Early Investment in Soil Conservation Research Continues to Provide Dividends

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Abstract. *Current soil conservation programs are built upon an established research legacy. Hugh H. Bennett, chief of the USDA Soil Conservation Service from 1935 to 1951, was instrumental in the establishment of a network of 35 soil conservation experiment stations (SCES). Research projects were initiated at the SCES in the 1930s to investigate the principal factors causing erosion and to identify the most effective and practical methods of controlling soil loss from agricultural areas. Information obtained from the SCES, and selected other locations, was assembled at the National Runoff and Soil Loss Data Center (NRSLDC) established on the campus of Purdue University in 1954. Data gathered at the NRSLDC was used to develop the Universal Soil Loss Equation (USLE). The USLE is recognized as one of the most important developments in soil and water conservation in the 20th century. The Revised Universal Soil Loss Equation was released in 1997 as an updated, computerized version of the USLE. Several soil conservation practices currently used on agricultural areas were developed, refined, tested, and adopted at the SCES. Data obtained from the SCES have been an essential component in the development and testing of several erosion and water quality models. It is a tribute to the early soil conservation researchers that information they collected in previous decades continues to be used by successive generations of conservationists and modelers.*

Keywords. *Erosion, Erosion control, Erosion models, Experiment stations, Hydrology, Runoff, Soil conservation, Soil erosion, USLE, Water conservation.*

Early soil conservation research programs provide the foundation for current conservation practices. Much of the data and information collected by early conservationists has been incorporated into guidelines and standards that are used today. This ASABE Centennial Paper provides a historic background on soil conservation research during the past century.

Early Federal Conservation Programs

Theodore Roosevelt convened the National Conference of Governors at the White House in May 1908 to consider America's natural resources. The president told conference attendees that "the conservation of natural resources is the most weighty question now before the people of the United States." It was recommended during the conference that a National Conservation Commission be appointed to advise the president on natural resources issues.

The first Forest Service (FS) experiment station was established in 1908 at Fort Valley in the Coconino National Forest in Arizona. Additional FS research stations were soon created in California, Colorado, Idaho, Utah, and Washington. The Forest Service initiated studies in 1915 to measure runoff and erosion from small plots on forest areas in Utah.

As a state senator from New York during 1911-1913, Franklin D. Roosevelt represented a constituency of farmers and was aware of the importance of promoting agriculture and soil conservation. He began his first term as president in 1932 during the Great Depression, and acted quickly and decisively to create programs that helped support the agricultural and forest economy, and protect soil resources (Laflen and Moldenhauer, 2003).

As president, Roosevelt initiated the Prairie States Forestry Project (PSFP) in 1934 to help establish shelterbelts and windbreaks. The PSFP was a cooperative effort between federal, state, county, and local agencies. The first tree planted in March 1935 as part of the PSFP program was located on a farm in Mangum, Oklahoma. Works Progress Administration (WPA) personnel performed much of the soil conservation-related work on forest areas.

The National Industrial Recovery Act (NIRA) was part of Franklin D. Roosevelt's "New Deal" program. The NIRA established the Soil Erosion Service (SES) in 1933. The SES utilized workers from the Civilian Conservation Corps to build drop inlets, construct grass waterways, stabilize gullies, and plant trees to control erosion. These programs implemented erosion control practices by employing workers from the depressed economy.

President Roosevelt sent standard legislation to the governor of each state that could be used in the establishment of Soil and Water Conservation Districts (SWCDs). By the end of 1937, districts were created in 23 states, and each of the states had SWCD laws by 1947. Local county SWCD workers and federal USDA employees collaborate jointly on conservation

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projects. Today, over 1300 SWCDs have been organized to assist farmers and landowners in controlling erosion.

A system of multifunctional Forest Service Research Centers was organized in 1946, with each center focusing on conditions within its established territory. Today, there are approximately 40 research and experimental areas in the National Forest System. The Forest Service Research and Development Division (FSRDD) currently conducts research to enhance the understanding of organisms, populations, ecosystems, and ecological processes. The FSRDD provides information required to manage forests and rangelands to sustain air, water, soil quality, and biological diversity. The Forest Service has conducted substantial research during the past century involving soil conservation (Dissmeyer and Foster, 1980).

