

Earth Science Case Study: Farmer Mark's Field



NCSSM

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NOTE! All of the materials for this case study are available on NCSSM's Gotwals Outreach page: <https://ncssm.instructure.com/courses/411>

North Carolina Standard Course of Study Objectives for Earth Science

The following objectives from the NCSCOS are potential targets for this case study.

- EEn.2.1 Explain how processes and forces affect the lithosphere.
- EEn.2.2 Understand how human influences impact the lithosphere.
- EEn.2.3 Explain the structure and processes within the hydrosphere.
- EEn.2.4 Evaluate how humans use water.

- EEn.2.8 Evaluate human behaviors in terms of how likely they are to ensure the ability to live sustainably on Earth.

1 Background

”Farmer Mark’s field” is a computational project designed to help students study various aspects of an agricultural system, specifically ground water runoff and soil erosion. In this project, students collect data, analyze that data using a spreadsheet, and then, using the results of their spreadsheet, run a soil erosion/agriculture model supported by Purdue University and the National Soil Erosion Research Lab (USDA).

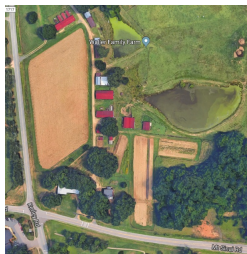


Figure 1: Aerial picture of Farmer Mark’s field, showing Kerley and Mt. Sinai intersection

”Farmer Mark’s field” is a small farm located in western Durham County, owned and farmed by Mark Waller. The field was previously used for tobacco, but now has been converted to an ecotourism farm, dealing primarily with pick-yourself strawberries. Farmer Mark also raises some cattle, boards horses, and keeps bees. This is a working farm, and it can be found at the intersection of Kerley and Mt. Sinai Roads in Durham. Just to the south, across Mt. Sinai, lies Forest View Elementary School. The Wallers live on the farm, and the farm has been in the Waller family for many generations. (Google Map coordinates: 35.9910055,-78.992142) [Source: <https://www.wallerfamilyfarm.com/Welcome.html>]

2 Computational Approach

There are three research questions for this case study:

1. RQ1: When it rains, where does the water go? Is there a concern about flooding in the elementary school to the south of the farm?
2. RQ2: For this particular field, how much topsoil runoff might there be? How much sediment is removed from the farm?

3. RQ3: What are some agricultural farming practices that might reduce soil erosion and topsoil runoff? Which of these prevent the least amount of soil runoff? Which of these are economically feasible?

There are three parts to this case study:

1. Slope evaluation: students will collect elevation data across a 50x100 foot grid (5000 square feet), the dimensions of the field. Based on this data, students will determine the slope of the field as a percentage and be able to create a 3D slope profile
2. Soil Erosion determination: using the Water Erosion Prediction Project (<https://milford.nserl.purdue.edu/>), and using data from the slope profile and knowledge about the location of the Waller farm,
3. Agricultural Practices (optional, depending on available time): students will use the WEPP model to evaluate different agricultural practices

2.1 Slope Evaluation

The steps for this task are as follows:

1. Students are provided with the handout shown in Figure 2, which is available as a PDF file from the Canvas site:

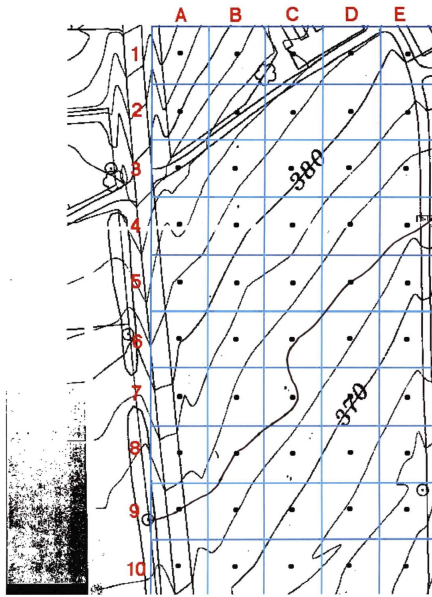


Figure 2: Overlay of grid on topographic map

2. Students will determine the spacing on the grid (for example, each contour line represents two feet. Using the dot at the center, the students should determine an elevation value for each of the grids. This data should be entered into Excel or Google Sheets following the same grid markers (for example, A1, B3, etc.). Figure 3 shows sample data. Student data will be approximate, but should be close:

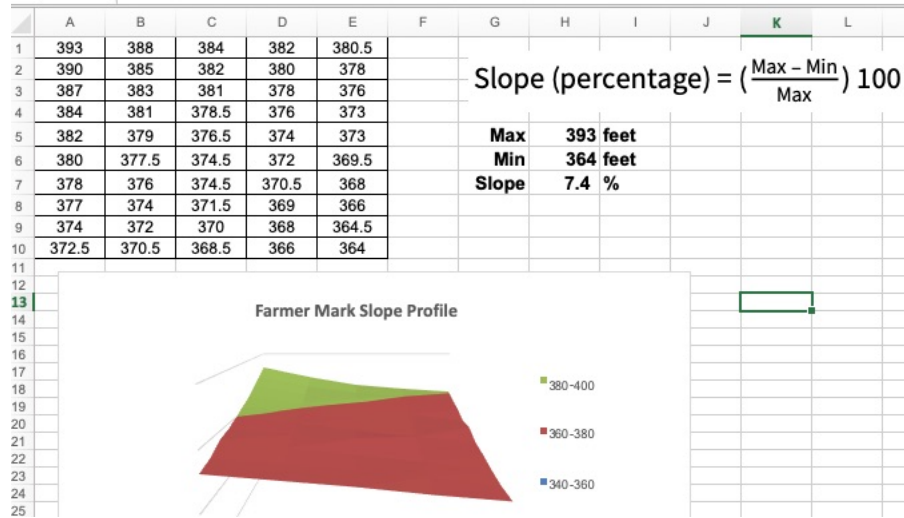


Figure 3: Screenshot of completed Excel spreadsheet, showing a 7.4% slope

- Using the data, students will find the min and max of the data points. In the example spreadsheet, we find the max in Cell H8 using the formula: =MAX(A4:E13) , and the min in Cell H9 using the formula =MIN(A4:E13) . The slope is found using the formula:

$$\text{Slope} = \frac{\text{Max} - \text{Min}}{\text{Max}} 100 \quad (1)$$

Note that the labels of "feet" and "%" are in in Cells H8, H9, and H10, respectively.

Many students, when looking at the aerial photo of the field (as shown in Figure 1, assume that the water flows into the pond directly to the east of the field. The 3D slope visualization should suggest, however, that water and the accompanying soil runoff flow to the bottom right (southeastern) corner of the field, and Farmer Mark has to work to ensure that water does not run over Mt. Sinai Road and into the school property, especially during heavy rain/flooding conditions.

2.2 Soil Erosion Determination

The steps for this section are as follows:

1. Go to the WEPP model at Purdue (<https://milford.nserl.purdue.edu/>), and click on the "Web Browser version", then "Basic Hillslope Profile". For the example shown, we have used this data:

- (a) State: North Carolina
- (b) Climate Station: Chapel Hill (closest weather station to Durham). Figure 4 shows rainfall amounts for Chapel Hill.

WEPP Climate Locations		Climate Parameters for CHAPEL HILL NC (nc311677)			
State (North Carolina) Go		35.92 N -79.07 W 590 Feet Elevation			
Month	Mean Maximum Temperature (F)	Mean Minimum Temperature (F)	Mean Precipitation (in)	Number of Wet Days	
January	50.34	27.68	3.5	10	
February	53.62	29.67	3.6	9	
March	61.35	36.3	3.8	10	
April	71.79	45.3	3.15	9	
May	78.9	53.89	3.7	10	
June	85.5	61.75	3.87	9	
July	89.05	65.76	4	10	
August	87.44	64.8	4.14	9	
September	81.82	58	3.01	7	
October	71.99	45.78	2.94	7	
November	62.8	36.87	2.96	8	
December	52.89	29.55	3.15	9	
Annual			41.82	107	

Figure 4: Rainfall amounts recorded at the Chapel Hill weather station

- (c) Field Length: 100 feet
- (d) Field Width: 50 feet
- (e) Slope Shape: Uniform
- (f) Steepness: 7% (this was determined using the spreadsheet)
- (g) Soil: Durham (LCOS – Loamy Course Sand). Figure 5 shows a "soil triangle" chart. Figure 6 shows the specifications for the Durham LCOS soil type. Note that Durham soil is 67.7% sand!

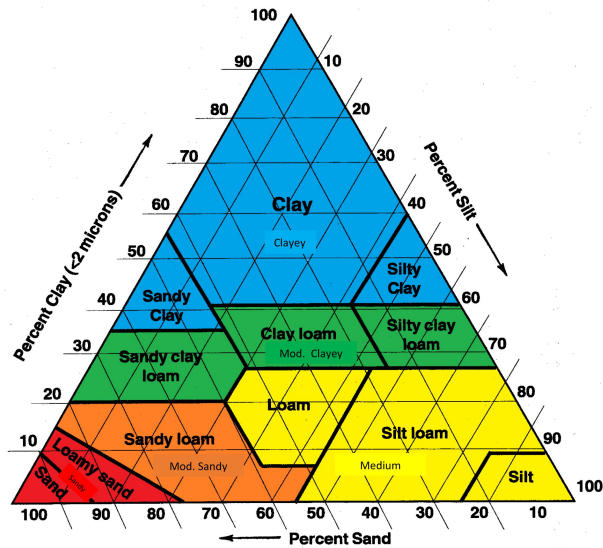


Figure 5: Chart of soil types

WEPP Soil Details for DURHAM (NC)

Soil Texture: LCOS

Initial Saturation Level: 0.75

Interrill Erodibility (kg*s/m**4): 4.56033e+06

Critical Shear: 2.36

Albedo: 0.23

Rill Erodibility: 0.0087

Effective Hydraulic Conductivity (mm/h): 16.56

Layer Information

Layer	Depth (mm)	Sand (%)	Clay (%)	Organic Matter(%)	CEC (meq/100g)	Rock(%)
1	406.4	83.1	3.7	1.25	2.9	3.9
2	914.4	61.3	26.5	0.42	5.3	3.6
3	1066.8	51.1	35	0.14	7	3.4
4	1219.2	70.2	19	0.05	3.8	3.5
5	1524	72.8	12.5	0.02	2.5	5.9

Figure 6: Specifications for Durham LCOS soil type

(h) Management: Fallow (nothing planted)

(i) Simulation Years: 1

Once completed, hit the "Calculate Soil Loss" button. The results for these parameters is shown in Figure 7.

