GC21C-0984: Multifunctional Agriculture: Conducting an Ecosystem Service Assessment for an Agricultural Watershed

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Introduction

To ensure food security for an exponentially growing global population that is grown on a finite number of farm fields, intensive agricultural management practices are being used. Intensive management practices can trigger rainfall-and tillage-induced **erosion events**, **degrade soil and water quality**, and **increase atmospheric fluxes of carbon dioxide (CO_2)**. Conservation practices, including reduced tillage and no-till, have been shown to offset some of these negative environmental effects. **These good land stewardship practices provide additional ecosystem services or benefits to a large number of stakeholders.**

In this study, a Multifunctional Agriculture (MFA) assessment of a representative agricultural watershed in Iowa was conducted by assessing dominant ecosystem services, including: water quality (runoff), crop/grain production, soil carbon sequestration, and reduction in CO_2 emissions. Services were identified using a newly developed coupled erosion and biogeochemical model framework with a geo-spatial platform. An economic cost-benefit analysis was also conducted to assess the feasibility of adapting various practices and the possibility of future monetary incentives.

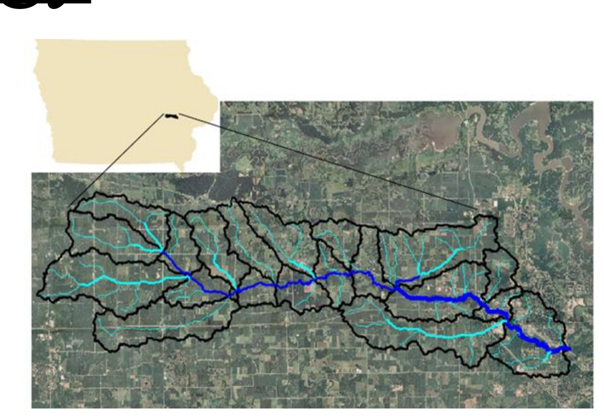
Objectives

- ✧ Develop a means for farmers and producers to make good land stewardship decisions that are based soundly on a holistic framework.
- ✧ Assess the potential for additional ecosystem services under different land management practices.
- ✧ Perform a cost-benefit analysis for current and alternative management practices and evaluate the overall soil health of the watershed.

Methodology

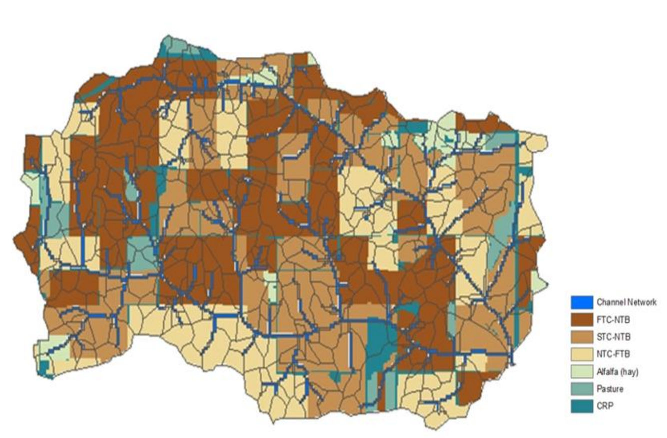
Site Description:

Name: South Amana Sub-Watershed
Location: Iowa County, Iowa
Drainage area: 27 km^2
Average precipitation: 890 mm/yr
Average daily temperature: 10 °C
Soil: Loess-derived; Silty clay loams



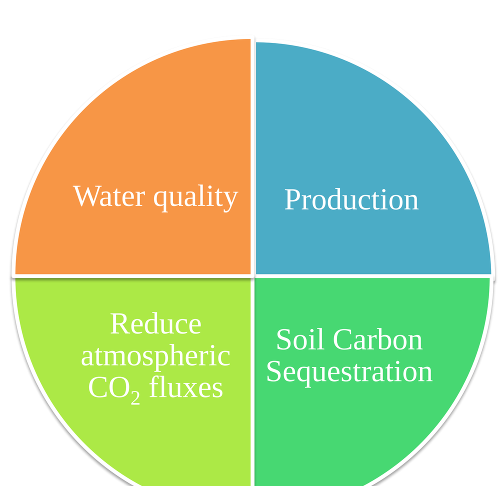
Management Practices:

