Reprinted from

Symposium on Machine Processing of Remotely Sensed Data and Soil Information Systems and Remote Sensing and Soil Survey

June 3-6, 1980

Proceedings

The Laboratory for Applications of Remote Sensing

Purdue University
West Lafayette
Indiana 47907 USA

IEEE Catalog No.
80CH1533-9 MPRSD

DEVELOPMENT OF A DIGITAL DATA BASE FOR REFLECTANCE-RELATED SOIL INFORMATION

ERIC R. STONER
NASA/Earth Resources Laboratory
NSTL Station, Mississippi

LARRY L. BIEHL
Purdue University/LARS

I. ABSTRACT

A digital soils data base was established for inclusion of soil reflectance data in addition to pertinent soil physical, chemical, engineering data and site information. This soils data base is being used by researchers to study the relationships between the reflectance and physical, chemical, engineering and site characteristics of soil upon which remote sensing technology for soil and crop survey is based. Information stored in the data base carries connotations for soil taxonomic classification as well as detailed descriptions of site characteristics such as climate, drainage, slope, erosion phase, topography, and parent material. Laboratory analyses can be entered into the data base for organic matter content, cation exchange capacity, texture, and many others. Engineering variables as well as engineering classification of soils can also be entered. The spectral data for each soil measured can be in the form of continous scan spectroradiometer data or multiband radiometer data.

The initial data included in the data base are physical, chemical, engineering, and site information for 500 soil samples from 39 states of the United States, as well as Brazil, Costa Rica, Sudan, Spain, and Jordon. The LARSPEC software package is available for researchers using the Purdue/LARS computer facility to access the information on the soils data base. The information on the data base is also available to researchers who do not have access to the Purdue/LARS computer facility.

CH1533-9/80/0000-0273 $00.75 ©1980 IEEE

II. INTRODUCTION

Spectroradiometric studies of soils under laboratory and field conditions are needed to develope an understanding of the factors influencing soil reflectance. A variety of soil parameters and conditions individually and in association with one another contribute to the spectral reflectance of soils. Some of these parameters include the following physical and chemical properties: moisture content, organic matter content, particle and aggregate size, iron oxide content and soil mineralogy. Conditions affecting the radiation of soils in their natural state are green vegetative cover, non-soil residue, surface roughness and crusting, and shadows, all which vary according to tillage operations, cropping or grazing systems, or naturally occuring plant communities.

To study the reflectance-soil parameter and condition relationships requires that the soil reflectance data, soil test results, and site information be easy to access and to manipulate. This paper discusses a data base that was designed and established for inclusion of soil reflectance data, physical, chemical, and engineering measurements and site information. The data base is accessible through a computer and is general enough to satisfy the needs of a wide range of experiments.

III. DATA BASE DESCRIPTION

The current soils data base resides on a few magnetic computer tapes. Generally, a given study will require a subset of the data on the tapes. The smallest complete unit within the data base is an observation. There are two sets of information with each observation: 1) the identification record with the soil characteristics and spectral observation parameters, and 2) the spectral data.

The soil characteristics in the identification record include (see Table 1)

1) taxonomic information,
2) sampling site descriptions,
3) physical measurements,
4) chemical measurements, and
5) engineering measurements.

The spectral observation parameters in the identification record include (see Table 2)

1) measurement geometry characteristics,
2) meteorological conditions,
3) instrument parameters.

In addition there are other data base variables that are free to be assigned by the researcher for parameters that are needed for his experiment but are not included in the basic set given in Tables 1 and 2.

The data base allows for a wide range of soil measurements, site information, and spectral observations parameters. However, it is not required that all of the measurements be made for a given observation to 'fill up' the identification record. Also some of the information of the identification record is coded so that it can be used by computer programs.[1]

The spectral information in the data base may be that collected by a continuous scan spectroradiometer or a multiband radiometer. It is possible to include spectral information from the reflective 0.4-2.4 μm, and/or emissive, 4.0-15.0 μm, portions of the electromagnetic spectrum. Generally, the reflective data will be in units of spectral bidirectional reflectance factor[3] and the emissive data, if included, will be in units of spectral radiance.

