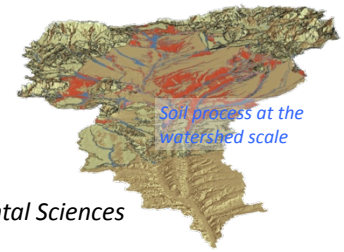
Comprehending Soil Process: Connecting Field Description with Quantitative Process Understanding

Stephanie A. Ewing
Montana State University Deptartment of Land Resources & Environmental Sciences
stephanie.ewing@montana.edu



About the class: Landscape Pedology

This upper division undergraduate class of about 40 students focuses on quantifying processes of soil development, taking advantage of local examples through field trips requiring hands-on evaluation of local soils and short, interpretive write-ups. There are two problem sets for practice in quantifying soils mass fluxes (carbon, silicon, nitrogen). Students learn fundamentals of soil description, soil taxonomy and landform assessment; and develop skills in written interpretation of soil processes in landscape context based on observation of a few soil profiles during each lab. Student learning goals:

1. Describe and interpret soils in terms of key processes;
2. Quantify mass fluxes within and through soils;
3. Understand Montana soils in global context and in terms of local land use/management.

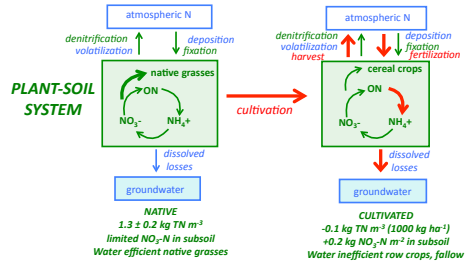
About the activity: Judith River Watershed virtual lab

The effects of cultivation and agricultural management practices have transformed the soil properties we observe and describe. This exercise asks students to quantitatively assess soil processes related to N leaching with agricultural management practice. They interpret soil descriptions in light of measured data from a USDA funded research project related to agricultural practices and elevated nitrate in groundwater. The exercise is intended to build the following skills:

1. Discern how cultivation (or other disturbance) changes the way soils look;
2. Quantify the effects of soil process using analytical data from soil profiles;
3. Write succinctly to relate observed soil properties with inferred soil process (nitrate leaching).

Background in lecture:

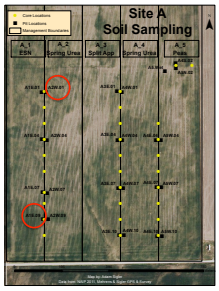
How does cultivation of semi-arid grasslands influence N dynamics?



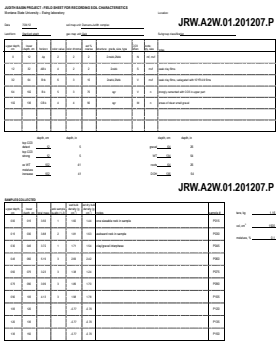
Three clues from the literature

1. In a central Montana grassland, 1000 kg N ha^{-1} is mobilized to the subsoil as nitrate with cultivation (Custer 1975);
2. Temperate steppe soils lost 20-40% of their organic matter upon cultivation, mostly in first couple of years (Davidson & Ackerman 1993);
3. Recovery of organic matter is N limited (Amundson 2001).

The assignment: short write-up based on profile descriptions; measured nitrate and water content



Soil locations on field A



Profile descriptions

Soil locations A2W.01 (left) and A1E.09 (right).

Real data!

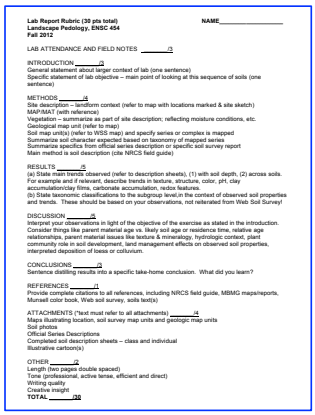
TABLE 1: ANALYTICAL DATA

		JRW.A2W.01.20 1207.P	JRW.A2W.01.20 1207.P	JRW.A2W.01.20 1207.P	JRW.A1E.09.201 207.P	JRW.A1E.09.201 207.P	JRW.A1E.09.201 207.P
upper depth, cm	lower depth, cm	nitrate N, ppm	wet BD, g cm-3	dry BD, g cm-3	nitrate N, ppm	wet BD, g cm-3	dry BD, g cm-3
0	15	5.79	1.589	1.347	6.995	1.646	1.363
15	30	1.84	1.818	1.532	2.880	1.831	1.480
30	45	2.37	1.694	1.404	2.668	1.769	1.484
45	60	2.83	2.674	2.447	3.518	1.959	1.687
60	75	1.81	1.358	1.294	4.930	1.962	1.706
75	90	1.06	1.861	1.810	4.813	2.118	1.856
90	105	1.40	1.959	1.884	4.760	2.504	2.324

Instructions for data development

1. Determine total nitrate (kg m^{-2}) in each depth increment and in each profile, accounting for estimated gravel content (show sample calcs);
2. Plot nitrate pools with depth and compare totals;
3. Determine height of water in each depth increment and in each profile; plot water heights with depth (show calcs);
4. Interpret depth trends and total pools of nitrate and water in light of soil development (in discussion section).

