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The development of U. S. soil erosion prediction and modeling

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Abstract

Soil erosion prediction technology began over 70 years ago when Austin Zingg published a relationship between soil erosion (by water) and land slope and length, followed shortly by a relationship by Dwight Smith that expanded this equation to include conservation practices. But, it was nearly 20 years before this work's expansion resulted in the Universal Soil Loss Equation (USLE), perhaps the foremost achievement in soil erosion prediction in the last century. The USLE has increased in application and complexity, and its usefulness and limitations have led to the development of additional technologies and new science in soil erosion research and prediction. Main among these new technologies is the Water Erosion Prediction Project (WEPP) model, which has helped to overcome many of the shortcomings of the USLE, and increased the scale over which erosion by water can be predicted. Areas of application of erosion prediction include almost all land types: urban, rural, cropland, forests, rangeland, and construction sites. Specialty applications of WEPP include prediction of radioactive material movement with soils at a superfund cleanup site, and near real-time daily estimation of soil erosion for the entire state of Iowa.

Key Words: Universal Soil Loss Equation, Water Erosion Prediction Project, Soil erosion, Erosion prediction, History of erosion prediction

1 Introduction

The objectives of this paper are to describe the development of soil erosion modeling research in the United States, to discuss the current state of such research, and to present a view on future directions in soil erosion modeling in the United States. The focus will be on the Universal Soil Loss Equation (USLE) and its development, followed by the development and application of the Water Erosion Prediction Project (WEPP).

We and others have written on this subject. For a more complete picture, the reader may also wish to read Meyer (1984), Meyer and Moldenhauer (1985), Laflen and Moldenhauer (2003), and Flanagan et al. (2007). The writings of Miller (1946a, 1946b), Duley and Miller (1923), and Duley and Ackerman (1934) provide views of early soil erosion plot experiments.

2 Empirical soil erosion prediction in the United States

McDonald (1941) described efforts to understand and control soil erosion in the earliest time of settlement in the U. S. Wind and water erosion were significant problems in the U. S. and in Europe. Early U. S. conservationists blamed erosion problems on plowing, continuous cropping, a lack of crop rotations, and a plentiful land supply. Many farmers advocated various measures to reduce soil erosion based on their observations and those published in Europe, sharing and publishing their thoughts on soil erosion, the causal factors, and how erosion might be controlled. One of those was the second president of the United States, Thomas Jefferson, who in 1813 advocated "horizontal plowing". Jefferson's letter (Jefferson, 1813) demonstrates his awareness of the on-and off-site effects of soil erosion, the role of runoff in soil erosion, and the interaction of soil conservation, hydrology and crop production, important scientific topics today in understanding, predicting and modeling soil erosion, 200 years later.

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2.1 *First measurements of soil erosion in the United States*

The earliest measurements of soil erosion in the U. S. were made in 1915 by the U. S. Forest Service in Utah (Forsling, 1931) and by Ray W. McClure, a Department of Soils undergraduate student at the University of Missouri (Miller, 1946a). A German scientist, Ewald Wollny, is credited with making the first scientific measurements of soil erosion in the late 19th century (Dotterweich, 2013).

McClure went to Professor M. F. Miller for a special problem. He was assigned a project to measure rainfall and runoff from a small bare plot over a 2 month period in the spring of 1915. Measurements were made after each rainfall event, and after the first runoff event he inquired of Miller how to handle sediment accumulated in the catch basin, an unexpected development. Miller advised him to measure the amount of sediment. He found that the soil lost contained more nutrients than would be applied to the soil in a year (Woodruff, 1987). The records from this work have apparently been lost.

The next year, a graduate student at the University of Missouri, R. M. Vifquain (Vifquain, 1917), followed McClure and collected runoff and soil loss data from a set of 4 plots, each 5.5 feet wide by 91 feet long, with a slope of 4% (Fig. 1). Details of the experiment as well as the runoff and soil loss data are available in Miller (1946b) and in Vifquain's thesis (Vifquain, 1917). The major focus of Vifquain's work was soil moisture rather than soil erosion, as was McClure's work. Vifquain's major professor was M. F. Miller.

In 1917, F. L. Duley developed a set of 7 erosion plots located on the campus of the University of Missouri in the same area used by Vifquain. This was the first study in the U. S. to focus on soil erosion on cropland. Duley and Miller (1923) were the first in the United States to report scientific measurements of soil erosion. Other scientific efforts related to soil erosion began to develop, and the U. S. Congress appropriated funds for soil erosion research. In 1928, the U. S. Dept. of Agriculture published a circular on "Soil Erosion—A National Menace" (Bennett and Chapline, 1928). Bennett (1939) indicated that the publication of this bulletin, plus the educational campaign by the USDA were critical elements in securing public and political attention to soil erosion.

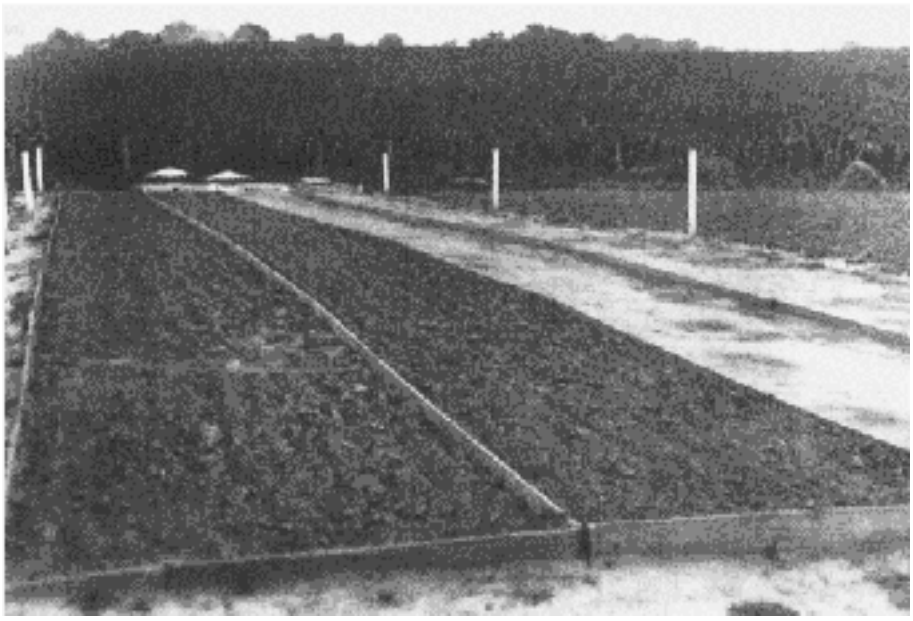

Fig. 1 Vifquain's plots in 1916, following McClure's plots in 1915

2.2 *Erosion research stations*

In the battle to control soil erosion, the first step was to develop a scientific basis for understanding soil erosion. Erosion research stations, also known as Soil Conservation Experiment Stations (SCES), were established representing ten major regions of the United States (Gilley and Flanagan, 2007). Plot design was based on the studies by Duley and Miller and associates at the University of Missouri (Meyer and Moldenhauer, 1985). The most common design was a plot 6 feet wide by 72.6 feet long, equal in area to1% of an acre. Slopes were usually those available at the site. Some sites had plot lengths much greater, and in some cases, much less than 72.6 feet. Eventually, the number of erosion research stations exceeded 30. The data collected provided a basis for the selection of conservation practices and for computing cropping and management effects on soil erosion. The SCES also