#769

Reprinted from Sediment Transport Modeling Proceedings
International Symposium/HY Div/ASCE
New Orleans, LA/August 14 — 18, 1989

EROSION AND SEDIMENTATION RESEARCH IN ARS

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Abstract

This is a very brief history of the growth of the erosion and sedimentation research program in the Agricultural Research Service of the U. S. Department of Agriculture.

Overview

Research by the Agricultural Research Service (ARS) has developed methods for predicting, measuring, and controlling erosion and sedimentation from agriculture. This was begun in the 1920s and initially done by the Soil Erosion Service of the Department of the Interior. The Soil Conservation Service carried on soil conservation research from 1935 until the Agricultural Research Service became a separate Agency in 1954.

The depression in the 1930s emphasized the need to solve the problems of soil erosion, sedimentation, and water conservation. Ten soil erosion experiment stations were initially established throughout the country at representative locations. Later other locations were established. These original research locations used a standard experimental design for field research. The collected data, with information from other sources,

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permitted the development of the Universal Soil Loss Equation and provided practices to reduce erosion and runoff. Also, rainfall simulators, runoff measuring devices, and soil moisture sensors were developed. This helped to refine and broaden the investigations of soil erosion by water.

Wind erosion research was intensified through the late 1930s as the impact of the dust bowl was fully appreciated. By 1947, a wind erosion research program had been started at Manhattan, KS and at nine other locations in the US and Canada. This research has continued. It has generated information on the mechanics of wind erosion and provided a wind erosion equation and useful wind erosion control practices. Sedimentation research was started in about 1934, and consisted of reservoir sedimentation studies, including field surveys and some laboratory density current experiments. It was soon augmented with stream valley deposition surveys in Mississippi, Wisconsin, and New Mexico. Stream channel sediment transport was started, with laboratory work being done at California Institute of Technology and at a controlled-condition outdoor facility on a river in South Carolina.

By 1955 the research was consolidated within the newly-formed ARS. It is now conducted at fifteen locations in the United States. Special laboratories, instrumented watersheds,and other field sites are used. The program encompasses fundamental and applied research on erosion and sedimentation, and the incorporation of research findings into practices for present-day agriculture. The research is coordinated with the needs of the Soil Conservation Service, the Corps of Engineers, the Environmental Protection Agency, and other agencies. It has five objectives:

1. Water erosion prediction and control to preserve and improve land productivity and prevent water quality degradation.
2. Wind erosion prediction and control to protect crops and soils and decrease air pollution.
3. Evaluation and prediction of sediment transport, sediment yield, and sediment properties.
4. Prediction and control of sediment deposition in reservoirs, valleys, and channels.
5. Stabilization of stream channels and control of gullies.

Both watershed and laboratory research is essential in formulating the general principles of erosion and sedimentation.

Research Watershed Investigations

The Department of Agriculture established a 112-acre watershed near Jackson, TN in 1917. Research consisted entirely of development of rainfall-runoff relationships. Following Congressional authorization in 1928, ten Regional Soil Erosion Centers were activated at Clarinda, IA; Hays, KS; Bethany, MO; Statesville, NC; Zanesville, OH; Guthrie, OK; Temple and Tyler, TX; Pullman, WA; and LaCrosse, WI. By 1935 a total of 36 additional Centers had been added, in 23 states and Puerto Rico. These Centers, operated by different Bureaus under USDA, nonetheless followed a standard procedure to formulate rainfall-runoff and sediment yield equations. In 1935 the ten original Centers were assigned to the newly-formed SCS.

In 1939 the Federal Interagency Sedimentation Project was established at the Iowa Institute for Hydraulic Research. It was later moved to St. Anthony Falls Hydraulic Laboratory, Minneapolis, MN. The Project produced field sedimentation measuring devices that enabled the Erosion Centers to introduce increasingly detailed investigations into their watershed research. The Soil Erosion Centers came under the jurisdiction of ARS in 1954, and in 1959 the Senate consolidated the watershed research program in six Regional Research Centers at Boise, ID; Tucson, AZ; Chickasha, OK; Columbia, MO; University Park, PA; and Tifton, GA. The Regional Watersheds concentrated on study of erosion and sedimentation by water; wind erosion research is concentrated at Manhattan, KS and Big Springs, TX.

In watershed research, control costs escalate rapidly and experimental approaches must accommodate observation of complex transient phenomena. In the past, continuity of observation has been the main factor in experimental design, while because of inherent uncertainties in watershed research, data analysis has often been limited to regression and graphical correlation. From 1960 on, digital computers have been relieving the constraints of watershed research by their capability to sort observations by primary and secondary (or more) independent variables. This approximates controlled laboratory conditions while retaining the "real world" flavor of the research. Current ARS watershed research uses computer manipulation of data with temporal and spatial variability to quantify environmental responses to land use and management practices. The present trend is toward producing causal or process-oriented watershed response prediction models, developed from watershed observation with a healthy infusion of laboratory experimental results for generality. Watershed response models must include subroutines dealing with climate, tillage, plant growth, overland flow, rill and channel hydraulics, erosion, sediment transport, and deposition.

