APPLICATION OF REMOTE SENSING OBSERVATIONS AS APEX MODEL INPUT FOR ESTIMATING SOIL EROSION

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1. INTRODUCTION

Soil erosion is one of the processes responsible for water and soil quality deterioration and is impacted by local soil and land cover conditions. One of the primary functions of land cover is to protect the soil and prevent land degradation by water and wind erosion [1]. Recent interest in biofuel energy production can compromise soil quality due to increased removal of crop residue to be used as source of biofuel feedstocks. Knowledge of the impact of human-induced changes to land cover is critical to developing ecosystem-based management approaches to address these issues.

In this work Percent Residue Cover Digital Maps (RCDMs) at 30 m resolution were created based on hyperspectral Cellulose Absorption Index (CAI) [2] and the multispectral Normalized Difference Tillage Index (NDTI) [3]. This study also addressed modification of the Agricultural Policy Environmental eXtender (APEX) (version 0608) field scale model to include the percent residue cover information from remote sensing (RS) products and land use characteristics [4]. Coupling remote-sensing information technologies with model capabilities can possibly be used to extend a model's capability for soil erosion environmental impact assessment associated with human-induced disturbances.

The main goal of this research was to improve the accuracy of soil erosion estimates by using residue cover information from a combination of remote sensing technologies and product enhancements to develop a modeling approach that provides effective guidelines for sustainable residue management. Increased understanding of the impact of using different remote sensing technologies as part of a hydrologic model simulation would support development of remote sensing products for future missions, such as Operational Land Imager (OLI) on LDCM and the HysPIRI hyperspectral sensor.

2. DATA AND METHODOLOGY

This study was conducted in the Midwest United States in Indiana, USA. The area consists of an agricultural watershed: The Mace watershed (MW) located within the Walnut Fork Creek Watershed (WFCW) near Darlington, north of Indianapolis (lat/lon 40.0/-86.7). Farming has been the principal sector of the economy with corn and soybeans as the primary crops in the area. Concurrent remote sensing data from 2008-2010 for Hyperion and Advance Land Imager (ALI) scenes were collected, cloud-free Landsat TM scenes were acquired, and airborne hyperspectral data were collected during targeted campaigns (before planting and after harvesting) and field transects were performed in selected fields for residue cover validation. Nine fields were selected based on the sensor's overlapped region and the main characteristics of the area (tillage practices, crop rotation, management practice, soil type and slope).

Landsat TM and ALI multispectral data were used to create the Normalized Difference Tillage Index (NDTI), and the Cellulose Absorption Index (CAI) was generated from the hyperspectral SpecTIR airborne data. Percent Residue Cover Digital Maps (RCDMs) at 30 m resolution were created based on the multispectral and hyperspectral indices via linear regression models [3]. The APEX field scale model developed by the Blackland Research and Extension Center in Texas was used to simulate soil erosion at the edge-of-field. Various studies emphasize that the APEX model is able to replicate field scale hydrology reasonably well for both uncalibrated and calibrated conditions [5]. Input data for the APEX model included topography data (e.g. Digital Elevation Model [DEM]), climate data (e.g. rainfall and temperature), surface and subsurface characteristics (SSURGO layer) and land use data provided by the USDA-National Agricultural Statistics Services (NASS) to account for change in land use due to crop rotation. Operation schedules were generated using APEX management scheduled option capability to perform each simulation based on actual management practice conditions in the area. The APEX model was modified to include the residue cover information obtained from the residue cover maps derived from remote sensing data when available, to determine the environmental significance relative to model field predictions of soil erosion associated with different agricultural management systems.

The study focuses on the predominant crop rotation shifts and the two main types of management operations in the study area. Three scenarios were investigated based on these characteristics. Each study scenario has three fields associated with their characteristics. Scenario 1: one-year Corn-Soybean (cs) rotation combined with management 1, Scenario 2: one-year Corn-Soybean (cs) rotation combined with management 2, and Scenario 3: one-year Soybean-Corn (sc) rotation combined with management 1. Management 1: Consists of chisel plow tillage practice and a conventional disking across the field in the spring close to the planting period. Management 2: consists of chisel plow tillage practice and a conventional disking across the field in the spring before corn is being planted, and a conventional disking across the field in the spring before the soybean is being planted (no other tillage practice during this year). Four models were compared: APEX-APEX (A-APEX) (baseline), APEX-SpecTIR (A-Spec), APEX-ALI (A-ALI), and APEX-TM (A-TM). The last 3 models correspond to models where available RS RCDMs (%) have been used to update the model's residue cover values based on SpecTIR, ALI and Landsat TM sensor data respectively.