The Soil Conservation Service

Hugh H. Bennett began his career as a soil surveyor for the USDA Bureau of Soils in 1903. In his work on mapping soils, Bennett often observed that productivity was substantially reduced on eroded cropland. He became a leader in the soil conservation movement in the 1920s and 1930s and urged the nation to address critical soil erosion issues. Today, Bennett is considered the father of soil conservation.

In the spring of 1935, Bennett was testifying before a congressional committee on the bill that would create the Soil Conservation Service (SCS) when dust clouds from the Dust Bowl moved over Washington, D.C. (fig. 1). He knew that a dust storm was coming and used it to dramatically demonstrate the need for soil conservation. During his testimony, Bennett asked the legislators to look out the window, and then said, "This, gentlemen, is what I have been talking about." Congress passed the Soil Conservation Act, and SCS became a permanent federal agency in 1935, with Bennett serving as its chief from 1935 until his retirement in 1951. In 1935, SCS had over 10,000 employees located throughout the U.S. (Nichols and Smith, 1957).

In 1934, USDA contained a Bureau of Agricultural Engineering and a Bureau of Chemistry and Soils. The functions of these two agencies were transferred to SCS after its establishment in 1935. Initially, SCS worked on demonstration projects, provided assistance to farmers and landowners, conducted soil erosion research, and developed conservation practices.

In 1994, SCS was reorganized and became the Natural Resources Conservation Service (NRCS). Public programs currently provided by NRCS help to sustain agricultural productivity and environmental quality while supporting continued economic development, recreation, and scenic beauty. Activities directed by NRCS help to reduce soil erosion, enhance water supplies, improve water quality, increase wildlife habitat, and reduce damages caused by floods and other natural disasters.

The Agricultural Research Service (ARS) was established in 1953 as the primary research agency for the USDA. Many SCS employees conducting erosion research became em-

Figure 1. *Science Newsletter* issue from 1935 with a cover article on "Dust Over Washington" showing how dust from eroding soils obscured the sun in the capital. Events such as this helped Hugh H. Bennett convince Congress to fund the soil conservation experiment stations and establish the Soil Conservation Service.

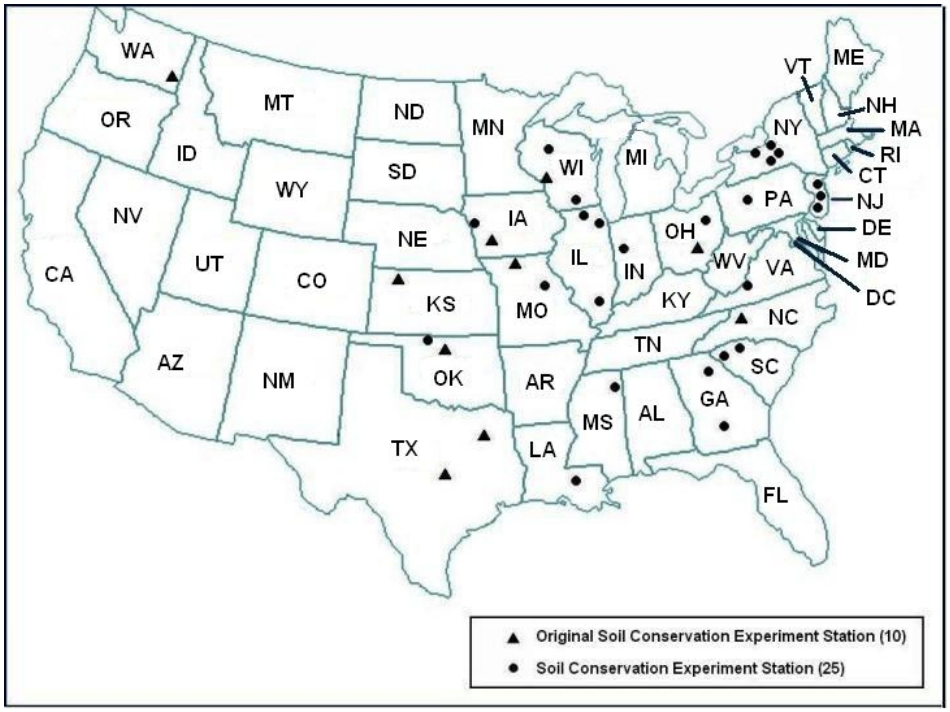

Figure 2. A soil erosion monitoring network of 35 locations was established. All of the Soil Conservation Experiment Stations except the Pullman, Washington, location were located east of the Rocky Mountains.

ployees of ARS. Natural resources and sustainable agricultural systems continue to be an important national focus of ARS. However, ARS national programs have evolved to include animal and crop production and protection, food safety and quality, and nutrition.

