A process based approach to quantification of soil erodibility in presence of vegetation

Anish Khanal

Department of Biosystems and Agricultural Engineering

Oklahoma State University

September 5, 2012

Overview

Quantification of effect of riparian vegetation on soil erodibility is critical for most of the stream-bank stabilization and soil conservation projects. It is widely accepted that root network of the riparian vegetation provide certain resistance to erodibility of the stream-bank soil by adding cohesive strength, both mechanically and hydraulically. Various models have been developed to quantify the effect of the root matrix on soil strength and most of them are empirical in nature. Estimation of the reinforcement provided by the root matrix using these empirical models is dependent on many extraneous factors besides the physical properties of the soil and hydraulic conditions. Consequently, the reinforcement provided by the root matrix is either under-estimated or over-estimated, jeopardizing the success of stabilization/conservation projects. Besides these empirical models, a process-based mechanistic model to predict the erodibility of soil is also available (Wilson, 1993). Recently, the model has been modified to predict the soil erodibilty in presence of seepage forces and model predictions have been verified with a lab test. This has renewed the interest in mechanistic models. However, the model has not been modified to quantify the effect of root-matrix in soil erodibility. Hence, there is a clear need to modify this model and develop a mechanistic method of quantifying effect of vegetation in soli erodibility.

Scope and objectives

Long term goal of the PI is to gain insight into physical property of soil in context of stream-bank stability and erosion processes. The *objective* of the proposal is to develop a method of estimating effect of presence of root matrix on the erodibility of soil within a theoretical framework that is based on fundamental processes involved in soil erosion. Central *hypothesis* of the proposal is that the parameters in Wilson's model affected by the presence of vegetation can be identified and the model can be modified with reference to those parameters. Rationale for the proposed research is that the improvement in quantification of the soil erodibility would contribute in improving the design of stream-bank stability and soil conservation measures by making them more efficient, feasible and cost-effective. The PI is well qualified to undertake the proposed research with extensive knowledge in fluvial hydraulics, soil engineering and experience in experimental methods for testing soil erodibility. The research has following specific aims.

Specific aim 1: Perform laboratory tests to measure the erodibility of soil sample with root matrix. Test samples will be prepared in the lab with root matrix and its erosion trend will be measured with 'mini' Jet apparatus. Results from the test will be used in Wilson's model to calculate the erodibility values of the samples.

Specific aim 2: Introduce the root matrix effect in the soil detachment model (Wilson, 1993) and identify the parameters in the model affected by presence of root matrix. The calculated values of erodibility from 'mini' Jet tests will be compared with the similar observations from the 'mini' Jet tests performed on samples without root matrix to parse out the effect of root matrix. Parameters of Wilson's fundamentally based detachment model that are affected by the root matrix will be identified.

Project outcomes

After the completion of the project, it is expected that a new method for quantification of soil erodibility will be developed. The new method will be based on the fundamental processes of the soli detachment. This method will be more efficient and applicable in the field. Opportunity to verify the model's predictions with laboratory tests provide this research with good chances of success.

Significance

Quantification of the effect of vegetation root matrix on erodibility of soil is critical to stream-bank stabilization and soil conservation measures. However, traditional methods of such quantification are empirical and inefficient (Wilson, 1993). Efforts to estimate the mechanical effects of vegetation on soil stability have been made in past (Pollen and Simon, 2005). However these efforts have been ineffective largely due to an empirical approach and lack of a proper laboratory or field method of measurements. Recently, much easier and effective laboratory apparatus to measure soil erodibility has been designed and tested (Al-Madhhachi et. al. 2012a). Similarly, a mechanistic model for quantification of soil erodibility (Wilson, 1993) has been modified to incorporate seepage forces and the modification has been evaluated with the aforementioned laboratory apparatus (Al-Madhhachi et. al. 2012b). These recent developments have raised the possibility of quantification of effect of vegetation root matrix on soil erodibility in a more mechanistic way.

