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Pioneering Soil Erosion Prediction

The USLE Story

J.M. Laflen & W.C. Moldenhauer

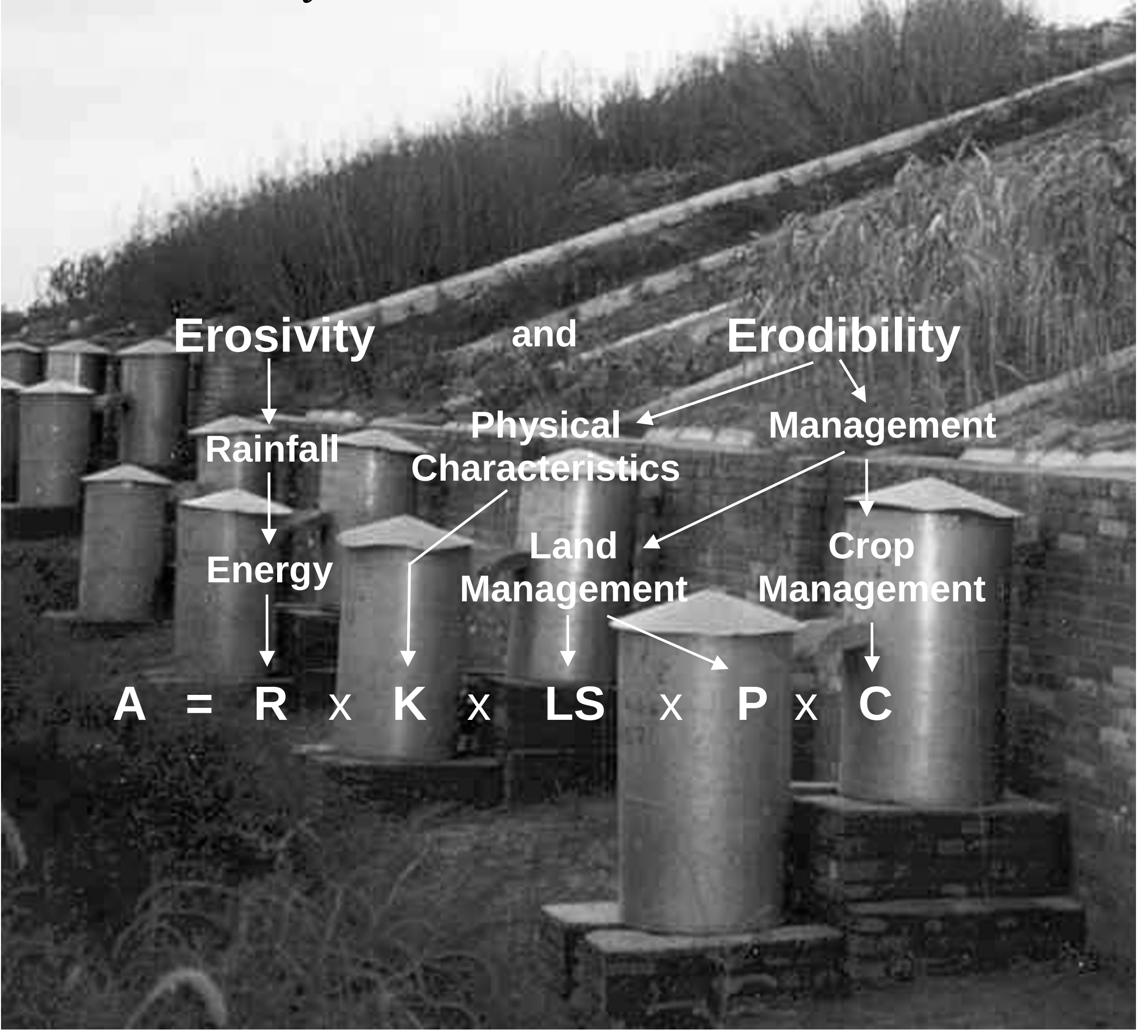

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Photo of W.H. Wischmeier by Samran Sombatpanit;
all other photos furnished by John M. Laflen

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FOREWORD

I like to read history books; only when we know about our past do we know best how and what to do now and in the future.

When I was working with the Land Development Department of the Royal Thai Government some years ago, some of us became interested in the Universal Soil Loss Equation (USLE) because it offered us a way of estimating the loss of soil caused by erosion. At the time, this equation, which was developed in the United States, was being applied in many parts of the world even though research workers were cautioned about its limitations. The reason for the caution was that the USLE had been developed with data gained from years of careful research on experimental plots under very specific conditions of rainfall, soil and slopes in the United Stares that do not necessarily prevail in other regions of the world.

Despite the warnings, the USLE has been widely used outside the U.S. because it provides a relatively simple way of estimating erosion and comparing the likely benefits of different soil conservation practices.

The USLE was revised, becoming the Revised Universal Soil Loss Equation or RUSLE. It has also been used as the basis for a number of other erosion prediction models.

The USLE and the RUSLE are the products of intensive efforts by a number of outstanding American scientists over a number of years. Some of these scientists are no longer with us but, fortunately, several are now valuable members of our Association. I felt that we should call on the benefit of their experience and knowledge to record the background and history of the USLE. As a result, two of our best-known members, John Laflen and Bill Moldenhauer, volunteered to write the story of the USLE for us. The result is this book. It shows how problems of soil erosion came to be recognized, how the concept of the USLE was developed, especially through the efforts of the late Walt Wischmeier, how various U.S. universities handled the research program and how the successive soil erosion prediction models have since been developed.