Soil Conservation Experiment Stations

Largely in response to Hugh H. Bennett's campaign for soil conservation, an amendment to the 1930 Appropriations Bill authorized the establishment of ten Soil Conservation Experiment Stations (SCES) (U.S. Congress, 1928). All of the SCES except one were located east of the Rocky Mountains, the principal crop production region at the time (fig. 2). Middleton et al. (1932, 1934) provided information on the physical and chemical characteristics of soils at the SCES.

The ten original SCES became an integral part of the research program of SCS. Research on erosion control and reclamation at several of the stations was published in USDA Technical Bulletins (Browning et al., 1948; Hays et al., 1949; Hill et al., 1944; Horner et al., 1944; Smith et al., 1945). The preface to each of these bulletins was signed by Hugh H. Bennett, Chief, Soil Conservation Service. Bennett used information obtained at the SCES in his classic book on soil conservation (Bennett, 1939).

The soil erosion monitoring network was soon expanded to 35 locations (fig. 2). It was originally intended that the SCES would be maintained for a 10-year period. However, data collection at five of the 35 SCES continued for over 20 years, and for 21 locations it ranged from 10 to 20 years. Soil conservation research efforts were reduced substantially during World War II.

A set of plots was established at each of the ten original SCES to study the effects of selected cropping and management practices on soil loss. Research projects were initiated to investigate the factors causing erosion and to determine the most effective and practical methods of controlling soil and water losses from agricultural areas. Experiments were conducted to determine the effectiveness of various types of vegetative cover, soil treatments, and cropping and management factors in reducing erosion (fig. 3). Studies were initiated at the SCES to evaluate the performance of terraces and check dams of different designs in removing runoff without injury to soils and crops, procedures for reclaiming and revegetating eroded land, and the use of manure as an erosion control measure (Gilley and Risse, 2000).

The equipment used to monitor erosion (fig. 4) was typically serviced within 24 hours of a runoff event. The erosion plots ranged from 1.8 to 3.7 m wide and from 6.1 to 30.5 m long (often the plots would be 1.8 m wide by 22.1 m long, encompassing an area of 0.004 ha). Plot borders were established using galvanized metal sheets, with a collection trough located at the bottom of each plot to channel runoff into a pipe. The pipe transported runoff and sediment into the first (sludge) tank. When a storm event occurred that exceeded the storage capacity of the first tank, the overflow was channeled through a flow splitter, and a fraction of the water was then collected in a second (aliquot) tank.

At each SCES, measurements from several plots were made throughout the year, including weekends and holidays. The quantity of runoff was determined, and runoff samples were collected for sediment analyses. The monitoring equipment was then prepared for the next storm event. The bottles containing runoff were weighed and oven-dried. Once dry, sediment weight was determined and calculations of runoff and soil loss were made.

Erosion control practices currently suggested for use on agricultural areas include contouring, grassed waterways, residue management, strip cropping, and terraces (Gilley, 2000). Each of these factors was evaluated and incorporated into the research and demonstration programs of the SCES.

Figure 3. Hugh H. Bennett, Chief, Soil Conservation Service, inspecting erosion research plots at the Red Plains Conservation Experiment Station near Guthrie, Oklahoma (photo courtesy of SWCS/JSWC).

Figure 4. Technicians servicing runoff and erosion plots at McCredie, Missouri, during the 1950s. Runoff and sediment from the bottom of the plots (left) was transported through a pipe to an initial collection (sludge) tank. When runoff exceeded the capacity of the tank, flow exited through a rectangular channel (center, with number "25" on it) to a flow splitter. A fraction of this outflow was then collected in the second (aliquot) tank.

The transfer of research information to producers and conservationists was an integral part of the mission of the SCES. Visitors to the stations were informed of the need for erosion control, the factors causing soil loss, and the application of various methods to control erosion.

In nature, hydrologic conditions often vary substantially among successive years. As a result, several years of record are required before significant differences among experimental treatments can be determined. Consequently, measurement of runoff and erosion from natural precipitation events is a labor-intensive, expensive, and lengthy endeavor. Thus, the collective information and data obtained from the SCES are unique and invaluable.