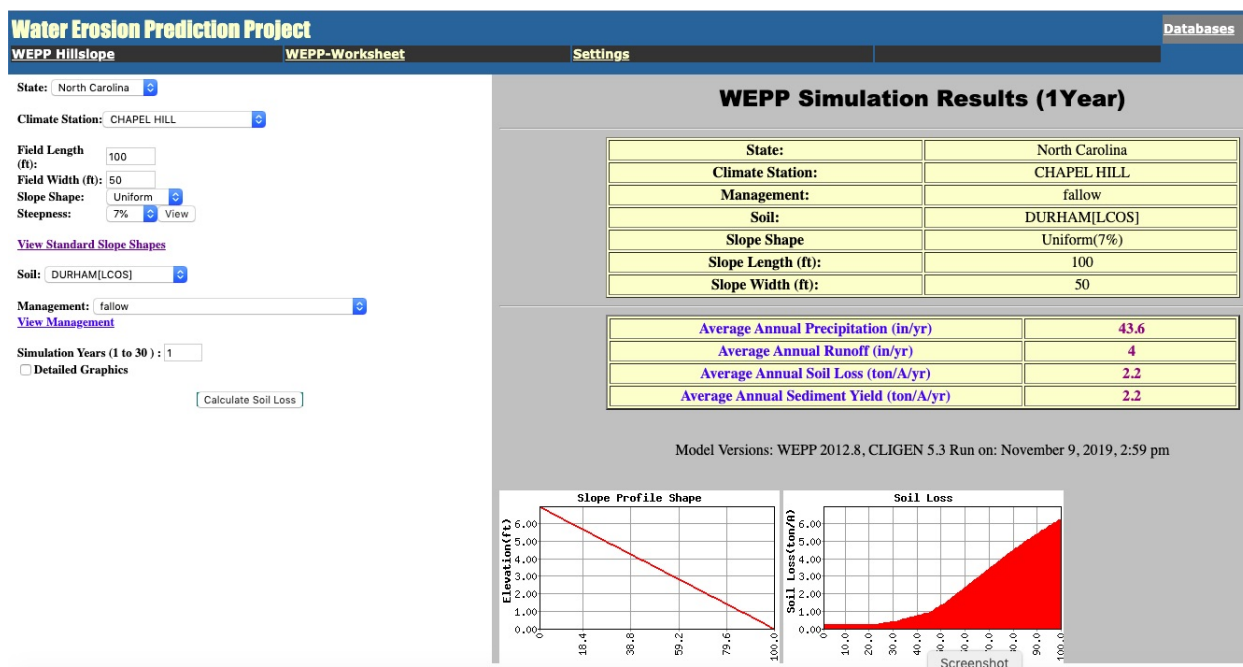


Figure 7: Screenshot of the WEPP model using Farmer Mark data

2.3 Agricultural Practices

Students can now investigate various options for agricultural management of the field. From the "Databases" tab (this can be found from the "Basic Hillside profile" page, top right corner), students can see what a farmer might do in terms of managing the field, with very specific practices and suggested dates for these practices. For example, the option "Barley, conventional tillage" management practice is shown in Figure 8. Note the very specific details regarding what should be done and when.

Management Schedule Barley, conventional tillage, Palouse		
Description: Landuse: Cropland Drainage: None		
Date	Operation Type	Operation Name
4/1/1	Tillage	Field Cultivation
4/3/1	Tillage	Field Cultivation
4/3/1	Tillage	Harrow-springtooth (coil tine)
4/5/1	Tillage	Anhydrous applicator
4/5/1	Tillage	Harrow-springtooth (coil tine)
4/10/1	Tillage	Drill with double disk opener
4/10/1	Plant-Annual	Barley
8/15/1	Harvest	Barley
10/15/1	Tillage	Chisel plow with coulters and straight chisel spike pt

Figure 8: Screenshot of the Barley conventional tillage management plan

Students can select all of the options, and determine which management plan results. The complete results can be found as an Excel spreadsheet on the Canvas page. Using the formula `=IF(C2=MIN(C$2:C$39), A2,"")` in Cell E2 and then doing a fill down, it can be determined that grass is the best management plan for reducing soil loss. However, you can now have the discussion of the economic value of planting grass. Farmer Mark raises cows and boards horses, so this might not be a nonviable option for him, but it is likely not as lucrative as planting soybean, corn, or even some type of grass (like bluegrass) that might be sold to landscapers.