The initial data included in the data base are spectroradiometric properties and physical, chemical, engineering and site information for 500 soil samples from 39 states of the United States, as well as Brazil, Costa Rica, Sudan, Spain, and Jordon (Table 3). The astericks in Table 1 indicate the physical, chemical, engineering and site information available for the 500 soil samples. The instrument that was used to collect the spectral data for the soils data base is the Purdue/LARS Exotech 20C circular variable filterwheel spectroradiometer system. The spectral data from the 500 soil samples covers the spectral range from 0.5 to 2.3 μm and was processed into units of spectral bidirectional reflectance factor.

IV. DATA BASE ACCESS

The LARSPEC software system is available for researchers using the Purdue/LARS computer facility to retrieve and manipulate the soils information in the data base.[2] The software system allows

Table 1. Soil characteristics and descriptions that may be included in the data base.

Taxonomic Information	Site Characteristics	Physical Characteristics
*Order	*Soil series name	*Soil moisture tension
*Suborder	*Horizon designation	*Water content
*Great group	*Moisture regime	Bulk density
*Subgroup name	*Drainage class	*Munsell color (moist)
*Particle size class	*Slope class	*Textural class designation
*Contrasting particle size class	*Erosion phase	*USDA particle size distribution:
*Mineralogy class	*Physiographic position	sand content
*Temperature regime	*Parent material	silt content
*Other modiifers	*Soil elevation	clay content
	*Natural vegetation or crop	very coarse sand
	*Site location	coarse sand
		medium sand
		fine sand
		very fine sand
		coarse silt
		fine silt
		Electrical conductivity
		*Erosion factor
		*Wind erodibility group

Table 1. Soil characteristics and descriptions that may be included in the data base (con't.).

Chemical Characteristics	Engineering Characteristics
*Organic carbon	*Liquid limit
Water pH	*Plastic limit
Buffer pH	*Plasticity index
*Extractable bases:	*Activity
calcium	*Liquidity index
magnesium	*Shrinkage limit
sodium	*Shrinkage ratio
potassium	*Volumetric shrinkage
extractable acidity	*Linear shrinkage
cation exchange capacity	*Compression index
base saturation	*ASTM particle size distribution:
*Iron oxide	medium sand
Aluminum oxide	fine sand
Manganese dioxide	fines
Silicon dioxide	*Specific gravity
*Available phosphorus	*AASHO soil classification
*Available potassium	*Unified soil classification

Table 2. Spectral observation parameters that may be included in the data base.

Measurement Geometry Characteristics	Meteorological Conditions	Instrument Parameters
Location name	Air temperature	Instrument name
Latitude	Wet bulb temperature	Scan rate
Longitude	Barometric pressure	Focal distance
Flightline	Relative humidity	Field of view
Illumination source	Cloud cover	Detector name
Irradiance zenith angle	Cloud type	Gain setting
Irradiance azimuth angle	Wind speed	Filter setting
View zenith angle	Wind direction	Facility operating instrument
View azimuth angle	Visibility	Data quality values
Distance to ground		
Date & time spectral data collected		

researchers to print, graph, and copy the soil information as the researcher requires.

The identification information may be printed as illustrated in Figure 1. Graphical displays of the spectral curves or functions of the spectral are possible on an electrostatic printer-plotter (Figure 2) or line printer type output devices. Scattergrams of the identification information and/or spectral data and simple correlation analyses allow researchers to initiate statistical analyses of soils data (Figures 3-4). The soil data may also be copied to other storage formats, such as cards, to be used by other statistical analyses software packages.

The soil information in the data base is also available to researchers who do not have access to the Purdue/LARS computer facility. The Laboratory for Applications of Remote Sensing at Purdue University should be contacted for information about obtaining the data.

Table 3. Distribution of initial soils in data base relative to geographic extent of these soils.