Hans A. Einstein, son of Albert H. Einstein, was an accomplished engineer recognized for his research on sediment transport. He was employed at the SCES near Clemson, South Carolina (1938-1943), and later at the USDA Cooperative Laboratory located at the California Institute of Technology near Pasadena (1943-1947). Einstein developed an analytic procedure for estimating sediment transport in open channels (Einstein, 1950).

National Runoff and Soil Loss Data Center

Walter H. Wischmeier became an employee of the USDA-SCS in 1940 at the University of Missouri in Columbia. He worked as a clerk assisting SCS research scientists until 1953, except for the period he served in WWII. Wischmeier received a BS degree in statistical theory from the University of Missouri in 1953.

All SCS research, except the soil survey program, was transferred to the Agricultural Research Service (ARS) when it was established in 1953. Former SCS soil conservation researchers, including Wischmeier, became employees of ARS. The National Runoff and Soil Loss Data Center (NRSLDC) was created at Purdue University in 1954, and Wischmeier served as its first director. The NRSLDC became the depository for much of the erosion data collected throughout the U.S. since the 1930s.

The NRSLDC was located in the Agricultural Engineering Building at Purdue University. The availability of outstanding computing facilities allowed rapid analyses and summarization of runoff and erosion data. Several clerks were hired at the NRSLDC to transfer records in the paper database obtained from the SCES onto punch cards (fig. 5).

A portable rainfall simulator, called the "rainulator" (fig. 6), was developed by NRSLDC scientists at Purdue University to produce artificial storms with the approximate kinetic energy of high-intensity natural rainfall (Meyer and McCune, 1958). The rainulator was used to measure runoff, erosion, and infiltration rates of treatments established on rectangular plots. Several years of labor-intensive data collection are required to evaluate soil and water losses resulting from natural precipitation events. Therefore, the rainulator soon became the instrument of choice for making runoff and erosion measurements (Meyer and Moldenhauer, 1985). Several rainfall simulation devices have been designed, fabricated, and used since the rainulator was introduced. The sprinkler heads identified by Meyer and McCune (1958) are used in many of the new-generation rainfall simulators.

The successful accomplishments of employees at the NRSLDC supported efforts in the 1970s to gain congressional

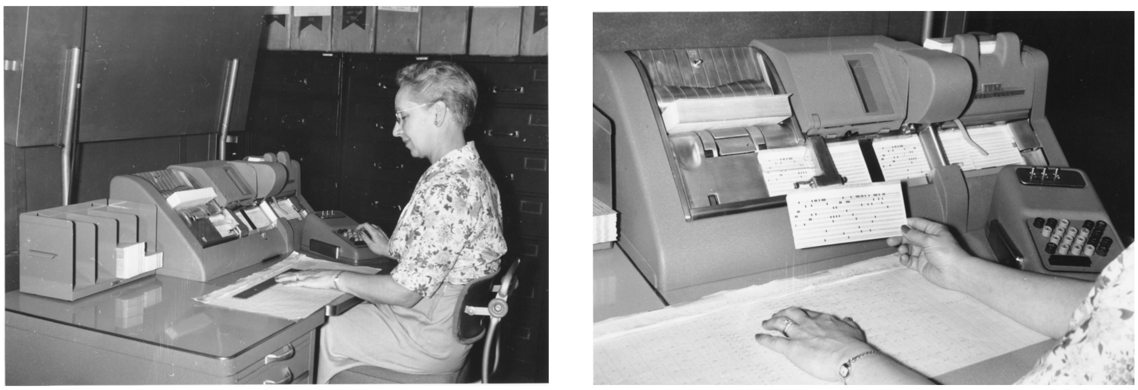

Figure 5. One of the statistical clerks (left) at the National Runoff and Soil Loss Data Center transferring information onto computer punch cards (right) during the 1950s.

Figure 6. L. Donald Meyer, Agricultural Engineer, National Runoff and Soil Loss Data Center (left) with the "rainulator" set up over erosion plots near West Lafayette, Indiana (circa 1960).

approval for a USDA conservation research facility on the campus of Purdue University. Congress authorized funding for the National Soil Erosion Research Laboratory (NSERL) in 1977, and the building was completed in 1981. The extensive collection of runoff and erosion data obtained in the 1930s, 1940s, and 1950s is maintained and managed at the NSERL, and much of this information is currently available on-line. Scientists and engineers at the NSERL are currently conducting research on fundamental erosion processes, erosion control, delivery of improved erosion prediction technology, and land management effects on soil and water quality.