This book has been specially published for the benefit of WASWC members and it is intended that, with the input of other members, more books of the same type will be produced over the coming years.

I would like to express my most sincere appreciation to the authors, reviewers and editor, all of whom have made valuable contributions to this small, but highly informative and useful publication for all WASWC members.

Samran Sombatpanit

WASWC President

PREFACE

Bill Moldenhauer and I have worked together in soil erosion research for 35 years, and enjoyed every minute of it. We have been retired from USDA-ARS for several years, and we are both members of WASWC (World Association of Soil and Water Conservation), with Bill having served in a leading role in getting it started, and continuing even today.

Samran Sombatpanit asked us to produce a small book about the evolution of the Universal Soil Loss Equation (USLE). This book is the result of that request. He gave us some advice: "the script should not be too deep on the engineering and mathematical side, but should give people a good idea of what USLE means and how it was developed, what for, and its (more useful) successors. The writing should be a light one that one may like to read continually to the end".

Well, we tried. We've got some heavy stuff in the book, but we've also tried to bring in some of the people and their individual contributions, as well as events. And, we've tried to be accurate. We've included things that we think not very many people know about, or had synthesized the information in the way we have.

We've tried to give our perspective of the flow of soil erosion prediction research and development over time in the development of the USLE. Surely we've omitted or glossed over some significant events, and highlighted some insignificant events. For that we apologize. But, we don't apologize for the wonderful associations we've had with many of the people we mention in this book.

To get to know and work with the likes of Dwight Smith, Walt Wischmeier, George Browning, Bob Norton, C.A. Van Doren, Don Meyer, George Foster, Ken Renard, Don McCool, Tam Olsen, Glenn Weesies, Bob Young, Jeff Porter, Dan Yoder, and David Whittemore (and others we've surely missed) is a reward in itself. We have been privileged.

We hope you enjoy this little book.

John Laflen, Buffalo Center, Iowa, USA
Bill Moldenhauer, Volga, South Dakota, USA

March 31, 2003

INTRODUCTION

The Universal Soil Loss Equation (USLE) is hailed as one of the most significant developments in soil and water conservation in the 20th century. It is a technology that is applied on every continent on earth where soil erosion caused by water is a problem. It is an empirical technology that has developed in an evolutionary manner in the last 60 years, and it is still undergoing evolution with the development of various revisions.

The USLE is the result of the work of many individuals over a very long period of time, and occurred because of the remarkable timing of events and support from surprising sources. This book is intended to describe the events in the evolution of the empirical erosion prediction technology that became the USLE.

The evolution of the USLE continues today with work on the Revised Universal Soil Loss Equation (RUSLE). This work is also briefly reviewed in this book.

THE BEGINNINGS

Recognition of the Soil Erosion Problem

Little research in soil erosion would have been conducted in the United States of America (USA) if soil erosion had not been recognized as a serious problem and a threat to the USA. While early farmers such as Jefferson (1813) recognized erosion as a problem, it was the early work of

Severe erosion on sloping bare areas generates considerable deposition scientists like Duley and Miller (1923) in Missouri that began to inform the public concerning soil erosion. However, it was not broadly recognized as a national problem until H.H. Bennett called it to the public's attention. H.H. Bennett laid the groundwork for public support of soil erosion as a "menace to the national welfare". In 1929, Congress appropriated US$160,000 for research into the causes of soil erosion, the preservation of soil and the prevention of erosion. Bennett (1939), in the preface to his book *Soil Conservation* attributed the educational campaign of the United States Department of Agriculture (USDA) and the publication in 1928 of the USDA Circular "Soil Erosion – A National Menace" (Bennett and Chapline, 1928) as critical elements in securing public and political attention to this menace.

Development of Plots

The period from 1930-1942 was the "golden years for conservation research" (Nelson, 1958). Erosion research stations were established representing ten major regions of the United States. These stations were located at Guthrie (Oklahoma), Temple (Texas), Hays (Kansas), Tyler (Texas), Bethany (Missouri), Statesville (North Carolina), Pullman (Washington), Clarinda (Iowa), La Crosse (Wisconsin), and Zanesville (Ohio). Plot design was based on the studies by M.F. 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, i.e., 1% 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 the 72.6 feet.

The formation of this network of erosion research stations, plus others initiated later, provided a repository of research data used by many scientists. These data provided a basis for the selection of conservation practices and for computing cropping-management factors. The soils on many of these stations were part of the "benchmark" soils. The data from these stations were used in developing the empirical erosion prediction technologies and in the analyses that led to the development of the USLE.

Support from a Surprising Source

While considerable public attention had been focused on soil erosion in the late 1920s, the problem facing most Americans was the Great Depression. In 1932, Franklin D. Roosevelt was elected president. President Roosevelt was the product of a privileged life, raised in New York City. But, his first political contest was in 1910 when he won a New York State Senate seat where he represented a considerable number of farmers (Freidel, 1990). His major emphasis was on promoting agriculture and conservation. As a state legislator, he worked diligently for farmers, and for conservation. This early interest proved to be important to soil and water conservation in the 1930s, and this early impact continues to this day.

The Great Depression severely impacted the United States. To stimulate the economy, Roosevelt established a program called the "New Deal" which was designed to stimulate recovery. It included the National Industrial Recovery Act, and the Soil Erosion Service, with H.H. Bennett as its first director, was estab-

Ephemeral gully in a field in central Indiana, USA

lished as a part of the Department of the Interior in September, 1933, less than 6 months after Roosevelt was elected president. With Roosevelt's background related to agriculture, it was possible to implement programs related to soil conservation. This would not have been possible without the direct and strong support of the president, and the support of the American people to improve the agricultural, and the national, economy.