Rubric for the write-up



Lab Report Rubric (30 pts total) NAME_____
Landscape Pedology, ENSC 454
Fall 2012

LAB ATTENDANCE AND FIELD NOTES _____/3

INTRODUCTION _____/3
General statement about larger context of lab (one sentence)
Specific statement of lab objective – main point of looking at this sequence of soils (one sentence)

METHODS _____/4
Site description – landform context (refer to map with locations marked & site sketch)
MAP/MAT (with reference)
Vegetation – summarize as part of site description; reflecting moisture conditions, etc.
Geological map unit (refer to map)
Soil map unit(s) (refer to WSS map) and specify series or complex is mapped
Summarize soil character expected based on taxonomy of mapped series
Summarize specifics from official series description or specific soil survey report
Main method is soil description (cite NRCS field guide)

RESULTS _____/5
(a) State main trends observed (refer to description sheets), (1) with soil depth, (2) across soils. For example and if relevant, describe trends in texture, structure, color, pH, clay accumulation/clay films, carbonate accumulation, redox features.
(b) State taxonomic classifications to the subgroup level in the context of observed soil properties and trends. These should be based on your observations, not reiterated from Web Soil Survey!

DISCUSSION _____/6
Interpret your observations in light of the objective of the exercise as stated in the introduction. Consider things like parent material age vs. likely soil age or residence time, relative age relationships, parent material issues like texture & mineralogy, hydrologic context, plant community role in soil development, land management effects on observed soil properties, interpreted deposition of loess or colluvium.

CONCLUSIONS _____/3
Sentence distilling results into a specific take-home conclusion. What did you learn?

REFERENCES _____/1
Provide complete citations to all references, including NRCS field guide, MBMG maps/reports, Munsell color book, Web soil survey, soils text(s)

ATTACHMENTS (*text must refer to all attachments) _____/4
Maps illustrating location, soil survey map units and geologic map units
Soil photos
Official Series Descriptions
Completed soil description sheets – class and individual
Illustrative cartoon(s)

OTHER _____/2
Length (two pages double spaced)
Tone (professional, active tense, efficient and direct)
Writing quality
Creative insight
TOTAL _____/30

Results

Calculations – a computational challenge

Water (w) heights (H) for each horizon (h):

$$H_{w,h} = \left[\rho_{wet} - \rho_{dry}\right]\left[\rho_{water\ 298K}\right]\left[d_h\right]$$

Units assessment:

$$cm_water_h = \left[\frac{g_wetsoil}{cm^3soil} - \frac{g_drysoil}{cm^3soil}\right]\left[\frac{1.0_cm^3water}{g_water}\right]\left[15_cm\right]$$

Sum these to determine total water in the profile (cm)

$$H_{w,total} = \sum_{h=1}^{n} H_{w,h}$$

where n is the number of horizons.

Nitrate (N) pools in each horizon:

$$N_{pool,h} = N_{conc}\left[\rho_{dry} - \left(f_{coarse}\rho_{rocks}\right)\right]d_h$$

Units assessment:

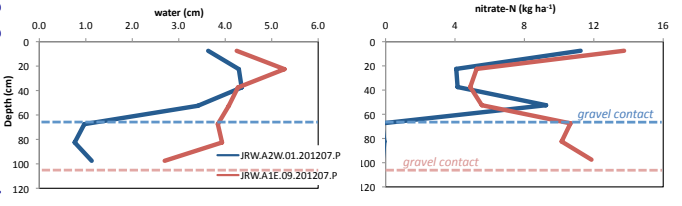
$$\frac{kg_N}{ha} = \left[\frac{mg_N}{kg_soil}\right]\left[\left[\frac{g_dry_soil}{cm^3_soil}\right] - \left(\left[\frac{cm^3_rocks}{cm^3_soil}\right]\left[\frac{2.65_g_rocks}{cm^3_rocks}\right]\right)\right]\left[15_cm\right]\left[\frac{kg}{1000_g}\right]\left[\frac{10^6_cm^3}{m^3}\right]\left[\frac{m}{100_cm}\right]\left[\frac{10^4\,m^2}{ha}\right]\left[\frac{kg}{10^6_mg}\right]$$

If these are negative, it is most likely due to (1) relative uncertainty in estimates of % coarse (~10-20%), and (2) relative uncertainty in bulk density due to gravel (~20% in lower horizons).

Sum these to determine total nitrate in the profile (kg/ha):

$$N_{pool,total} = \sum_{h=1}^{n} N_{pool,h}$$

Excel plots – also challenging



Two observations and an interpretation

1. Nitrate and water co-vary in the lower but not upper soil depths.
2. Peak nitrate occurs at the surface and above the gravel contact.
3. Given identical N inputs in this study, the lower inventory with shallower gravel contact could indicate nitrate leaching (and there are other possibilities).

Outcomes

1. Struggle with algebra and units pays off in many cases but is frustrating for some.
2. Discerning observation from interpretation – tricky to assess.
3. Relating the interpretation and discussion to the question posed – rarely accomplished in written reports.

References

Amundson, R. (2001) The carbon budget in soils. Annu. Rev. Earth Planet. Sci. 29:535–562.
Custer, S. G. (1975) Nitrate in Ground Water -- A Search for Sources near Rapelje, Montana. Northwest Geology 25–33.
Davidson, E. A. & Ackerman, I. L. (1993) Changes in soil carbon inventories following cultivation of previously untilled soils. Biogeochem. 20, 161-193.