Soil order	soil samples in data base		United States extent
	number	percent of U.S. soils	percent
Mollisol	146	30.4	24.6
Alfisol	80	16.7	13.4
Entisol	78	16.2	7.9
Aridisol	50	10.4	11.5
Ultisol	44	9.2	12.9
Inceptisol	36	7.5	18.2
Spodosol	30	6.2	5.1
Vertisol	8	1.7	1.0
Histosol	8	1.7	0.5
Oxisol (non-U.S.)	4	-	<0.02
Not specified (non-U.S.)	35	-	-
Total	519		

```
RUN SEQUENCER ....................                55   DATE DATA COLLECTED ....                  9/15/78
DAY OF YEAR DATA COLLECTED ........              258   OBSERVATION NUMBER ............                64
SERIAL NUMBER .................                    6   TIME DATA COLLECTED ..............        213100
EXPERIMENT NUMBER ..............             7810C701   EXPERIMENT NAME .......              SOIL STUDY
PRINCIPAL INVESTIGATOR                   STONER, ERIC   SCENE TYPE ............               SAMPLE 25
LOCATION ................            LARS W.LAFAYETTE   REFORMATTING DATE .......              11/ 9/78
REFORMATTING CALIBRATION CODE ......               1   LATEST ID UPDATE DONE ..                2/14/79
NUMBER OF SAMPLE GROUPS ............               1   REFLECTIVE CALIBRATION OBS 1 ..              65
CALIBRATION TABLE NUMBER ...........               2   ILLUMINATION ....................        GE DXW
IRRADIANCE ZENITH ANGLE (DEGREES) ..              10   IRRADIANCE AZIMUTH ANGLE (DEGREES) .         90
VIEW ZENITH ANGLE (DEGREES) ........               0   VIEW AZIMUTH ANGLE (DEGREES) .......          0
DISTANCE TO GROUND (METERS) .....               2.44   FOCAL DISTANCE (METERS) ..........         2.44
LOCATION LATITUDE ..............              402500N   LOCATION LONGITUDE ..............      865500W
ID RECORD TYPE(=1 CROPS,=2 SOILS) ...              2   ORDER ...........................          ALF
SUBORDER ..........................              BOR   GREAT GROUP ......................         EUTR
PARTICLE SIZE CLASS ...................           13   CONTRASTING PARTICLE SIZE CLASS .....         0
MINERALOGY CLASS .......................           1   OTHER MODIFIERS ......................        0
TEMPERATURE REGIME ............               FRIGID   MOISTURE ZONE ..................          HUMID
DRAINAGE CLASS ..........................          3   SLOPE CLASS ..........................        2
EROSION PHASE ...........................          0   PHYSIOGRAPHIC POSITION ...............        4
PARENT MATERIAL .........................         49   SUBGROUP NAME ........                  GLOSSIC
SOIL SERIES NAME ......                    ONTONAGON   YEAR SOIL SAMPLE COLLECTED ..........        78
STATE ABBREVIATION ..................             MI   COUNTY CODE .........................       131
MULTIPLE SAMPLING NUMBER .............             1   CONSECUTIVE SAMPLING NUMBER .........         1
HORIZON ......................                    AP   SOIL TESTING LAB NUMBER ...........        1321
ORGANIC CARBON (PERCENT) .........              4.88   CALCIUM (MEQ/100G) ..................      14.1
MAGNESIUM (MEQ/100G) ..............              7.1   SODIUM (MEQ/100G) ...................       0.1
POTASSIUM (MEQ/100G) ................            0.8   EXTRACTABLE ACIDITY (MEQ/100G) ....        15.9
CATION EXCHANGE CAPACITY ..........             38.0   BASE SATURATION (PERCENT) ..........         58
SOIL MOISTURE TENSION (BARS) .                  0.10   WATER CONTENT (PERCENT) ..........        47.50
MUNSEL COLOR (MOIST) ..              C2.5YR3.0/6.0   MUNSEL COLOR HUE1 (MOIST) .........          2.5
MUNSEL COLOR HUE2 (MOIST) ..........              YR   MUNSEL COLOR VALUE (MOIST) ..........       3.0
MUNSEL COLOR CHROMA (MOIST) ........             6.0   TEXTURAL CLASS ........                    CLAY
SAND CONTENT -USDA- (PERCENT) .....              7.3   SILT CONTENT -USDA- (PERCENT) .....        22.3
CLAY CONTENT -USDA- (PERCENT) .....             70.4   VERY COARSE SAND -USDA- (PERCENT) .         0.1
COARSE SAND -USDA- (PERCENT) ......              0.8   MEDIUM SAND -USDA- (PERCENT) ......         1.7
FINE SAND -USDA- (PERCENT) ........              2.8   VERY FINE SAND -USDA- (PERCENT) ...         1.9
COARSE SILT -USDA- (PERCENT) ......              4.6   FINE SILT -USDA- (PERCENT) ........        17.7
EROSION FACTOR (K) ................             0.28   WIND ERODIBILITY GROUP ..............         4
LIQUID LIMIT ..........................           74   PLASTIC LIMIT ........................       37
PLASTICITY INDEX ......................           37   SHRINKAGE LIMIT ......................       21
SHRINKAGE RATIO ...................              1.6   VOLUMETRIC SHRINKAGE ..............       105.6
LINEAR SHRINKAGE ..................             21.3   COMPRESSION INDEX ................        0.576
SPECIFIC GRAVITY (G/CU CM) ........             2.41   UNIFIED SOIL CLASSIFICATION .......          MH
EXPERIMENTER'S PARAMETER C) ....              341.00   DATA QUALITY FACTOR 1    ( 0.55,   0.0986)
DATA QUALITY FACTOR 2    ( 0.65,   0.0094)            DATA QUALITY FACTOR 3    ( 1.05,   0.0150)
DATA QUALITY FACTOR 4    ( 1.65,   0.0142)            DATA QUALITY FACTOR 5    ( 2.20,   0.0191)
FACILITY NAME .........            PURDUE / LARS   INSTRUMENT NAME .......       EXOTECH MOD 20C
SCAN RATE ..........................            0.25   HIGH SQUARE WAVE LEVEL (VOLTS) ..        4.955
LOW SQUARE WAVE LEVEL (VOLTS) ...               0.002   FIELD OF VIEW (DEGREES) ..........        0.75
SURFACE CONDITION -- PLOWED HAYFIELD

COMMENTS --                     SE1/4SE1/4SE1/4NE1/4SEC 28,T48N,R40W
```