A major event in public awareness was the great dust storm on May 12, 1934. It originated in the Great Plains, and swept across the country to the Atlantic coast, causing street lights to be turned on in Washington D.C. H.H. Bennett was testifying before Congress when the dust storm arrived in Washington D.C. Undoubtedly, H.H. Bennett was a genius at bringing to decision makers' attention the threat of soil erosion to the wellbeing of the nation.

In 1935, the Soil Conservation Act was passed. This was a major milestone because it committed the U.S. government to soil conservation. It was from these series of laws that most soil erosion activities of the U.S. Government were established, and they continue to today.

Most of the work related to erosion prediction was conducted by USDA scientists employed by the Soil Conservation Service (SCS). The close connection between research and the soil conservationists in the USDA-SCS would seem to be important. Politically, there was a very close connection between research and the users. Users had a direct voice within the agency on research emphasis. The USDA Agricultural Research Service (ARS) was established in 1953, and many SCS employees engaged in research became employees of the ARS. While this did establish some insulation between the developers and users of the technologies, the close relationships continued as a model for USDA research.

While the emphasis in this section was on the politics that provided the funds and direction for much of the work, it is important to recognize that the early work was done a decade or so before the federal funding was available. Miller originated the plots in Missouri in 1917; Baver (1938) called these the "germ from which the soil and water conservation activities in this country have developed" (Baver may have been a bit prejudiced – he was a member of the Soils Department at the University of Missouri, and so was Miller, during much of the 1930s). Baver also disclosed that "Miller and his personal friend, H.H. Bennett, have indeed been the pioneers who have blazed the trails of thinking in the field of soil conservation in America". Baver (1938) also pointed out that Wollny carried out fundamental investigations relating to soil and water conservation in Germany beginning as early as 1874. Baver reported much of Wollney's data. He found it strange that "such excellent investigations should not have received the recognition due to them". Apparently, Baver was the first U.S. scientist to find and report on Wollney's work.

SOIL EROSION PREDICTION DEVELOPMENTS LEADING TO THE USLE

It is clear from the equations and relationships developed that the USLE is the result of an evolutionary development that continues even today. Meyer (1984) wrote on the "Evolution of the Universal Soil Loss Equation". This section is an attempt to detail the most significant steps that took place prior to the USLE.

First Steps

In 1940, Zingg evaluated data from field experiments under natural rainfall and from a rainfall simulation experiment. While others, including Duley and Ackerman (1934), had published papers where the effect of slope and length on soil erosion had been measured, no relationships had been published. Zingg's (1940) relationship was

$$X = C\ S^m\ L^n \quad [1]$$

Where X is total soil loss from a land slope of unit width, C "a constant of variation", S was land slope (%), L was horizontal length of land slope, and m and n were exponents. Zingg also expressed average soil loss per unit area from a land slope of unit width as

$$A = C\ S^m\ L^{n-1} \quad [2]$$

The value of m was (derived from the simulated rainfall experiment) 1.4, and for n was 1.6.

The following year, D.D. Smith (1941) expanded Zingg's work to

$$A = C\ S^{1.4}\ L^{0.6}\ P \quad [3]$$

Where P is the ratio of soil loss with a mechanical conservation practice to soil loss without the practice. Smith retained the m and n values on length and slope derived by Zingg. He then used equation 3 with measured annual values of A, and values of S and L from individual plots to compute C values for various rotations and soil treatments. The data used were collected on the Shelby soil, the same soil used by Zingg in his rainfall simulation study.

Smith's work in 1941 moved the USLE development (although it wasn't known by that name then) along substantially. Smith was a guiding light in the USLE development from its earliest days through the 1970s. His paper published in 1941 (Smith, 1941) established the concept of an allowable soil loss, now known as the '**T value**' for a soil. Smith based the allowable soil loss on maintenance of soil fertility. His observation was that it was about 4 tons/acre for the Shelby soil in Missouri.

There was little apparent progress in soil erosion prediction related to the USLE reflected in published papers for the next several years because of the Second World War (WWII). However, despite the war, much soil erosion data was collected from erosion plots at a large number of stations in the United States. And, fundamental erosion processes were identified and published by Ellison (1944). These works were important in understanding erosion research data, and eventually, in modeling soil erosion (Meyer and Wischmeier, 1969).

Severe sheet, rill and gully erosion due to a severe storm when the soil was unprotected

The next major published work presented a full soil erosion prediction technology (Browning et al., 1947). Browning's major contribution in this work was the development of erodibility factors for a suite of Iowa soils, and the permissible soil loss for each of the soils in this suite. He used these and Smith's equation to compute slope length limits for various management systems for these soils. While he did not explicitly express a soil erodibility factor, his was the first quantitative approach to soil erodibility, representing a major step forward toward a soil erosion prediction technology.

Pre USLE Prediction Equations

In 1947, a group of workers (T.C. Peele, H.O. Hill, O.E. Hays, John Lamb Jr, George Browning, D.D. Smith, C.A. Van Doren, B.H. Hendricson and R.A. Norton), led by G.W. Musgrave, met to evaluate the factors involved in soil erosion. From this work, an equation called the Musgrave equation (Musgrave, 1947) was developed. The group was a diverse group from the standpoint of experience in soil erosion. Musgrave, Norton, and Browning had all been associated with one of the original erosion research stations established at Clarinda (Iowa), Hill had been the project supervisor at a station near Temple (Texas), Smith the project supervisor at Bethany (Missouri), Van Doren was a USDA scientist at Urbana (Illinois), Peele was a USDA scientist in South Carolina, and, Hays was a project supervisor at La Crosse (Wisconsin). They represented a very broad range of erosion, crop production, soils and climate experiences. The result was the first complete equation for predicting soil erosion. The relationship is shown in Table 1.