The Universal Soil Loss Equation

The development of mathematical equations to estimate soil erosion and the effects of selected conservation, cropping, and management practices on soil loss began in the 1940s. Zingg (1940) published the results of a comprehensive study on the effects of slope steepness and length on soil erosion. The influences of selected cropping and support practice factors on erosion were soon added (Smith, 1941). Austin W. Zingg and Dwight D. Smith, agricultural engineers working at the SCES near Bethany, Missouri, used information collected at several SCES in their analyses.

Data assembled at the NRSLDC were used to develop an empirical equation for predicting soil erosion by water. The Universal Soil Loss Equation (USLE) resulted from analyses of more than 11,000 plot-years of research data from 47 locations in 24 states, including information collected from the SCES. The USLE was first released in 1961 (Wischmeier and Smith, 1961) and revised and updated in 1965 and 1978 (Wischmeier and Smith, 1965, 1978). Long-term average annual erosion (A) can be estimated with the USLE using the following relationship:

$$A = R \times K \times L \times S \times C \times P$$

where R is the rainfall and runoff factor, K is the soil erodibility factor, L is the slope length factor, S is the slope steepness factor, C is the cover and management factor, and P is the support practice factor (Wischmeier and Smith, 1978).

The effects of climate, crop productivity level, crop sequence, residue management, soil properties, selected conservation practices, and time and method of seeding can be evaluated with the USLE. The USLE has been used extensively for conservation planning and estimating sediment yield (Meyer, 1984) and is recognized as one of the most significant developments in soil and water conservation in the 20th century. The American Society of Agricultural Engineers honored the USLE on April 25, 2003, with a Historic Landmark dedication at Purdue University, and the marker is permanently displayed outside the NSERL.

An extensive five-year erodibility experiment using the rainulator was conducted on 55 Corn Belt soils in the 1960s (Wischmeier and Mannering, 1969). This study was critically important for development of the soil erodibility nomograph (Wischmeier and Smith, 1978) that made the USLE easy to apply to soils with diverse physical and chemical characteristics.

Erosion Prediction Using Computer Technology

The Revised Universal Soil Loss Equation (RUSLE) was developed as an updated computerized form of the USLE (Renard et al., 1997). Additional research and experimental data were used in the development of RUSLE. The same formula structure as the USLE was used in RUSLE, but several improvements were made, including new and revised isoerodent maps, a time-varying approach for estimating the soil erodibility factor, a sub-factor method for evaluating the cover management factor, a new equation to reflect slope length and steepness, and revised conservation practice values. A broad range of construction, farming, forestry, and mining conditions can be evaluated using RUSLE.

The WEPP (Water Erosion Prediction Project) model is a process-oriented, continuous simulation computer program that can be applied to hillslope profiles or field-sized watersheds (Flanagan and Nearing, 1995). WEPP uses a daily time step to update soil, crop, and residue conditions that affect soil erosion. When rainfall occurs, the plant, residue, and soil characteristics on the simulation day are examined to adjust the infiltration parameters, which are subsequently used to determine if runoff will occur. If runoff is predicted, the model will compute soil detachment, sediment transport, and deposition for overland flow, rill, and channel areas using a number of conceptual components. Data collected from the SCES have been used to test selected WEPP model components (Tiwari et al., 2000; Zhang et al., 1996). Flanagan et al. (2007) describe management of the WEPP program, development of the erosion prediction technology, and the future of WEPP technology.

As part of the WEPP field experimentation program, soil erosion measurements were made at 33 sites throughout the U.S. Rill and interrill erodibility were measured from rainfall simulation tests. The resulting data were compiled and used in parameterization and testing of the WEPP model (Elliot et al., 1989; Gilley et al., 1990). As was true for the information collected at the SCES, it is anticipated that the runoff and erosion data obtained as part of the WEPP project will also be a valuable resource in future erosion and water quality modeling activities.

Several water quality models, including GWLF (Haith and Shoemaker, 1987), GLEAMS (Leonard et al., 1987), AGNPS (Young et al., 1987), SWAT (Arnold et al., 1998), and GSSHA (Downer and Ogden 2002), employ USLE technology. The technology utilized in many of the recently developed water quality models would not have been available without the information obtained from previous soil conservation research, including data collected at the SCES.

