Facilitating Soil Calculations with Logical Spreadsheeting

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1. Introduction

Undergraduate soils students frequently find difficulty with the nutrient, water, and crop calculations required in beginning and intermediate soils courses. Practitioners in soil, fertilizer, and crop-related occupations frequently encounter calculations and conversions of amounts and quantities of nutrients.

In the extreme case, students find the number and complexity of the calculations beyond their capability, particularly those students with limited preparation in mathematics, basic chemistry, and physics.

This situation seems to be similar among various universities, languages and cultures. The objective of our effort was to test a spreadsheet approach to organize, simplify, teach, and empower students to carry out routine soil, water, and crop calculations.

Example problems:

A. Fertilizer Calculation Spreadsheet Suppose you have received fertilizer recommendations of 100 kg N ha^{-1}, 50 kg ha^{-1} P_2O_5, and 50 kg K_2O ha^{-1}. You have available 50 kg bags of 15-15-15 and 50 kg bags of urea. You plan to apply about ½ of the N preplant and ½ topdress. You will apply P and K preplant, only N is topdress applied. How many bags of 15-15-15 and urea do you need to buy to apply to a field of 300 meters by 100 meters?

B. Fertilizing Lettuce Suppose you have the following information on the soil of your garden. For a sample 0-20 cm you know the bulk density is 1.25, the organic C is 10 g kg^{-1},soil solution P is 2.5 mg kg^{-1}, soil solution K is 10 mg kg^{-1}, water content is 30%. Please answer the following questions:

a) What is the amount of organic N in the surface 20 cm of soil assuming a C/N ratio of 12
b) Calculate the quantity of inorganic N assuming a rate of mineralization of 3% per year
c) Assuming the lettuce uses the surface 20 cm of soil, calculate the quantity of soil solution K available to the crop
d) Calculate the amount of soil solution P available to the lettuce.
e) Calculate the quantity of 20-10-10 needed to supply the needs of lettuce assuming it needs 150 kg N ha^{-1}.

Steps in Logical Spreadsheeting: (after Buckmaster, 2006)

1. Prepare a framework of the problem first by locating three Sections (groups of rows): Data/Inputs, Calculations, and Results and assigning four columns: a name/description(Data), b(Value), c(Units) and d(Notes) to each of the three Sections (Figures1,3)

2. Identify given information (Inputs), desired results (Results) and then identify intermediate values required for the solution (Calculations) and complete columns a, b, c, and d for these Sections.

3. Enter all given and assumed information in the Data Section.

4. Enter Excel formulae for Calculations and Results Sections.

5. Re-sequence Calculations and Results so that the sheet reads top to bottom according to a logical sequence of calculations.

6. Replace the = in formulae (column b) with '=, copy to column d and then delete the ' so that formulae again calculate properly.

7. Add comments or text boxes as necessary to document the work.

8. Repetitive analyses can be made easier with 1 or 2 dimensional Look-up tables. Also consider the "Solve for" Add-in if needed.

9. More experienced users might wish to carry out linear and nonlinear programming (Li et al, 1996) and simulation experiments using Excel Add-ins.

2. Materials and Methods

The problem solving structure using Excel as proposed by Buckmaster (2006) was adapted for carrying out fertilizer calculations. The data entry section was color-coded yellow, while the remainder of the spreadsheet was password protected to help ensure that inadvertent change in the spreadsheet did not occur.

A.Fertilizer Calculation Spreadsheet

Data Entry:	Values	Units
Desired Nitrogen	100	kg N/ha
Desired Phosphorus	50	kg P2O5/ha
Desired Potassium	50	kg K2O/ha
Pre-plant (Fertilizer 1)	15-15-15	
Pre-plant (Fertilizer 2)	0-0-60	
PrePlant&TopDress (Fert. 3)	46-0-0	
Field size (length)	300	meters
Field size (width)	100	meters

Calculations:		Units
Area (m2)	30000	m2
Area (ha)	3	hectares
Nitrogen (Fert 1)	15	N
Phosphorus (Fert 1)	15	P2O5
Potassium (Fert 1)	15	K2O

Results:		Units
Amt of Pre-plant(Fert 1):	1000	kg
Amt of Pre-plant(Fert 2):	0	kg
Amt Add. Pre-plant(Fert. 3):	163.0435	kg
Amt Top-Dress(Fert. 3):	163.0435	kg
Total fertilizer cost	100000	your currency

Figure 1. Illustration of the Fertilizer Calculation Spreadsheet as developed using Logical Spreadsheeting.