The Musgrave equation's rainfall factor was based on unpublished work by Hays where he had shown that erosion at La Crosse (Wisconson) was correlated with the maximum amount of rainfall in a 30 minute period in a storm, raised to the 1.75 power. The relationship was tested at many locations, and seemed to be satisfactory. The equations' soil erodibility value was determined for soils that were at the different erosion stations, based on measured values of soil erosion that were adjusted to a common rainfall value – 1.25 inches of rain for 30 minutes, and adjusted to a land slope of 10% and a plot length of 72 feet. Data were used from fallow and continuous row crop plots. The erodibility values were expressed as inches of soil loss per year. The Musgrave equations' slope and length factors were similar in form to those of Zingg, with values slightly different because they were available from many more sites and record lengths were longer. The exponent of slope was 1.35 and on length it was 0.35.

Table 1 Equations in the development of soil erosion prediction technology

Zingg, 1940	$A = C' \; L^{.0.6} \; S^{1.4}$
Smith, 1941	$A = C'' \; L^{0.6} \; S^{1.4} \; P$
Browning, 1947	$A = C''' \; L^{0.6} \; S^{1.4} \; P$
Musgrave, 1947	$A' = (P_{30}/1.25)^{1.75} \; K' \; (L/72)^{0.35} \; (S/10)^{1.35} \; C^*$
USLE, 1965	$A = EI_{30} \; K \; (L/72.6)^{0.5} \; (0.065 + .045\,S + .0065\,S^2) \; C \; P$
USLE, 1978	$A = EI_{30} \; K \; (L/72.6)^{0.5} \; (65.4 \sin^2\Theta + 4.56 \sin\Theta + 0.065) \; C \; P$
RUSLE, 1997	$A = EI_{30} \; K \; (L/72.6)^{m} \; (a \sin\Theta + b) \; C \; P$

A — Soil loss in tons/acre
A′ — Soil loss in inches/year
C′, C′′, C′′′ — Coefficients
C* — vegetal cover factor
P_{30} — Maximum Precipitation amount (inches) falling in 30 minutes in a storm
K′, K — Soil erodibility factors
L — Slope length in feet
S — Slope in percent
Θ — Slope angle in degrees
C — Cropping management factor
E — Storm rainfall energy in hundreds of foot-tons per acre
I_{30} — Maximum rainfall intensity in a 30 minute period within a storm in inches per hour
P — Conservation practice factor
M — Exponent on length term-values depend on slope or slope and rill/interrill ratio
a, b — coefficients in function making up slope term – values depend on slope

The Musgrave equation used a Vegetal Cover Factor that expressed relative erosion for different covers. Continuous row crops had values of 100, and hay, pasture, woodland and forests had values less than 1. An example of a further breakdown of the vegetal cover factor was illustrated using a table for the Pacific Northwest that included different tillage regimes and managements for the same crops. There was some indication that conservation practices were considered in the vegetal factor, but they could have been considered separately.

In an example presented for the Marshall Soil (erodibility of 0.33 inch/year adjusted to the maximum 30 minute rainfall amount in a year of 1.25 inches, 10% slope, 72 foot length) where 30 minute maximum rainfall was 1.35 inches, slope was 5%, length was 150 feet, and the crop was wheat (vegetal factor = 0.2), the average predicted soil loss was:

$$\text{Soil loss} = (R)^{1.75}\ (K)\ (L)^{.35}\ (S)^{1.35}\ (C) \qquad [4]$$

$$\text{Soil loss} = (1.35\text{in}/1.25\text{in})^{1.75}\ (.33\ \text{in/yr})\ (150\text{ft}/72\text{ft})^{.35}\ (5\%/10\%)^{1.35}\ (0.2) = 0.038\ \text{inch/yr} \qquad [5]$$

Where R is the ratio of the 30 minute maximum rainfall amount to the baseline 30 minute maximum rainfall amount, L is the ratio of slope length to the baseline 72 foot length, S is the ratio of slope to the baseline 10% slope, and C is the vegetal factor. Assuming a bulk density of 80 lbs per cubic foot, soil loss would be estimated to be about 5.5 tons/acre/year.

The Musgrave equation expressed soil erosion in terms of inches per year. It was in many ways very similar to the USLE. The Musgrave equation was based on data from many of the same locations, and on much of the same data as was the USLE. It used similar techniques in developing factor values. And, both technologies heavily involved many of the same scientists.

The Musgrave equation was widely used, but not always in its original form. Lloyd and Eley (1952) described a graphical solution of probable soil loss for the Northeastern Region of the United States, where soil loss was expressed in tons per acre. They used the Musgrave equation, but rather than using the ratios to baseline values for R, L and S, they used the values directly.

For the example above,

$$\text{Soil loss} = (1.35)^{1.75}\ (.33)\ (150)^{.35}\ (5)^{1.35}\ (0.2) = 5.67\ \text{tons/acre/yr} \qquad [6]$$

The equation worked well without any particular multiplication constant to convert from inches of soil erosion to tons/acre because the product of the denominators in the above factors, when raised to the exponents was

$$(1.25)^{1.75} \ (72)^{.35} \ (10)^{1.35} = 148 \qquad [7]$$

This is almost identical to the factor to convert inches of soil erosion to tons per acre of soil erosion (with bulk density assumption above):

Factor-inches to tons/acre conversion:

$$(80 \text{ lbs/ft}^3) \ (3630 \text{ ft}^3\text{/acre inch})/(2000 \text{ lbs/ton}) = 145 \qquad [8]$$

Hence, the factors, including soil erodibility values, could be transferred between the Musgrave equation as originally presented in inches of soil erosion and the Musgrave equation when used in terms of tons/acre.