3. EXPERIMENTAL RESULTS AND CONCLUSIONS

Comparison analysis between the various model performances shows that there is a significant difference ($p<0.05$) (Figure 1) in erosion estimates for the A-APEX model and A-Spec model scenarios; showing positive interaction effect between the models and the studied scenarios. A-APEX model and A-Spec model shows that the main effect on soil erosion predictions occurred in fields associated with Scenario 1 with an increase in soil erosion, while fields associated with Scenario 3 have a decrease in soil erosion estimated at the edge-of-field (Table 1). Overall, average soil erosion estimates from A-Spec model are higher than the ones from A-APEX model. Average soil erosion estimates (overall) from the A-ALI model are slightly lower than the A-APEX model estimates with no significant difference ($p>0.05$) in any scenario. Results show that A-TM decreased soil erosion values for the three studied scenarios (Table 1) compared to A-APEX with significant differences ($p<0.05$) mainly when comparing results from Scenario 3.

Table1. Annual Average water erosion losses (T/ha) to the edge-of-field from the three scenarios from APEX-APEX, APEX-SpecTIR, APEX-ALI, and APEX-Landsat TM models for the study period.

Case	APEX-APEX Annual Average Soil Erosion (t/ha)	APEX-SpecTIR Annual Average Soil Erosion (t/ha)	APEX-ALI Annual Average Soil Erosion (t/ha)	APEX-TM Annual Average Soil Erosion (t/ha)
Scenario 1	2.33	3.99	2.84	2.30
Scenario 2	1.79	2.17	1.81	1.37
Scenario 3	6.56	4.02	5.14	3.28

Management practices in Scenario 1 and Scenario 3 are more intense conventional practices compared with the management practice in Scenario 2. This would imply that remote sensing residue cover information could be more critical to consider when conventional management practice implications are investigated. Also, since residue cover estimates from SpecTIR RCDMs are considered more accurate than estimates from the A-APEX model, it can be concluded that the A-APEX model appears to be less accurate when estimating soil erosion for conventional practices. The average slope in the region is less than 2%; however, Scenarios 1 and 3 contains fields for which slopes are greater than 2%. Soil erosion results from both models (A-APEX and A-Spec) differ even more in these two scenarios, which may imply that this type of study will be much more important in areas with greater slopes (slope > 1-2%). Although residue cover estimates from ALI RCDMs are somewhat better than

A-APEX model residue cover estimates, in this study ALI residue cover data did not provide additional information value beyond the routines in the APEX-APEX. Possible bias induced into the model when adding residue cover information from Landsat TM RCDMs could result in underestimating soil erosion overall. From a long term perspective this work provides a better understanding of the consequences of soil erosion mainly due to conventional management practices while providing valuable guideline information regarding development and evaluation of environmental policies and regulations. However, in the short term the results may be critical in offering guidance on specific issues related to water quality TMDLs (Total Maximum Daily Loads) that are based on a more detailed analysis. Since A-SpecTIR is considered to provide improved results it can be concluded that RS information can be valuable at long term and short term spatial and temporal scales when the impact of soil erosion is investigated.

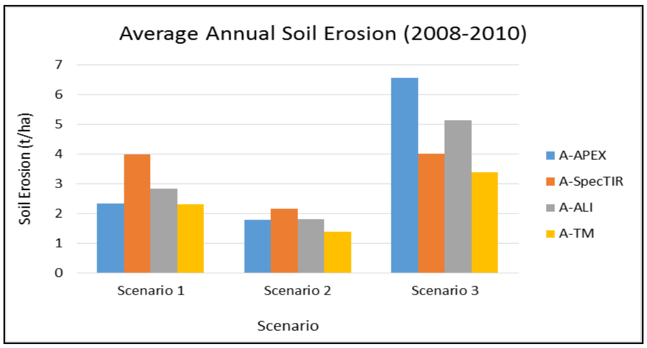

Figure1. Annual average of water erosion losses (edge-of-field) from APEX-APEX, APEX-SpecTIR, APEX-ALI, and APEX-Landsat TM models for the three scenarios during the study period (2008-2010).

4. REFERENCES

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