B.Fertilizing Lettuce

At a graduate level, students at the University of Hawai`i analyzed the word problem concerning Fertilizing Lettuce (Example B), developed the spreadsheet shown in Fig.3 and presented it to the class. All class members received a copy of the completed spreadsheet for their files and future reference.

Students worked in teams and noted that this was a new way to think about calculation problems. They found this way of organizing the word problems clear and logical. Students indicated that they wish they had learned this way of solving calculation problems when they first took soils courses. Some said that when taught this way, the soil calculations were much more interesting and less intimidating. Students appreciated the introduction to such a clear, powerful way to do calculations that previously were a source of anxiety and stress.

3. Results and Discussion

Figure 2. Students at UniZambeze, Mocuba, Mozambique carry out fertilizer calculations using Excel spreadsheets similar to the one in Figure 1.

Data	Value	Units	Notes	
Bulk density	1.25	tonnes	Given	
Organic C	19	g kg^{-1}	Given	
Total P	420	mg kg^{-1}	Given	
Soil Solution P	2.5	mg kg^{-1}	Given	
Soil Solution K	10	mg kg^{-1}	Given	
Amount of H_2O	0.3	decimal	Given	
C-N Ratio	12	ratio	Assumption	
Mineralization	3%	% yr	Given	
Crop N absorption	150	kg ha^{-1}	Given	
Calculation				
1 hectare	10000	m^2	Conversion	
20 cm soil	0.2	m	Conversion	
Area of 20cm depth ha^{-1}	2000	m^3	Calculation	
Organic C	47500	g kg^{-1}	Calculation	
Amount of N mineralized	1.1875	g kg^{-1}	Calculation	
Results				
Organic N	3958.33	g kg^{-1}	=(B25/B13)	Part A
Inorganic N	118.75	kg ha^{-1}	=(B32*B14)	Part B
Soil Solution K	6	kg ha^{-1}	=(B23*B10*B26)/B27	Part C
Soil Solution P	1.5	kg ha^{-1}	=(B9*B23*B26)/B27	Part D
Fert quantity 20-10-10	156.25	kg	=(B15-B33)/0.2	Part E

Figure 3. Illustration of student's solution to Example Problem B. Fertilizing Lettuce.

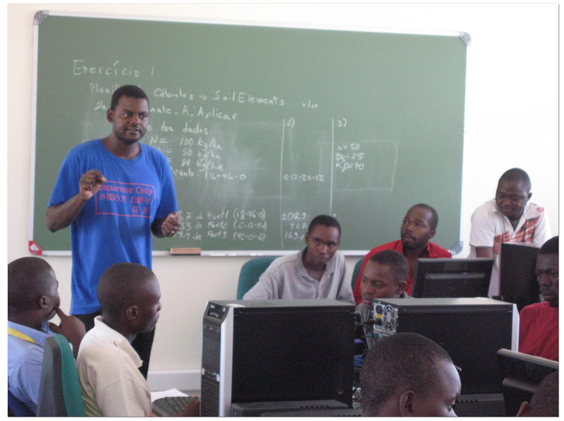

Figure 4. Dr. Chongo, UniZambeze explains a concept being taught using the Fertilizer Calculation Spreadsheet.

4. Conclusions

1. Students learned to carry out fertilizer calculations and routine soil, water, and crop calculations.
2. Students learned preliminary concepts of modeling:
   a. How to think through a calculation problem logically and accurately.
   b. How to carry out What-if analyses
3. Students reduced their fear and anxiety of soil calculations
4. Students were empowered to use the problem-solving technique to other disciplines and problems requiring quantitative analysis and calculation such as economics, calibrations, and transformations.

5. Literature cited

Buckmaster, D. 2006. Effective Problem-Solving with Excel. American Association of Agricultural and Biological Engineering and Purdue University, West Lafayette, Indiana.

Li, Z.C., I P.G. Widjaja-Adhi, T. S Dierolf, and R.S. Yost. 1996.Liming Material Selection by Computer Spreadsheet. J. Nat. Res. and Life Science Education. 25:26-30.

6. Acknowledgments

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