UNIVERSAL SOIL LOSS EQUATION — USLE

There had been considerable activity in developing equations for predicting soil erosion, but equations used seemed to have limits as to area of applicability, or factor values seemed to be inadequate. The Musgrave equation and the work of Browning et al. (1947) had established factor values based on the ratio of soil loss for a particular management to soil loss for a fallow condition or a continuous row cropped condition. Later work had shown that a continuous fallow and a continuous row crop could not be used interchangeably; hence soil erodibility values derived using continuous row crop data were invalid. The Musgrave equation rainfall factor seemed inadequate for use over the entire United States, and improvements were needed. But results had been encouraging in the development of the Musgrave equation, and the widespread use of a slope-practice method developed by Smith and associates. The technologies used in the US were merging into one technology – the Musgrave equation was developed by a large group that had been involved in the development of the various technologies. The development of an equation that could be used over the entire United States seemed possible. The existing technologies in the late 1940s and early 1950s had proven to be immensely useful. Hence, there was a great deal of interest on the part of the federal agencies to develop more broadly based technologies for erosion prediction.

In 1954, the National Runoff and Soil Loss Data Center was established by the USDA-ARS at Purdue University in West Lafayette (Indiana). The center was to be the central location for the soil erosion data that had been collected from studies located in many regions of the United States. W.H. Wischmeier was designated as the leader of the work. The center was responsible for summarizing and analyzing this immense data set which eventually exceeded 10,000 plot-years of soil erosion and runoff data.

In 1956 workshops were held at Purdue to extend existing methods of soil erosion prediction to areas where soil erosion measurements had not been made. The results of these workshops resulted in a basic equation very similar to the slope-practice and Musgrave equations, except, there was agreement that there was insufficient information to add a rainfall factor.

From 1954 onward, the focus was on analyzing the existing data sets, and developing an overall scheme for analyzing these data to support a broader prediction technology built on the previous work. Major works published related to the accomplishment of this goal included:

- Rainfall energy and its relationship to soil loss (Wischmeier and Smith, 1958).
- Factors affecting sheet and rill erosion (Smith and Wischmeier, 1957).
- Soil erodibility evaluations for soils on the runoff and erosion stations (Olson and Wischmeier, 1963).

- Cropping-management factor evaluation for a Universal Soil Loss Equation (Wischmeier, 1960).

- A rainfall erosion index for a Universal Soil Loss Equation (Wischmeier, 1959).

- First publication of the USLE in an Agricultural Handbook, *A universal equation for predicting rainfall-erosion losses – An aid to conservation farming in humid regions* (Wischmeier and Smith, 1961).

- 2nd publication of the USLE in an Agricultural Handbook, *Predicting rainfall-erosion losses from cropland east of the Rocky Mountains – Guide for selection of practices for soil and water conservation* (Wischmeier and Smith, 1965).
- 3rd publication of the USLE in an Agricultural Handbook. *Predicting rainfall-erosion losses – A guide to conservation farming* (Wischmeier and Smith, 1978).

The Unit Plot

The unit plot concept was widely used in establishing factor values for the USLE. The unit plot was defined as a plot 72.6 feet long with a 9% slope, maintained in a continuous regularly tilled fallow condition with up-and-down hill tillage. The unit plot was used as a base condition to which all other topographic, cropping and management, and conservation practices were related. Data collected on plots that had different slopes and lengths could be adjusted to the unit plot slope and length, and then compared across locations to establish more reliable factor values.

The unit plot was not a new concept. The Musgrave equation used a base slope of 10% and a base slope length of 72 feet, with adjustments required for other slopes and lengths. Cropping and management were expressed in terms of percentage of either a continuous fallow or continuous row cropped conditions. The impacts of conservation practices were expressed in terms of percentage of up-and-down hill tillage.

Runoff plots at Ansai, Shaanxi Province, China

While the unit plot concept was widely used, there has never been a unit plot, or if one ever existed, data from it has not been found. In Olson and Wischmeier's work on soil erodibility there are no soil erodibility values computed for a 9% slope on fallow plots, and there were only 2 locations where soil erodibility values were computed from 9% slopes, and both of these were from cropped plots. None of the benchmark soil erodibility values were derived from unit plots. The unit plot concept, while very useful, was apparently a myth as far as soil erosion measurements were concerned. A unit plot never existed! Or if it did, data from it was never reported.

R – Rainfall Factor

In 1958, Wischmeier and Smith used precipitation and soil loss data from fallow plots at Bethany (Missouri) (3 plots on Shelby soil, 10 yr data, 1 of the 3 plots with 7 inches of topsoil removed), Clarinda (Iowa) (1 plot on Marshall subsoil, with 7 inches of topsoil removed) and La Crosse (Wisconsin) (1 plot on Fayette soil, 6 yr data, 10% slope) to determine the best characteristics of rainfall for estimating storm soil loss. The results of this analysis indicated that the rainfall characteristic best for estimating single storm soil erosion was the product of the total kinetic energy of the storm rainfall and the maximum rainfall intensity over a continuous 30 minute period during the rainstorm – this was known as EI or the R factor. The R factor was better than rainfall amount, rainfall energy, maximum 15 or 30 minute intensity, and a multiple linear regression combining the above variables. When the multiple linear regression approach was combined with R, R^2 values were improved, but not sufficient to merit this more complex rainfall factor. For a particular soil on a plot with a slope of 9% and 72.6 feet, the slope of the relationship between soil loss and the rainfall factor, as determined by linear regression, was defined as the soil erodibility value (K factor) for that soil. In 1959, Wischmeier examined this rainfall factor further by evaluating its suitability at other locations, and for various cropping periods. In all cases, including management, crops, soils and climates far different than those in the 1958 analysis, the R value proved to be a good rainfall characteristic for estimating soil loss. Periods included seasonal and annual periods.