- 3 Corn-Soybean rotations (Over 80%)
  - Fall-Till Corn No-Till Soybean (FTC-NTB)
  - No-Till Corn Fall-Till Soybean (NTC-FTB)
  - Spring-Till Corn No-Till Soybean (STC-NTB)
- Alfalfa (hay) production
- Prairie (livestock grazing)
- Conservation Reserve Program (CRP)



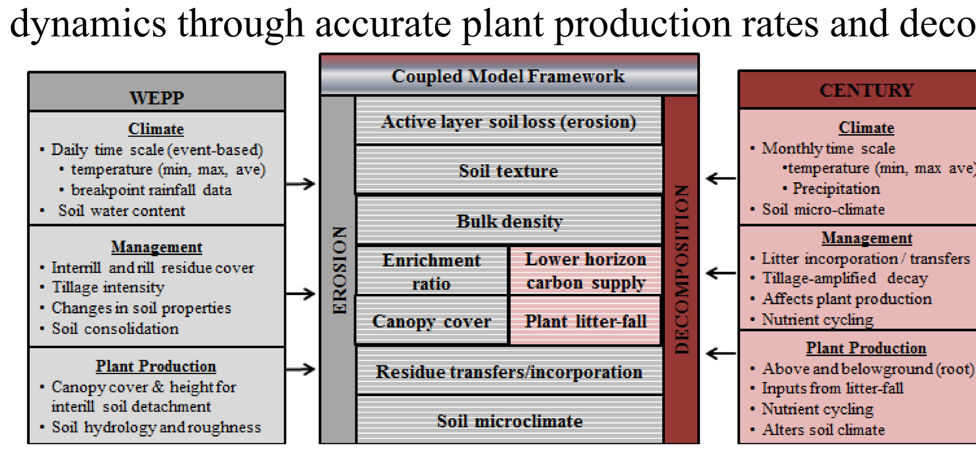
Defining Ecosystem Services for this Study:

1. Production rates for the various management practices included grain yields (corn & soybeans), alfalfa hay production, returns from livestock pasture grazing, and annual governmental rental payments (CRP).
2. Water quality was determined by assessing individual hillslope contributions of surface water runoff and sediment yield.
3. Soil carbon sequestration rates were determined by changes in soil organic carbon .
4. Heterotrophic soil respiration was the indicator used to determine CO_2 emissions.



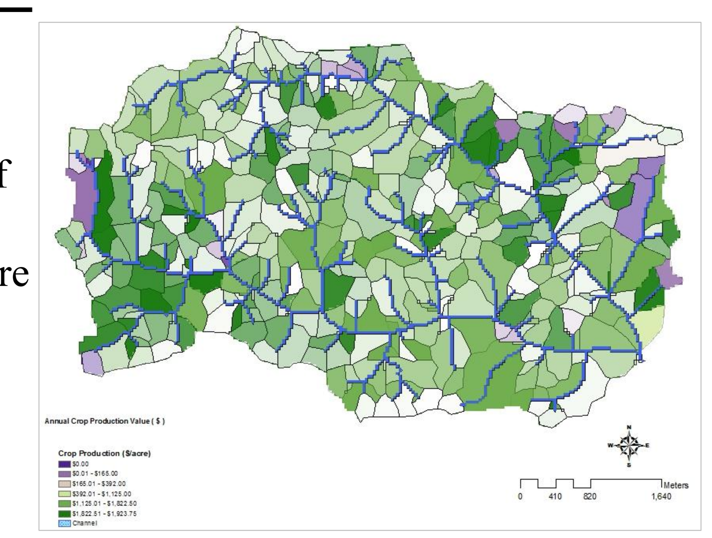
Methodology (cont.)