Summary

Early soil conservation researchers were dedicated to the protection and preservation of our natural resources. The programs they developed for land use, soil protection, and water conservation have helped to maintain and improve the soil resources upon which American agriculture and forestry depend. The soil and water conservation practices they developed, refined, tested, and adopted continue to be used extensively today.

Information collected by SCES employees was originally maintained as part of a handwritten paper database. Processing and analysis of this enormous data set using equipment available in the 1950s was a monumental task. Several erosion and water quality models have been developed utilizing data and information collected at the SCES and assembled at the NRSLDC. Each empirical erosion prediction equation represented state-of-the-art technology at the time of its release. These models were often used for several years, and then revised and updated. Newer erosion prediction technology based on fundamental physical processes has more recently been developed.

A constant in each succeeding erosion prediction procedure has been the source of field experimental runoff and soil loss data used for model factor development, parameterization, and testing: the unique and invaluable collective data set obtained from the SCES. It remains a paradox that handwritten data meticulously collected by dedicated researchers in a previous era serves as a critical component of technology developed for the electronic age. Thus, it is a tribute to early conservationists that their investment of time and resources in soil conservation research continues to provide dividends.

References

Arnold, J. G., R. Srinivasan, R. S. Muttiah, and J. R. Williams. 1998. Large-area hydrologic modeling and assessment: Part I. Model development. *J. American Water Resources Assoc.* 34(1): 73-89.

Bennett, H. H. 1939. *Soil Conservation.* New York, N.Y.: McGraw-Hill.

Browning, F. M., R. A. Norton, A. G. McCall, and F. G. Bell. 1948. Investigation in erosion control and the reclamation of land at the Missouri Valley Loess Conservation Experiment Station, Clarinda, Iowa, 1931-42. Tech. Bull. No. 959. Washington D.C.: USDA.

Dissmeyer, G. E., and G. R. Foster. 1980. A guide for predicting sheet and rill erosion on forest land. Tech. Pub. No. SA-TP 11. Washington, D.C.: USDA Forest Service.

Downer, C. W., and F. L. Ogden. 2002. Gridded surface subsurface hydrologic analysis user's manual: Version 1.43 for WMS 6.1. ERDC Technical Report. Vicksburg, Miss.: Engineering Research and Development Center.

Einstein, H. A. 1950. The bed-load function for sediment transportation in open channel flows. Agric. Tech. Pub. No. 1026. Washington, D.C.: USDA.

Elliot, W. J., A. M. Liebenow, J. M. Laflen, and K. D. Kohl. 1989. A compendium of soil erodibility data from WEPP cropland soil field erodibility experiments 1987 & 88. NSERL Report No. 3. West Lafayette, Ind.: USDA-ARS National Soil Erosion Research Laboratory.

Flanagan, D. C., and M. A. Nearing. 1995. USDA-Water Erosion Prediction Project hillslope and watershed model documentation. NSERL Report No. 10. West Lafayette, Ind.: USDA-ARS National Soil Erosion Research Laboratory.

Flanagan, D. C., J. E. Gilley, and T. G. Franti. 2007. Water Erosion Prediction Project (WEPP): Development history, model capabilities, and future enhancements. *Trans. ASABE* 50(5): 1603-1612.

Gilley, J. E. 2000. Erosion. In *Encyclopedia of Science and Technology.* 9th ed. M. D. Licker, ed. New York, N.Y.: McGraw-Hill.

Gilley, J. E., and L. M. Risse. 2000. Runoff and soil loss as affected by the application of manure. *Trans. ASAE* 43(6): 1583-1588.

Gilley, J. E., E. R. Kottwitz, and J. R. Simanton. 1990. Hydraulic characteristics of rills. *Trans. ASAE* 33(6): 1900-1906.

Haith, D. A., and L. L. Shoemaker. 1987. Generalized watershed loading functions for stream flow nutrients. *Water Resources Bulletin* 23(3): 471-478.

Hays, O. E., A. G. McCall, and F. G. Bell. 1949. Investigations in erosion control and the reclamation of eroded land at the Upper Mississippi Valley Conservation Experiment Station near La Crosse, Wisconsin, 1933-43. Tech. Bull. No. 973. Washington, D.C.: USDA.

Hill, H. O., W. J. Peevy, A. G. McCall, and F. G. Bell. 1944. Investigations in erosion control and the reclamation of eroded land at the Blackland Conservation Experiment Station, Temple, Texas, 1931-41. Tech. Bull. No. 859. Washington, D.C.: USDA.