It is interesting that in Wischmeier and Smith's analyses, rainfall energy for every plot was a better predictor than was rainfall amount, and for 3 of the 5 plots, both rainfall energy and rainfall amount was a better predictor than was the 30 minute maximum intensity.

The energy per unit rainfall relationship at that time was expressed in a log function that gave nearly linear energies for rainfall intensities above about an inch per hour. More recent work has shown that it is a constant above an inch per hour (Renard et al., 1997). The Musgrave equation's rainfall factor, R α $P^{1.75}$ could also be expressed in terms related to the USLE rainfall factor. In the case of the Musgrave equation, [α is the symbol for proportional to] P was the maximum amount of rainfall that fell in a 30 minute period in the storm. Total energy in the most intense 30 minute period could be approximated by the product of a proportionality constant and the precipitation amount in the 30 minute period. And, the intensity in the 30 minute period could be approximated as the product of a constant and $P^{0.75}$. The major difference between the Musgrave equation rainfall factor and the USLE rainfall factor would be the energy that occurred outside the 30 minute maximum intensity period (which in some cases was negligible, and in other cases was significant) and the use of intensity to the 0.75 power rather than to the first power. The latter, as compared to the USLE, had no effect at 1 inch per hour, but an increasing effect as intensity increased. Given the widespread variability in the data, it was surprising that the relatively minor differences between the Musgrave and the USLE rainfall factors could be detected experimentally.

The title of the 1959 paper by Wischmeier was "A rainfall erosion index for a Universal Soil Loss Equation". This was the first instance found where the term "Universal Soil Loss Equation" was used in a publication. In the following years, the term "Universal Soil Loss Equation" became common usage. In an interview published in 1984 (Journal of Soil and Water Conservation, 1984), Wischmeier indicated that the earlier equations were local or regional in application, and the USLE expressed the concept of a generally applicable equation, freed of geographical orientation. The major limitation of the earlier techniques was the geographic limitation of the rainfall factor.

The adoption of the EI term for the rainfall factor in the USLE required its distribution over time for locations in the U.S. where the USLE was to be applied. By 1965 when the Agricultural Handbook 282 was published, data showing the distribution of

EI for half month periods was available for areas east of the Rocky Mountains, as well as a map giving average annual values for the same areas. Additionally, statistics related to probabilities of occurrence of single-storms and single-year R values were given for many locations in the United States.

K – Soil Erodibility Factor

The first step in soil erodibility (K) evaluations for the USLE was the publication of K values for the runoff and erosion stations. In that publication, Olson and Wischmeier (1963) computed soil erodibility values based on the new rainfall factor. No data was from a unit plot, and only 8 of the 28 computed values were based on fallow plots. All the data were adjusted to the unit plot. Data for cropped plots were restricted to intertilled plots that had been turn plowed. Each plot-year was evaluated separately, adjustments where required were based on the cropping periods defined for the USLE.

Severe erosion on the Loess Plateau in Shaanxi Province, China

Wischmeier and Mannering (1969), using a rainfall simulator, measured soil loss on 55 Corn Belt soils. They computed soil erodibility on the data adjusted to the unit plot as the slope of the linear relationship between the rainfall factor and soil erosion. Then, they related soil erodibility to a number of variables using multiple regression techniques. A major finding was that very fine sand behaves much more like silt than like sand.

Wischmeier and co-workers in 1971 published the results of additional analysis on the data from the study of Wischmeier and Mannering (1969). The study of Wischmeier and Mannering had included storms of 2.5 inches of rainfall in one hour on a dry soil, followed a day later by a half hour storm at 2.5 inches/hr, and that followed immediately by a similar storm. Wischmeier et al. (1971) used 13 of the 2.5 inch storms, 4 of the first half hour storms and then 3 of the last 2 storms combined to compute a K value for each soil. These K values were then related to soil characteristics using statistical procedures. As in the Wischmeier and Mannering work, soil texture and organic matter were the most important parameters, soil structure and permeability were also important. These results were compared with 13 of the 23 benchmark soils that were included in the work of Olson and Wischmeier (1963).

Using these results, Wischmeier et al. (1971) developed a soil erodibility nomograph that has been proven to be easily usable for estimating soil erodibility for most soils. The development of the erodibility nomograph has been critical for the use of the USLE.

In 1961, Laflen was invited to attend a workshop in Little Rock, Arkansas, where the USLE was presented to soil conservation workers involved in erosion prediction. D.D. Smith, W.H. Wischmeier, and T.C. Olson were among the presenters. There were a number of Soil Conservation Service soil scientists and agronomists from each state in the Southeast portion of the U.S. One of the major activities was a smoke filled evening session where K values were assigned to soils in the Southeast part of the United States. This was accomplished by comparing the benchmark soils with major soils in the various states, and then expanding these to other soils. Most of these comparisons were quite subjective in nature, with only personal experiences as guidance. But, the personal experiences were quite wide. The development of the soil erodibility nomograph greatly improved estimation of soil erodibility for the nation's soils, providing for a consistent and science based technology.