Figure 1. Example of the identification information available for each soil sample.

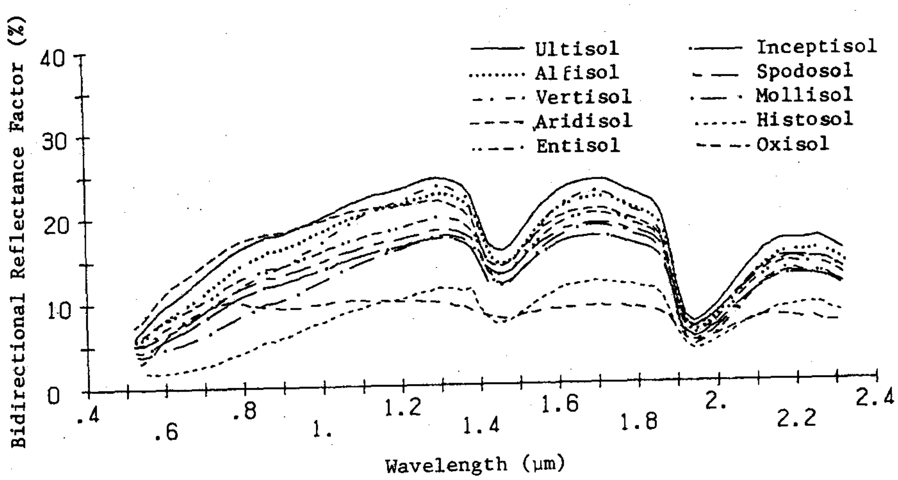

Figure 2. Reflectance spectra of 484 soil samples averaged by soil taxonomic order (see Table 4).

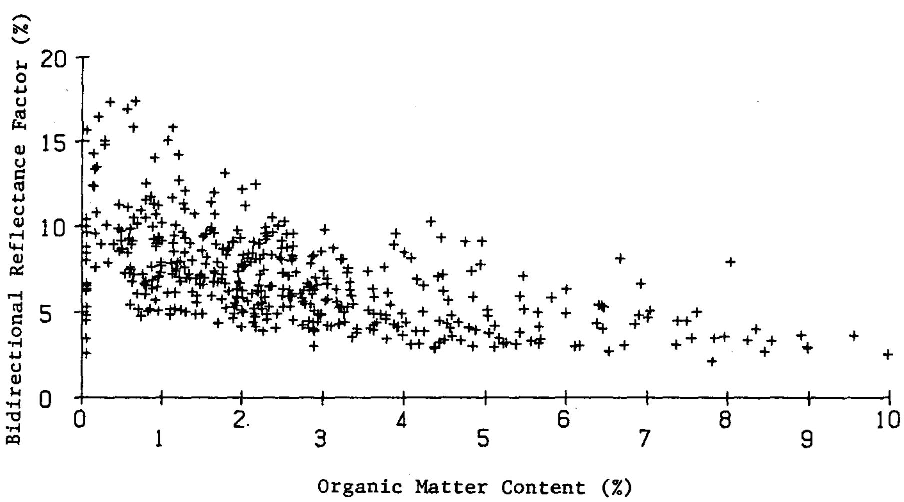

Figure 3. Graphical display of reflectance in the 0.52-0.62 μm wavelength band plotted as a function of organic matter content of 480 U.S. soil samples containing less than 10% organic matter.

