source value of (P) indicates that the corresponding non-null value existed prior to when that field became calculabl
phdb	bdovendrywhole_s	Indicates if the non-null value in the corresponding column was manually entered (M), calculated (C), or if its source is unknown (P). A source value of (P) indicates that the corresponding non-null

		value existed prior to when that field became calculabl
phdb	bdovendryfineearth_s	Indicates if the non-null value in the corresponding column was manually entered (M), calculated (C), or if its source is unknown (P). A source value of (P) indicates that the corresponding non-null value existed prior to when that field became calculabl
phdb	obsgravsoilmoistfe_s	Indicates if the non-null value in the corresponding column was manually entered (M), calculated (C), or if its source is unknown (P). A source value of (P) indicates that the corresponding non-null value existed prior to when that field became calculabl
phdb	bdfieldmoistfineearth	The oven dry weight of the less than 2 mm soil material per unit field moist volume of soil exclusive of the desiccation cracks.
phdb	bdfieldmoistwhole	The oven dry weight of the whole soil per field moist unit volume of soil exclusive of the desiccation cracks.

In the past the free-form *Pedon Horizon Field Measured Property* table `phfmp` had been used for bulk density measurements, so there is bulk density data in there.

phfmp Table

TablePhysicalName	ColumnPhysicalName	ColumnDescription
phfmp	recuseriidref	The key of the NASIS user who last updated the corresponding record.
phfmp	seqnum	Sequential number of the feature being described.
phfmp	fmpname	The name assigned to an user defined field measured property. To be used when the parameter to be recorded does not already exist elsewhere in the database.
phfmp	fmpvalue	The measured or observed value of the specific user defined parameter.
phfmp	fmpunits	The unit of measure associated with a particular field measurement.
phfmp	phiidref	An internal ID (integer) that is part (or all) of a key that uniquely identifies a record in another table. Also known as part (or all) of a

		"foreign key". In cases where the _iid_ref is used as part of a lookup (choice list) into another table, NASIS u
phfmp	phfmpiid	An internal ID (integer) that is part (or all) of a key that uniquely identifies a record. Also known as part (or all) of the "primary key". This value is managed by NASIS and cannot be edited.
phfmp	recwlupdated	The date and time the corresponding record was last updated.

Note that in *Field Measured Property* the name and unit of measure are free-form text fields. Measures are made as needed based on region, soil type, and project scope – and there are few to no limits on what you can put in there by design. Note that in modern NASIS, there is a place for most common measurements used for soil survey activities – so it is rare that new data are put in there, but it is the mechanism for incorporating data from new or unique methods. Bulk density now gets its own table, but there is also the *Pedon Horizon Lab Results* table.

The *Pedon Horizon Lab Results* `phlabresults` table includes attributes that are commonly measured by the "field" laboratories operated in local Soil Survey Offices. There are three child tables of *Lab Results* related to hydrometer particle size analysis, COLE, and mineral grain count. Many of these are important to soil interpretations, taxonomy or both and may be measured by a variety of sources depending on the needs of the soil survey. Like `phdb`, `phlabresults` provides a mechanism to account for subsampling layers; `sampledepthtop` and `sampledepthbottom` need not match the top and bottom depth of the horizon they came from.

`[Table omitted]`

Laboratory sampling

We are starting a new dynamic soil properties project in our office where we will be tracking the effects of vegetation removal for fire suppression on soil properties. This will involve laboratory characterization and a particular focus on properties like near-surface bulk density.

When we do that sampling we will enter our field descriptions from the sampling day into NASIS, and we will fill out the *Pedon Horizon Sample* table. There is a field here to note how many bulk sample bags and the number of bulk density clods were collected for each layer (`labsampnum`) that gets sent to Lincoln. Note also that it is implied that the 20-76mm rock fragments have been *removed* from bulk sample bags and weighed in the field. A volumetric correction is applied later for "Whole Soil" conversions on the whole coarse fraction.

Physical Column Names in phsample Table

TablePhysicalName	ColumnPhysicalName	ColumnDescription
phsample	fldsampid	The sample ID for the soil sample assigned at the time of sampling in the field by the person doing the sampling. This value should be whatever identifying label that is put on the tag of the sample bag in the field at the time of sampling.
phsample	seqnum	Sequential number of the feature being described.
phsample	labsampnum	The internal laboratory sample number for the horizon. Constructed by the two digit fiscal year * 10000 + consecutive sample number in that year.
phsample	phiidref	An internal ID (integer) that is part (or all) of a key that uniquely identifies a record in another table. Also known as part (or all) of a “foreign key”. In cases where the _iid_ref is used as part of a lookup (choice list) into another table, NASIS u
phsample	phlabsampiid	An internal ID (integer) that is part (or all) of a key that uniquely identifies a record. Also known as part (or all) of the “primary key”. This value is managed by NASIS and cannot be edited.
phsample	recuseriidref	The key of the NASIS user who last updated the corresponding record.
phsample	recwlupdated	The date and time the corresponding record was last updated.
phsample	numberofothersamples	The number of other samples refers to the actual number of other sample types such as compliant cavity or cores that are associated with a specific layer.
phsample	numberofnaturalfabricclods	The number of natural fabric

		clods refers to the actual number of clods sent to the laboratory for a single sampled layer.
phsample	numberofbulkdensityclods	The number of bulk density clods refers to the actual number of clods sent to the laboratory for a single sampled layer.
phsample	numberofbulksampbags	The number of bulk sample bags that have been sent to the laboratory corresponding to a particular layer. When soils have a large number of rock fragments, or contain high organic matter content it is sometimes necessary to send in multiple bags of soil
phsample	layerdepthbottom	The depth from the top of the soil to the bottom of the sampled layer. Most commonly this depth is the same as the depth to the bottom of the horizon. Could be the same as the depth to the bottom of the horizon, but does not need to be.
phsample	layerdepthtop	The depth from the top of the soil to the top of the sampled layer. Most commonly this depth is the same as the depth to the top of the horizon. Could be the same as the depth to the top of the horizon, but does not need to be.
phsample	wtlt20mm	The Weight in KG of the less than 20 mm fraction less any tare weight.
phsample	wt20to76mmdiscardedfragments	The Weight in KG of the less than 20 to 75 mm fraction less any tare weight.

Note that data brought in to NASIS from the KSSL laboratory snapshot is stored in the *NCSS Pedon Lab Data* and *NCSS Layer Lab Data* tables in NASIS. These are different from the pedon data tables where primary soil observations by Soil Survey Offices are stored.

2) If you are soil data user, how do you identify 'usable' bulk density data in a database/dataset?

Generally, I am happy if bulk density input data (masses, core volume, etc.) and method are provided – rather than baked into the results.

I look to the schema of the database, table names and/or column names to find where and how primary measurements are stored. Bulk density technically is a combination of several physical measurements, some of which may be assumed constant for e.g. a given core tool. The way that the soils were sampled and aggregated should be obvious. This level of granularity may not be present in a single dataset, but I generally go to the finest level of aggregation (i.e. individual reps/summary stats or constituent measurements)

I also want to know what soil volume each sample or set of samples is supposed to be summarizing; and consider this along with the volume of the sampling device/method. The geometry of the volume being *summarized* by e.g. cores/clods is typically a top and bottom depth for a 1-D profile description, but detailed descriptions in e.g. cryoturbated materials may have more complicated geometry.