Modeling Framework::
Two coupled models collectively simulated a wide range of management practices, soil types, climates, and topography. The Water Erosion Prediction Project (WEPP) accounted for the effects of rainfall-and tillage-induced erosion, while the biogeochemical process model CENTURY simulated soil carbon dynamics through accurate plant production rates and decomposition.



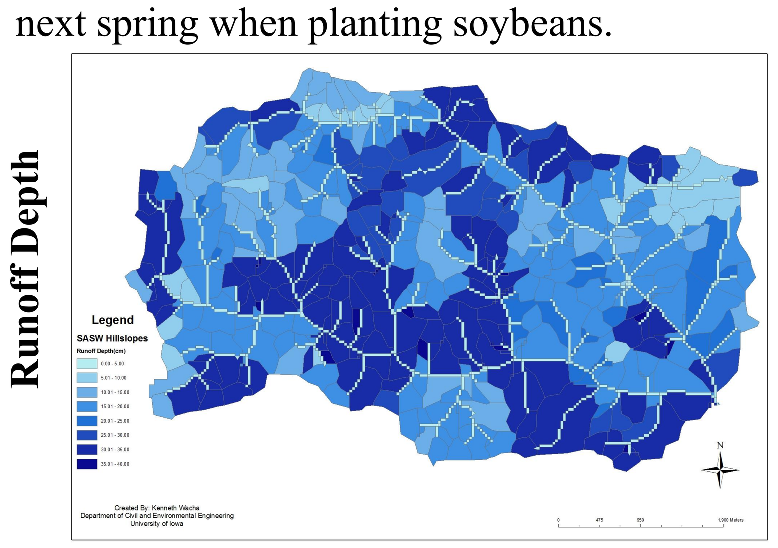
Results

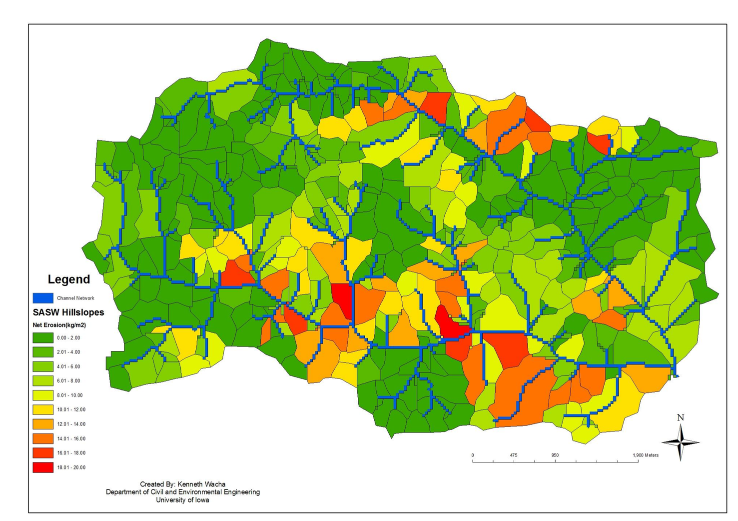
1. Crop Production:
The corn-soybean rotations had the largest income derived from grain production ($1,150/acre). The use of higher tillage intensities resulted in higher corn yields. Pasture and hay practices produced on average $910/acre incomes. CRP land generated the least amount of income, as it was estimated receiving an annual governmental payment of $260/acre.



2. Water Quality:
Alfalfa (hay) produced the least runoff (5 cm/yr) followed by CRP with an average of 9 cm/yr. Low runoff was attributed to higher water uptake from perennial vegetation, as well as increased infiltration. All grassland management practices were below tolerable soil erosion rates (5ton/acre). The highest runoff and sediment yields came from FTC-NTB. This was caused by performing a deep fall tillage directly after corn harvest, which decreased surface residue into the next spring when planting soybeans.