LS – Length and Steepness of Slope Factor

Smith and Wischmeier (1957) evaluated the effect of slope and length on soil erosion for several locations. Data evaluated included slopes ranging from about 1% to 25%. No single data set covered the entire range. The derived relationship was a quadratic relationship expressing the effect of slope on soil loss as

$$S = (0.43 + 0.30\, s + 0.043\, s^2)/6.613 \qquad [9]$$

Where S is the slope factor and s is percent slope. When s is 9%, the numerator of the equation is 6.613, S is the ratio of erosion for a given slope to erosion for a slope of 9%.

Smith and Wischmeier in 1957 also evaluated the effect of slope length on soil erosion. They defined slope length as the distance from the point of origin of overland flow to either where the slope decreases to the point that deposition begins, or to the point where runoff entered a well defined channel.

Smith and Wischmeier found, as others had, that soil loss per unit area varied as the m^{th} power of slope length, and they expressed it as

$$L = (\lambda/72.6)^m \qquad [10]$$

Where L is the slope length factor, λ is slope length and m is the slope length exponent.

Wischmeier and Smith found that the value of m varied widely from year to year, even at times becoming negative.

Average values for locations varied between 0 and 0.9. They recognized that the relationship had been controversial, largely because of the wide variation in experimental results which had not been satisfactorily explained, and also because there had been no specific agreement on what constituted length of slope.

They clearly recognized that the effect of slope length on soil erosion was influenced by slope, soil, vegetation and management. The USLE used a value of 0.5, but values of 0.6 were recommended for slopes greater than 10%, and values of 0.3 were recommended for very long slopes under the furrow irrigated conditions of the high plains of western Texas where soils were frequently dry and deeply cracked and had a decrease in runoff with increased slope lengths.

For most situations, the Length and Slope factors were combined into the equation

$$LS = \lambda^{0.5} (0.0076 + 0.0053s + 0.00076s^2) \qquad [11]$$

When the USLE Handbook (Wischmeier and Smith, 1965) was revised (Wischmeier and Smith, 1978), the length factor was changed only slightly. The recommendation that the value of m be increased for slopes steeper than 10% was removed. For slopes less than 1%, values of m of 0.2 were recommended. The major change adopted was the expression of the slope factor S as

$$S = 65.41 \sin^2\theta + 4.56 \sin\theta + 0.065 \qquad [12]$$

The change was made because erosional forces are functions of the sine of the slope, and projections of soil erosion well beyond the range of the experimental data become more realistic because predictions rise much slower when the sine of the slope is used rather than the tangent of the slope.

The various effects of slope on soil erosion that were developed from Zingg to RUSLE are shown in Figure 1. There were no data used above a slope of 25%, so relationships above about 25% are extrapolated beyond the range of the experimental data. It is apparent that there is little difference in the predicted effect of slope on soil erosion between the relationships up to slopes of about 20%. While severe soil erosion occurs on many slopes above 20%, most agricultural applications occur at smaller slopes, although there are significant exceptions. The RUSLE curve is based on work by McCool et al. (1987).

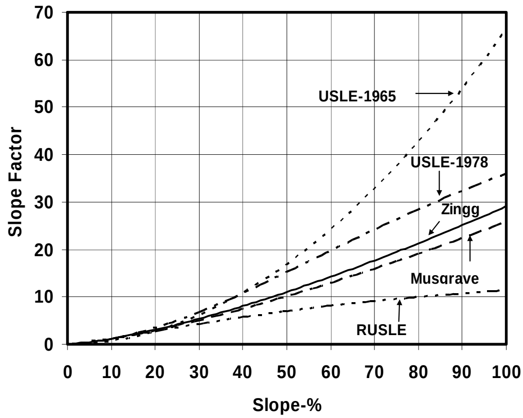

Figure 1 Effect of slope on soil erosion expressed by different technologies

C – Cropping and Management Factor

The Cropping and Management Factor (C) for the USLE is defined as the ratio of soil loss from a particular cropping and management to soil loss from a continuously tilled fallow area. Earlier C values had been defined as the ratio for a particular cropping and management to soil loss from a continuously tilled fallow area or to soil loss from a conventionally tilled row cropped area.

With the R value valid for seasonal periods, crop stage periods could be used rather than annual values in determining seasonal cropping and management factor values. This was a major difference between the USLE and the preceding erosion prediction technologies. It was also the beginning of much greater flexibility in applying the USLE to new situations – including construction and forest applications. Eventually, this led to a subfactor approach to computing cropping and management factors (Wischmeier, 1975). This approach was followed in developing RUSLE (Renard et al., 1997).

There is a big contrast between the well protected terraced areas and the adjacent eroded areas. Loess Plateau, Shaanxi Province, China

In 1960, Wischmeier published the results of an extensive cropping management factor evaluation for "a Universal Soil-Loss Equation". In this paper, he described 5 cropping periods which would suffice to describe the periods needed to estimate soil erosion for most cropping and management systems. He used over

8,000 plot-years of soil loss and related data from erosion plots in 21 states for this analysis. Crops included were corn, cotton, meadow and small grains. It is interesting to note that this work did not include soybeans, a minor crop at the time, and it did not directly include very much that would be counted as a conservation tillage system.

By 1965, the work on C values had been expanded to include much minimum tillage. The technology was much more complete, and the effect of soybean production on soil erosion could be estimated. By 1978, the applications were much expanded, with much more complete information on various tillage systems, and included almost any plant that might be grown. Procedures were included for applications to construction areas, forest, pasture, range and idle land.