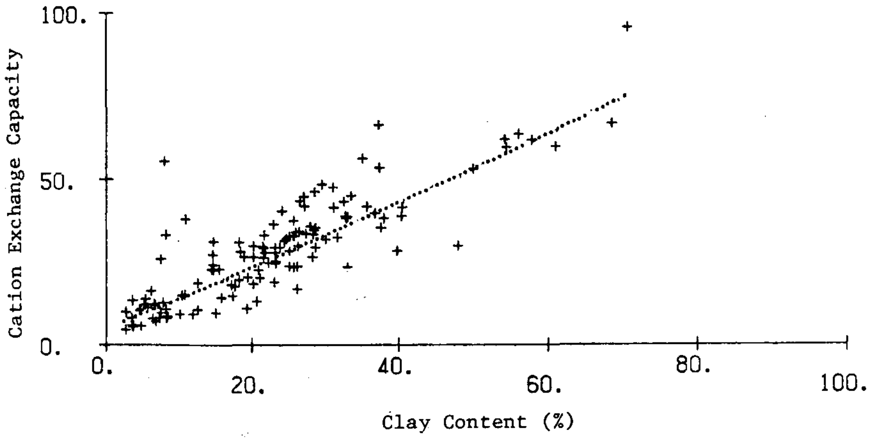

Figure 4. Graphical display of cation exchange capacity plotted as a function of clay content for 128 U.S. soil samples from the subhumid moisture zone.

V. ACKNOWLEDGEMENTS

This research was sponsered by the National Aeronautics and Space Administration, contract NAS9-15466.

VI. REFERENCES

1. Biehl, L. L. 1979. "Soil Information Codes for LARSPEC Soils Data Base", LARS Publication 111479, Laboratory for Applications of Remote Sensing, Purdue University, West Lafayette, IN.

2. Fuhs, N. C., and L. L. Biehl. 1979. "LARSPEC Users Manual", LARS Publication 121279, Laboratory for Applications of Remote Sensing, Purdue University, West Lafayette, IN.

3. Nicodemus, F. E., J. C. Richmond, J. J. Hsia, I. W. Ginsberg, and T. Limperis. 1977. "Geometrical Considerations and Nomenclature for Reflectance", National Bureau of Standards Monograph 160, U. S. Government Printing Office, Washington, D.C.

4. Stoner, E. R. 1979. "Physicochemical, Site, and Bidirectional Reflectance Factor Characteristics of Uniformly Moist Soils", Ph.D. Thesis, Purdue University, West Lafayette, IN. Also published as LARS Technical Report 111679.

5. Stoner, E. R., M. F. Baumgardner, L. L. Biehl, and B. F. Robinson. 1979. "Atlas of Soil Reflectance Properties", LARS Technical Report 111579, Laboratory for Applications of Remote Sensing, Purdue University, West Lafayette, IN.

Eric R. Stoner earned the B.S. degree in agronomy from the Pennsylvania State University in 1970, and received the M.S. degree in soil fertility and plant nutrition from Purdue University in 1972. From 1972 to 1974 he worked for the Brazilian Ministry of Agriculture in Mato Grosso State while serving with the United States Peace Corps, following this with a two-year position at the Brazilian Space Research Institute. From 1976 until obtaining the Ph.D. degree in 1979, he was a graduate research assistant in the Purdue University Agronomy Department while conducting research on the factors influencing soil spectral response. At present he is employed by NASA/Earth Resources Laboratory, NSTL Station, MS.

Larry L. Biehl, research engineer in the Measurements Program Area at LARS, has a B.S. degree in electrical engineering and an M.S. degree in engineering from Purdue University. He has had roles in NASA's Skylab program as a data analyst, NASA's Thematic Mapper Study as project manager and analyst, the LACIE Field Measurements Project, and currently the AgRISTARS Supporting Research Project. His present roles include overseeing the spectral data calibration and correlation, coordinating entry of the field research data into the library and developing improved software for more efficient analysis of spectrometer data. Mr. Biehl is a member of Eta Kappa Nu and Tau Beta Pi honorary societies.