Integration of agricultural production systems simulator (APSIM) into a graduate soil science course taught at a distance

Kayla Griffith
July 25, 2014

Program of Study Committee:
Thomas E. Loynachan, Major Professor
Richard M. Cruse
Daniel R. Dobill
Kenneth J. J. Moore
Who is Kayla?
Career Since Graduation

2013-2014: MTU/USFS PEATcosm Research Assistant
Outline

• Introduction and Development
  – AGRON 502
  – APSIM
• Objectives
• Methods and Results
• Discussion and Conclusions
• Future Ideas
Creative Component Development
# MS AGRON Course Structure

<table>
<thead>
<tr>
<th>First Semester Intro Courses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agron 501: Crop Growth and Development</td>
</tr>
<tr>
<td>Agron 502: Chemistry, Physics, and Biology of Soils</td>
</tr>
<tr>
<td>Agron 503: Climate and Crop Growth</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Second Semester Courses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agron 511: Crop Improvement</td>
</tr>
<tr>
<td>Agron 512: Soil - Plant Environment</td>
</tr>
<tr>
<td>Agron 513: Quantitative Methods for Agronomy</td>
</tr>
<tr>
<td>Agron 514: Integrated Pest Management</td>
</tr>
<tr>
<td>Agron 531: Crop Management and Ecology</td>
</tr>
<tr>
<td>Agron 532: Soil Management</td>
</tr>
<tr>
<td>Agron 533: Crop Protection</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Summer and Third Semester Courses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agron 591: Agronomic Systems Analysis</td>
</tr>
<tr>
<td>Agron 592: Current Issues in Agronomy</td>
</tr>
<tr>
<td>Agron 594: Workshop in Agronomy</td>
</tr>
<tr>
<td>Agron 599M: Creative Component</td>
</tr>
</tbody>
</table>

Total Program Credits = 40
MS AGRON Course Structure

- Agron 501: Crop Growth and Development
- Agron 502: Chemistry, Physics, and Biology of Soils
- Agron 503: Climate and Crop Growth
- Agron 511: Crop Improvement
- Agron 512: Soil-Plant Environment
- Agron 513: Quantitative Methods for Agronomy
- Agron 514: Integrated Pest Management
- Agron 531: Crop Management and Ecology
- Agron 532: Soil Management
- Agron 533: Crop Protection
- Agron 591: Agronomic Systems Analysis
- Agron 592: Current Issues in Agronomy
- Agron 594: Workshop in Agronomy
- Agron 599M: Creative Component

Total Program Credits = 40
Agronomy 502 Index

**Soil Basics**
- Introduction
- 1: Soil Development & Classification
- 2: Soil Mineralogy & Weathering
- Soil Basics Summary

**Soil Chemistry**
- Soil Chemistry Introduction
- 3: Ion Exchange
- 4: Ion Distribution
- 5: Ion Activity & Liming
- 6: Solubility & Chemical Reactions
- Soil Chemistry Summary

**Soil Physics**
- Soil Physics Introduction
- 7: Soil Physical Properties — Solids
- 8: Water Storage and Flow in Soil
- 9: Soil Temperature
- Soil Physics Summary

**Soil Biology**
- Soil Biology Introduction
- 10: Soil Organisms
- 11: Soil Organism Interaction
- 12: The Carbon Cycle
- 13: The Nitrogen Cycle
- Soil Biology Summary

**Soils, Roles, and Issues**
- Case Study and Summary
Ion Exchange

Developed by F. Troeh

Readings


Introduction

About 1850, a man named Thompson in Yorkshire, England, made an interesting discovery. He spilled an ammonia solution on some soil and noticed that the strong ammonia smell was gone. He told his friend, Sir Thomas Way, about it. Way experimented by doing the same thing, but went further with it. He poured an ammonium sulfate solution on the top of a soil column and found that calcium sulfate came out the bottom. The anion was the same, but the cation had changed. He had discovered the process we call cation exchange.

Fertile soils have the ability to store plant nutrients and release them gradually as growing plants need them. Several different processes are involved, including the decomposition of organic matter and dissolution of slightly soluble mineral matter. Cation exchange is a very important part of this overall system. Anion exchange also occurs, but it plays a lesser role. Both will be considered in this lesson.