The significance of this research lies in the fact that it would mark a remarkable shift in method of quantification of one of the important physical property of soil. Recent improvements in laboratory techniques and in the model provide an exciting opportunity to modify the model and consequently develop a new method to quantify the effect of vegetation in soil erodibility.

Materials and methods

Specific aim 1: Soil sample for the 'mini' Jet test will be obtained from a nearby stream-bank. The water content of the sample will be measured. A set of test samples will be prepared at 8%, 12% and 14% water content by simply adding water to the soil samples and mixing thoroughly. The test samples will be compacted in three different standard molds. Seeds will be sprinkled on top of the samples for growing vegetation (probably Bermuda grass). The erosion in the test samples will be measured using the 'mini' Jet apparatus after allowing the vegetation roots to penetrate the soil sample. Similar tests will be performed on test samples without the vegetation.

Specific aim 2: Erodibilty of soil with and without the vegetation will be calculated using the Wilson's model. Effect of the root matrix will be parsed out in terms of parameters of the model.

This will hopefully lead towards modification of the Wilson's model for purposes of measuring effect of vegetation in erodibility of soil.

Budget

All the materials and apparatus required for the project are available at the Biosystem and Agricultural Engineering laboratory.

Labor

15 man hour * $20 per hour $300

Total cost $300

Timeline

Monday ,Sep 17	Tuesday, Sep 18	Monday, Oct 1	Monday, Oct 8
10:00AM-2:00 PM	10:00AM-2:00 PM	10:00AM – 2:00 PM	
Preparation of Test samples	'mini' Jet Tests on non-vegetated samples	'mini' Jet Tests on vegetated samples	Completion of all analysis

References

Wilson, B.N., 1993. Development of a fundamentally based detachment model. Transactions of the ASAE, 36(4):1105-1114.

Pollen, N., Simon, A., 2005. Estimating the mechanical effects of riparian vegetation on stream bank stability using a fiber bundle model. Water Reources Research, 41,W07025.

Al-Madhhachi, A.T., Hanson, G.J., Fox, G.A., Tyagi, A.K., and Bulut, R., 2012a. Measuring soil erodibility using laboratory 'mini' JET tests. Transactions of the ASABE (in review).

Al-Madhhachi, A.T., Hanson, G.J., Fox, G.A., Tyagi, A.K., and Bulut, R., 2012b. Mechanistic Detachment Rate Model to predict soil erodibilty due to fluvial and seepage forces: I. Model Development. Transactions of the ASABE (in review)

ANISH KHANAL, E.I.

209 Ag Hall
Stillwater, Oklahoma
Cell: (415) 9921384
Email: anish. khanal@okstate.edu

Education

M.S., Civil Engineering (concentration in water resources), Southern Illinois University at Carbondale, 2011
B.S., Civil Engineering, Institute of Engineering, Tribhuvan University, Nepal, 2008

Employment experience

Research Assistant, Department of Biosystem and Agricultural Engineering, Oklahoma State University, August 2012 to present.

Research Assistant, Department of Geology, Southern Illinois University, August 2010 to May 2012

- Planned, formulated and executed numerical hydrodynamic models for study of impact of river training structures.

Research Assistant, Department of Civil and Environmental Engineering, Southern Illinois University, April 2010 to August 2010

- Operated boat mounted Acoustic Doppler Current Profiler (ADCP) unit in field condition.
- Processed and mapped raw data from the unit.

Teaching Assistant, Department of Civil and Environmental Engineering, Southern Illinois University, January 2010 to April 2010.

- Assisted in instruction and grading of fluid mechanics laboratory class.

Computer skills

- Basic programming in FORTRAN
- Basic scripting in MATLAB
- AutoCAD
- ArcGIS 9.X
- HEC RAS
- MIKE 21
- MODFLOW

Instrument skill

- Able to prepare, execute and post process discharge measurement operations with **Acoustic Doppler Current Profilers (ADCP)**

Professional certification

- Passed Fundamentals of Engineering (FE) Exam, April 2011, Michigan state board