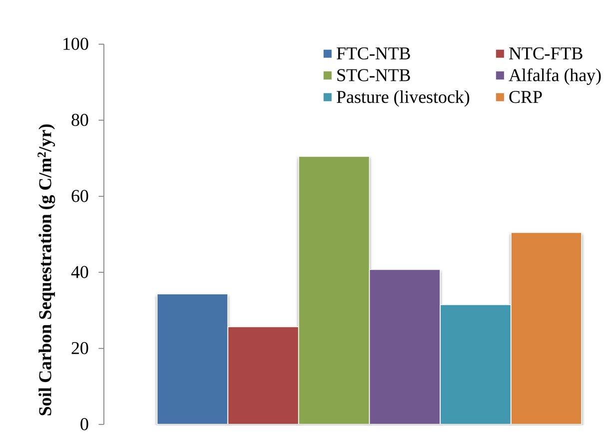
Runoff Depth



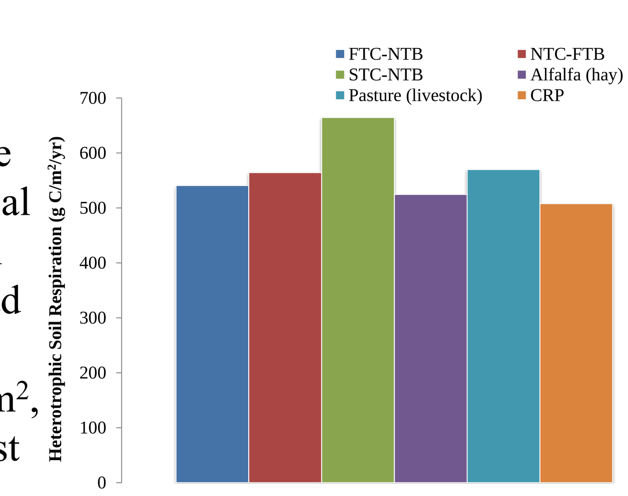


Erosion Rates

3. Soil Carbon Sequestration:
Highest amounts of soil carbon sequestration are provided by the STC-NTB rotation (70 g C/m^2), followed by CRP (50 g C/m^2). Corn and soybeans produce the most biomass which provides large fluxes of litterfall to the soil surface upon harvest. The rotation NTC-FTB stores the least amount of carbon annually (25 g C/m^2) due to high amounts of carbon lost due to erosion and performing a fall cultivation which enhances mineralization rates.



4. CO_2 emissions:
CRP and alfalfa have the lowest annual heterotrophic respiration rates, averaging 507 g C/m^2 and 524 g C/m^2, respectively. This was attributed to preserving soil aggregate structure by not performing tillage, which enhances microbial activity. Pasture management had notably higher respiration rates due to grazing and burning effects. In all cases corn had higher respiration rates than soybeans. The highest soil respiration rates come from STC-NTB, averaging 665 g C/m^2, due to conducting spring tillage when precipitation is highest in the watershed.

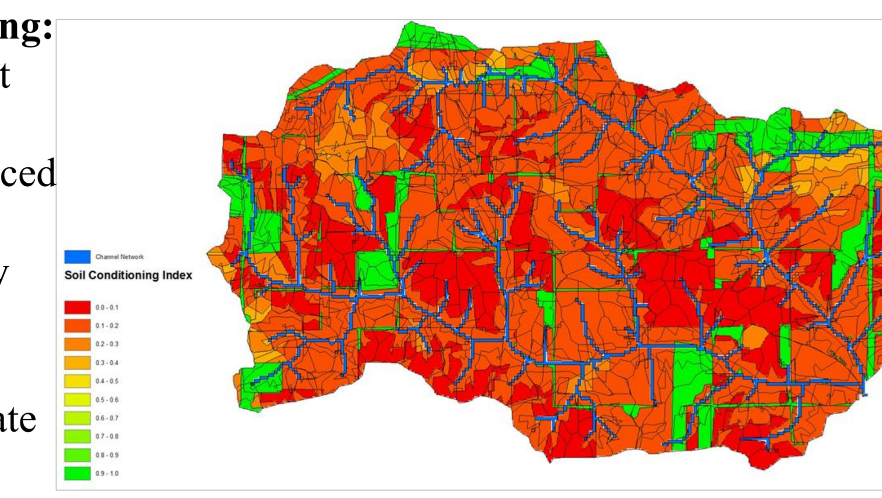


Results (cont.)