Horner, G. M., A. G. McCall, and F. G. Bell. 1944. Investigations in erosion control and the reclamation of eroded land at the Palouse Conservation Experiment Station, Pullman, Washington, 1931-42. Tech. Bull. No. 860. Washington, D.C.: USDA.

Laflen, J. M., and W. C. Moldenhauer. 2003. Pioneering soil erosion prediction: The USLE story. Special Pub. No. 1. Beijing, China: World Association of Soil and Water Conservation.

Leonard, R. A., W. G. Knisel, and D. A. Still. 1987. GLEAMS: Groundwater loading effects of agricultural management systems. *Trans. ASAE* 30(5): 1403-1418.

Meyer, L. D. 1984. Evolution of the universal soil loss equation. *J. Soil Water Cons.* 39(2): 99-104.

Meyer, L. D., and D. L. McCune. 1958. Rainfall simulator for runoff plots. *Agric. Eng.* 39(10): 644-648.

Meyer, L. D., and W. C. Moldenhauer. 1985. Soil erosion by water: The research experience. *Agric. History* 59(2): 192-204.

Middleton, H. E., C. S. Slater, and H. G. Byers. 1932. Physical and chemical characteristics of the soils from the erosion experiment stations. Tech. Bull. No. 316. Washington. D.C.: USDA.

Middleton, H. E., C. S. Slater, and H. G. Byers. 1934. Physical and chemical characteristics of the soils from the erosion experiment stations, second report. USDA Tech. Bull. No. 430. Washington, D.C.: USDA.

Nichols, M. L., and D. D. Smith. 1957. Progress in erosion control over the past 50 years. *Agric. Eng.* 38(6): 422-425, 460.

Renard, K. G., G. R. Foster, G. A. Weesies, D. K. McCool, and D. C. Yoder. 1997. *Predicting Soil Erosion by Water: A Guide to Conservation Planning with the Revised Universal Soil Loss Equation (RUSLE)*. Agriculture Handbook No. 703. Washington D.C.: USDA.

Smith, D. D. 1941. Interpretation of soil conservation data for field use. *Agric. Eng.* 22(5): 173-175.

Smith, D. D., D. M. Whitt, A. W. Zingg, A. G. McCall, and F. G. Bell. 1945. Investigations in erosion control and reclamation of eroded Shelby and related soils at the Conservation Experiment Station, Bethany, Missouri, 1932-42. Tech. Bull. No. 883. Washington, D.C.: USDA.

Tiwari, A. K., L. M. Risse, and M. A. Risse. 2000. Evaluation of WEPP and its comparison with USLE and RUSLE. *Trans. ASAE* 43(5): 1129-1135.

U.S. Congress. 1928. House Committee on Appropriations, subcommittee hearing on the Agricultural Appropriations Bill for 1930. U.S. (70th) Congress, 2d sess., 310-330. Washington, D.C.: GPO.

Wischmeier, W. H., and J. V. Mannering. 1969. Relation of soil properties to its erodibility. *SSSA Proc.* 33(1): 131-137.

Wischmeier, W. H., and D. D. Smith. 1961. A universal equation for predicting rainfall-erosion losses: An aid to conservation planning in humid regions. Special Report No. 22-66. Washington D.C.: USDA-ARS.

Wischmeier, W. H., and D. D. Smith. 1965. *Predicting Rainfall-Erosion Losses from Cropland East of the Rocky Mountains: Guide for Selection of Practices for Soil and Water Conservation.* Agriculture Handbook No. 282. Washington D.C.: USDA.

Wischmeier, W. H., and D. D. Smith. 1978. *Predicting Rainfall Erosion Losses: A Guide to Conservation Planning*. Agriculture Handbook No. 537. Washington D.C.: USDA.

Young, R. A., C. A. Onstad, D. D. Bosch, and W. P. Anderson. 1987. AGNPS, Agricultural nonpoint-source pollution model: A watershed analytical tool. Conservation Research Report No. 35. Washington, D.C.: USDA.

Zhang, X. C., M. A. Nearing, L. M. Risse, and K. C. McGregor. 1996. Evaluation of runoff and soil loss predictions using natural runoff plot data. *Trans. ASAE* 39(3): 855-863.

Zingg, A. W. 1940. Degree and length of land slope as it affects soil loss in runoff. *Agric. Eng.* 21(2): 59-64.