The topic of ion exchange has several dimensions. Practical considerations include the importance it has to plant growth, how much of it there is in a particular soil, and what can be done to use it most effectively. A more basic understanding adds an analysis of the mechanisms and the materials involved as well as the analytical techniques needed to evaluate ion exchange.
Measuring Cation Exchange Capacity

Alternative Method to Measure CEC

An alternate procedure for calculating the CEC involves measuring the principal basic cations extracted in step 1 of the above procedure (at least Ca$^{2+}$ and Mg$^{2+}$; others as well if high accuracy is required). Next, a second determination is made to quantify the acidic cations, H$^+$ and Al$^{3+}$ (if present). The acidic cations may be measured by the change in acidity of either an unbuffered extracting solution such as 1 N potassium chloride or a buffered solution such as 0.5 N barium acetate at pH 8. The sum of the acidic and basic cations is then taken as the cation exchange capacity of the soil.

Estimation of CEC Based on Clay Content

Estimates of cation exchange capacity are based on the clay and organic matter contents of the soil. These may have been measured, or they may have been estimated from the texture and color of the soil. The dominant type of clay mineral(s) present must also be known or assumed, but this is usually predictable for a given location. For example, the clay in most Iowa soils is a mixture of illite and the beidellite form of smectite. Typically, these materials will have cation exchange capacities of about 30 meq/100 g for the illite and 80 meq/100 g for the smectite, or about 60 meq/100 g for the mixture. An average value of 200 meq/100 g may be assumed for the soil organic matter.

Study Question 3.6
Using the above values, estimate the cation exchange capacity of an Iowa soil that contains 25% clay (10% illite and 15% smectite) and 4% organic matter (as indicated by its dark soil color). Enter the estimated CEC values in the box:

<table>
<thead>
<tr>
<th>Colloid</th>
<th>meq CEC/100g soil</th>
</tr>
</thead>
<tbody>
<tr>
<td>Illite</td>
<td></td>
</tr>
<tr>
<td>Smectite</td>
<td></td>
</tr>
<tr>
<td>Organic Matter</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
</tr>
</tbody>
</table>

Check Answer
Discussion Topic 5.1

From the soil you described from your area in Lesson 1 and using the [Soils Data Mart](#), answer the following questions as separate paragraphs in your posting in the SNS Discussion area:

1. What is your soil’s topsoil and subsoil pH as indicated by the Soils Data Mart data?
2. How does this differ from the actual pH of the farm/field you chose to represent your soil (from soil testing data if you know this...speculate if you don’t know)?
3. Does the taxonomic name of your soil indicate pH? If so, what part of it does this?
4. How does the pH of your soil affect crop production (directly or indirectly)?
5. What is the depth to carbonates in your soil? How does that relate to pH of your soil at various depths?
6. What soil series in the Case Study is most closely related to your soil in terms of pH and briefly define why?

You can only see the posts for your discussion group. Remember that the original discussion posts are only a portion of your grade for discussion topics. You are responsible for reading all of the posts and replying to several others. For more detail regarding expectations in the course for discussion topics, see [Expectations and Grading](#) in the introduction lesson. Also, several of your classmates are the discussion leaders for this lesson. Help them out by posting early and often.

Assignment 5.1: Case Study pH

Utilizing the [Case Study soils](#) and the [Soils Data Mart](#), summarize general differences between the soil series on the Homeplace farm and your soil regarding carbonate presence and soil pH (both from Soil Data Mart and map of soil pH on Homeplace field). To complete the assignment:

1. Fill in the red boxes in the CaseStudy.xls worksheet.
2. Upload CaseStudy.xls with completed portions for A5.1 to the assignment-upload area of the SNS.
3. Indicate 3 observations comparing your soil to the case study soils or between the case study soils. Type or copy/paste them in the assignment comment box in the SNS.
Agricultural Production Systems Simulator (APSIM)

Simulation of a series of models.

Oh, ok... hold on, what?

http://www.ars-grin.gov/mia/Pages/Hydrology/computerModel.htm
Computer Simulation

http://www.apsim.info/
Objectives

- Soil physics exam
- New lesson 7
- Integrate APSIM into lessons 7, 8, and 9
- Student surveys
2. Soil Texture (16 pts.)
   A. Rank the following soil textures from highest permeability (1) to lowest permeability (4). Make assumptions as necessary.
      ____  Silty Clay
      ____  Loamy Sand
      ____  Sandy Loam
      ____  Silty Clay Loam

   B. Rank the following soil textures from highest Available Water Holding Capacity (1) to lowest Available Water Holding Capacity (3) per volume of material. Make assumptions as necessary.
      ____  Silty Clay
      ____  Loamy Sand
      ____  Sandy Loam
      ____  Silty Clay Loam
b. Match each above soil texture to its corresponding available soil water graph (A-D).