Instrumentation for model development data has not kept pace with computational capability. ARS research watersheds include intensive raingauge networks, but the unreliability of individual gauges is a well-known limit on the efficacy of such networks. Networks of precalibrated runoff measuring devices allow reliable hydrologic measurements, but associated sediment transport measuring devices are still difficult to calibrate and labor-intensive to operate.

ARS research watersheds represent climates ranging from semiarid to humid, and land use ranging from grazing to intensive cropping. Not all watersheds include sufficient sediment sampling facilities to measure total sediment transport (most include suspended sediment samplers but not bedload samplers). Thus, data analysis in most watersheds requires the use of experimentally-determined bedload transport relations. In some cases, as at Chickasha, OK, total sediment yield can be estimated from deposition measurements in a reservoir.

Fundamental and Developmental Research

In the space available here, only brief discussions of ARS fundamental research in the five categories can be given.

1. Soil Erosion by Water: In the 1930s and 40s, erosion of soil by rainfall was investigated. Methods for measuring raindrop sizes and intensities were created by SCS scientists in Washington, D. C., and at Auburn, AL before the formation of ARS. From 1965 to 1971, raindrop erosion processes were studied by ARS scientists at Durham, NH and Morris, MN. An SCS-designed rainfall simulator was in service by 1936. Improved simulators were developed by the ARS at W. Lafayette, IN. They permitted investigating the erosive capabilities of rainfall and overland flow, the erodibility of soils, and erosion protection by crop canopies and residue. From 1934 to 1982 ARS used the results of this research to develop the Universal Soil Loss Equation and many erosion control practices including conservation tillage. The advent of computers during the 1960s started the development of process-based prediction and planning models, and improvement of the USLE.

2. Soil Erosion by Wind: By 1949 the aerodynamics of aeolian soil erosion were being defined, and wind tunnels reproducing natural near-surface airflow had been put into use. Erosive forces exerted on aggregate soil particles and the erosive processes experienced by soils were studied. The relative aeolian erodibility of many soils was defined. Soil erosion principles and related airflow principles were compiled from 1950 to 1963, and the portable wind tunnel was developed. This device allowed near-laboratory control of conditions in experiments on real soil surfaces. With basic data that could be combined readily with the results of field research, many wind erosion control procedures ranging from crop residue management to windbreak placement were devised from 1950 to the present.

3. Sediment transport, yield, and properties: Some of the earliest basic research done by SCS in the early 1930s concerned the application of fluid mechanics to the design of devices for removing sediment from irrigation water diverted from rivers. The middle 1930s saw classical and elegant research on particle motion and sediment suspension; this provided a foundation for sediment transport research within ARS from 1955 to the present. This has led to better understanding of the mechanisms of sediment production. In the late 1960s public interest in sediment-related pollution developed. ARS responded with research on the chemical-sorbing, concentrating, and transporting properties of sediments. With related field research, the fundamental research led to improved sediment production control, and many useful planning and prediction models.

4. Sediment deposition: Pre-ARS research by the SCS included laboratory experiments on density flows that carry sediment into reservoirs. Many reservoirs were being built and information was needed on filling rates and effective reservoir life. With the formation of ARS, this research was relegated to other agencies. However from 1959 on, ARS has devised ways to measure reservoir sedimentation rates using sediment density probes. Sediment layers with high levels of nuclear weapons test fallout have been used as marker beds for defining the sedimentation histories of reservoirs. Sedimentation in stream valleys is a manifestation of erosive upland destruction and depositional bottomland destruction. The SCS started valley deposition surveys in 1935. These were continued by ARS. Basic research supporting these efforts concentrated on probe techniques for locating soil surfaces under more recent deposition, and in the 1980s, on noninvasive location of paleosol profiles for detailing the erosive and depositional history of a

stream valley, to understand overall morphological mechanisms.

5. Channel and gully stabilization: Laboratory design of concrete grade control structures was undertaken by the SCS in the decade just before the formation of ARS. Through 1960-1980 it was augmented by investigation of structural and vegetative channel bank stabilization mechanics, based upon study of bank failure from fluidization, gravitational slump or rotational collapse, and avulsion due to direct erosive flow forces. Peripheral shear stress in bendways was examined in the laboratory, as was inflow of groundwater at channel bank toes. The erodibility of typical clay bank materials was found by experiment. The erosion resistance of many suitable channel-protecting plants was also found. Recently the expense of concrete grade control structures necessitated the design of cheaper structures. Similitude principles have been invoked for designing sheet pile and riprap structures above energy dissipation basins. Comparable energy dissipation basins for cantilevered pipe outfalls into channels have also been produced, using similitude principles. This research has led to economical and environmentally sound channel and gully stabilization practices.

Conclusions

The foregoing is a brief summary of half a century of erosion and sedimentation research by the Soil Erosion Service, the Soil Conservation Service, and the Agricultural Research Service. Strategic planning has only recently been explicitly used to manage erosion and sedimentation research; nevertheless, history shows that ARS and its forerunner agencies have adhered to a commonality of purposes and a continuity of plans throughout their erosion and sedimentation research programs.