Evaluation of Management Practices:
Soil quality can be measured through the Soil Conditioning Index (SCI), which reflects the ability of a soil to respond to the external influences of erosion and land management through SOM. SOM strongly reflects the soil condition because it relates to several soil characteristics, including aggregate stability and water holding capacity. A positive SCI suggests an improving soil condition, while conversely a negative SCI suggests a degrading condition.

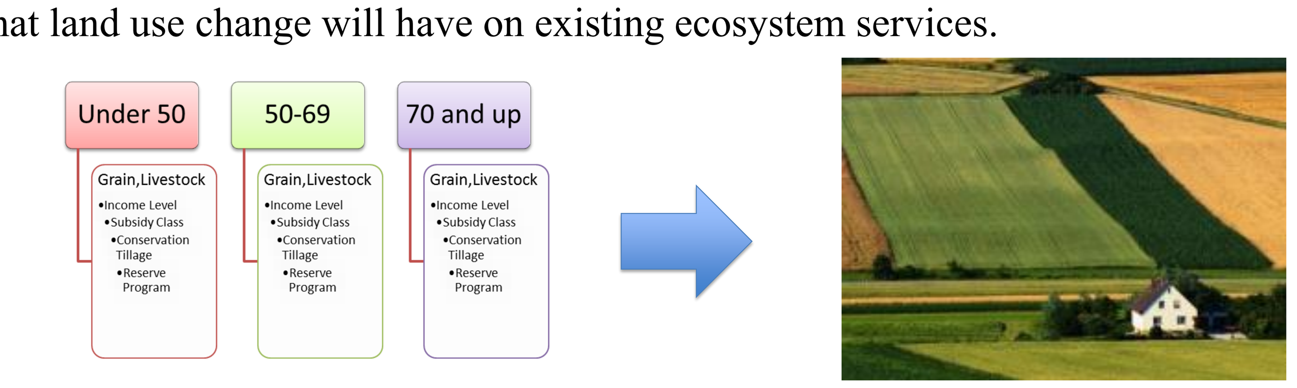
- The highest SCI rankings (> 0.70) were given to the grassland management practices, namely, CRP, alfalfa, and pasture. This was attributed to a constant canopy cover supplied from perennial vegetation, which decreased the rates of erosion and provided high amounts of surface organic material.
- The corn soybean rotations had SCI values ranging from 0.37 to 0.08, with STC-NTB being highest and NTC-FTB being the least. STC-NTB received a higher rating because of using reduced tillage before planting corn and the no-till planting of soybeans, which resulted in lower erosion rates.
- However, when considering all management practices for the sub-watershed, the average SCI value is 0.22 + 0.11. This reflects an overall positive trend that stocks of SOM are increasing. These results help support the claim that conservation practices, namely no-till, work by increasing SOM, improving soil aggregates, and preserving soil resources.

Overall management practice rating:
The overall top ranking management practice in terms of soil quality is undoubtedly CRP. However, a balanced management practice that maintains high soil quality and is economically sound is the corn-soybean rotation, STC-NTB. This rotation can build stocks of SOM while having moderate losses due to erosion.



Ongoing Work

Future alternative scenarios can be developed that include increased corn production and the use of bio-diverse rotations (corn-corn-oats-alfalfa-alfalfa). From these future predictions we can assess if current farmers will adopt a certain practice and what impacts that land use change will have on existing ecosystem services.



Conclusions

- ➢ A coupled model framework was used to assess the current ecosystem services provided from agricultural land management practices.
- ➢ The use of conservation practices is improving the soil quality of the watershed.
- ➢ Corn-soybean rotations provide the largest income from grain production, but also sequester carbon in the soil.
- ➢ CRP provides the largest decrease in surface water runoff and CO_2 emissions.
- ➢ The corn-bean rotation, STC-NTB, is a balanced management practice that maintains high soil quality and is economically sound. This rotation can build stocks of SOM while having moderate losses due to erosion.
- ➢ Overall the MFA assessment can provide a framework for the development of payment incentives for ecosystem services supplied by agroecosystems which promote more sustainable land management practices.

Acknowledgements

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