- Clay
- Loamy Sand
- Sandy Loam
- Silt Loam

![Graphs A, B, C, D showing volumetric water content and depth](image)
Was the question two graphic effective in helping you demonstrate your knowledge of available soil water?

Number of students

<table>
<thead>
<tr>
<th>Strongly agree</th>
<th>Agree</th>
<th>Neither agree nor disagree</th>
<th>Disagree</th>
<th>Strongly disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>14</td>
<td>6</td>
<td>3</td>
<td>2</td>
</tr>
</tbody>
</table>
3. **Soil Temperature (12 pts)**

The following temperature data was taken in Ames, Iowa. One of the curves is for air temperature and the other is for soil temperature at 10cm depth over time.

![Graph of temperature over time](image)

i. Determine which curve is air temp. and which is soil temp.

Red=
Blue=

ii. What time of day does the lowest part of the curves (trough) represent (6:00am, 12 noon, 6:00pm, or midnight)? Briefly describe how you determined this?
Nicollet Soil Temperature

Temperature °F

Date

January March May July September November
a. Which curve represents the loam soil and which represents the sandy soil?

<table>
<thead>
<tr>
<th>Soil Type</th>
<th>Curve Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loam</td>
<td></td>
</tr>
<tr>
<td>Sandy</td>
<td></td>
</tr>
</tbody>
</table>
Were the graphics in question three effective in helping you demonstrate your knowledge of soil temperature?
Simulations that generate graphics similar to graphics on the soil physics exam would benefit AGRON 502 course material.
Lesson 7

Soil Physical Properties — Solids

Developed by D. Dobill and K. Griffith

- What are soil physical properties?
- How can you determine soil texture in your area?
- What is soil structure and can it be modified?

Questions?

Reading

The Nature and Properties of Soil (14th Ed.), p. 121-162

Introduction

In previous lessons we have discussed soil in terms of formation and chemistry. In the next three lessons we will discuss soils in terms of their physical properties, characteristics that can be seen or felt, including texture, water content, temperature, and others. We previously defined soil in terms of mineralogy but in our soil physics lessons we will discuss soil in terms of physical size. This lesson will focus on soil mineral material, specifically soil texture, structure and related soil properties. Understanding the difference in soil mineralogy and soil texture is particularly important when it comes to understanding clay. We have previously defined clay as the arrangement of elements to form a structure
Lesson 7: Soil texture by depth
Did the lesson 7 APSIM activity help you understand soil solids?

![Bar chart showing the number of students' responses to the question. The chart indicates that the majority of students agreed or strongly agreed with the statement.](chart.png)
Lesson 8: Saturated water flux

Below is a graph of saturated water flux. Spend some time and compare the fluxes of each soil. Remember to revisit each soil to get an idea of each respective soil’s properties.
Lesson 8 continued: Unsaturated water flow

Unsaturated Water Flow

Below is a graph of unsaturated water flow and a graph of the specific soil’s water content. Spend some time and compare the curves. Once you have an understanding of the curves please answer the questions below.
Did the lesson 8 APSIM questions help you better understand soil water?
APSIM Integration: Lessons 7, 8, and 9

Lesson 9: Soil temperature by depth

The graph below presents the soil temperature of a soil at different depths over a yearly growing season.
Lesson 9 continued: Soil temperature by type

The graph below shows soil temperature for four soil types at the same depth.

- Silty Clay
- Sandy Clay
- Sand
- Clay

Temperature (°F) vs Date

17/05/2011, 21/05/2011, 27/05/2011
Did the lesson 9 activities help you to better understand soil temperature?
General Survey Questions: Fall 2013
Do you feel the APSIM activities were overall easy to understand?

- Strongly agree: 2
- Agree: 10
- Neither agree nor disagree: 3
- Disagree: 4
- Strongly disagree: 0
Overall, did the lesson graphics and exam graphics help you to visualize and master the course material?
Discussions and conclusions

• The majority of students responded positively to APSIM survey questions.
• Students’ free-response answers shed more light on their feelings towards APSIM.
Future Ideas

• 502
  – Tweaking current APSIM images.
  – Updating a soil temperature activity in lesson 9 to be APSIM based instead of excel based.

• MS Agronomy Program
References


Thank you!

• My committee: Tom Loynanchan, Richard Cruse, Dan Dobill, and Ken Moore
• Iowa State University, MS Agronomy Program Faculty and Staff, Agronomy Development Lab, Gretchen, Sotiris, Dawn, and 502 Students!
• Michigan Tech students, co-workers, and supervisors.
• Jennifer Eikenberry
• My friends and family: Grandmom, Pop, Jeffrey, Mom, Dad, Lesley Dame, Mickey
Questions?