P – Conservation Practices Factor

The Conservation Practices Factor (P) – later called the Erosion Control Practice Factor (1965) and Support Practice Factor (1978) – is the ratio of soil loss for a specific practice to the soil loss with up-and-down hill culture.

The initial practices considered for the USLE were contouring, stripcropping, contour stripcropping, and terraces. These were expanded to include contour listing, controlled-row grade ridge planting, contoured residue strips, and terraces of various types. Most P values were recognized to have slope-length limits and to have values that varied by land slope.

Smith in 1941, when discussing contouring, indicated that the "value of contouring decreases with increased amount and rate of rainfall". In that instance, Smith was making the case for the use of long-term records to insure a sufficient sampling of weather. The values used in the USLE in all cases were nationwide values independent of weather. Hence, a P value for contouring on a particular field was independent of the location of the field. A field in Savannah, Georgia, would have the same P value for contouring as an identical field located near Huron, South Dakota. RUSLE has major improvements in this area of estimation of the effect of conservation practices.

Terraces on the Loess Plateau, Shaanxi Province, China

USLE, RUSLE and WEPP

Wischmeier and Smith (mostly Wischmeier) completed the revision of the USLE resulting in the Agricultural Handbook 537 in 1978 (Wischmeier and Smith, 1978). By the early 1980s there was considerable interest in both the action agencies and the research community in updating the USLE. At the same time, the successful development of a field scale model for Chemicals, Runoff, and Erosion from Agricultural Management Systems —

CREAMS (Knisel, 1980), and the increasing use of computers had demonstrated that a new generation of erosion prediction technology built upon fundamental processes, and operated via computer, was a distinct possibility. In the early 1980s, two workshops were held at Purdue, one to arrive at a consensus regarding a revision of the USLE (eventually named Revised Universal Soil Loss Equation — RUSLE) and the other to begin planning for a technology (which eventually became the Water Erosion Prediction Project — WEPP) to replace the empirical technology for erosion prediction. George R. Foster was designated as the ARS scientist to lead both efforts.

Planning for WEPP commenced quickly, and while planning also began for RUSLE, it languished. By 1986, WEPP planning was well advanced. Work was underway in 1986 in developing a major field research project to collect the data for soil erodibility and hydraulic conductivity. Work was underway in determining what approaches would be taken and what science would be used. But, little progress was being made with RUSLE. Most of the ARS science power needed to develop RUSLE was more than fully engaged in WEPP. And, to do RUSLE right was not an inconsequential task. The action agencies still needed RUSLE.

In September, 1987, G.R. Foster left ARS to become a Department Head at the University of Minnesota. At a meeting in Boise (Idaho) in August, 1987, the decision was made that L.J. Lane, ARS at Tucson (Arizona), would become the WEPP Project Leader. The Federal Agencies that used the USLE recognized that if they waited for WEPP to be completed, the USLE would be hopelessly out of date. ARS committed to do RUSLE under the leadership of K.G. Renard, ARS, Tucson (Arizona). Renard and Laflen (Laflen was within a month of being the National Soil Erosion Research Laboratory (NSERL) director at West Lafayette Indiana, USA, on the campus of Purdue University) informally agreed that the NSERL would provide much of the support for that effort. In early 1988, at a program review, research plans were formally approved that included RUSLE as a major activity of the NSERL.

In September and October, 1987, considerable planning was conducted within the ARS and SCS groups that would be responsible for RUSLE. A meeting of ARS and SCS scientists was held at St. Paul, Minnesota, in November, 1987. Present were R.A. Young, D.K. McCool, J.P. Porter, G.A. Weesies, K.G. Renard, G.R. Foster and J.M. Laflen. The decision was made to implement RUSLE on a Personal Computer, with J.P. Porter of the National Soil Erosion Research Laboratory to coordinate that effort .

In 1987 and early 1988, Porter wrote a computer program that would do the computations for RUSLE. It was built using the existing R factor database, supplemented with a climate database

Grassed waterways properly designed and maintained provide non–erodible channels for runoff water from farm fields, eliminating most channel and gully erosion

needed to estimate residue decomposition (monthly temperature and precipitation). It used a time varying soil erodibility value, based upon the standard USLE K value and temperature, the standard LS value for the USLE, a subfactor approach based upon the work of Laflen et al. (1985, 1990), which was built in part from the subfactor approach of Wischmeier. P factors were based upon the existing approaches used in the USLE.

Porter recognized that the language used in the program (BASIC), or even FORTRAN, would not result in a user friendly computer program. In 1988, Porter employed D.A. Whittemore to program RUSLE. Whittemore developed a C based program that is essentially what is used today (i.e., 2003) for RUSLE. The first version of the program was completed in 1989. Porter supervised the development of the program, incorporating components from all involved in the RUSLE project, principally those attending the St. Paul meeting in 1987. G.A. Weesies was very heavily involved in working with Porter and Whittemore to see that the program would meet the needs of the Federal Action Agencies, principally the Soil Conservation Service (SCS).

In 1989, Porter left, and in the fall of 1989, D.C. Yoder became the RUSLE leader in the National Soil Erosion Research Laboratory (under the overall leadership of Renard). His immediate objective was to complete and test the RUSLE program. In early 1990, Weesies and Yoder gave the first workshop with RUSLE at the Missouri state office of the SCS. Yoder continued with the development of RUSLE, in particular, working with Foster to get improved estimates of conservation practice effectiveness in the RUSLE P factor. Efforts were made to improve the time varying K value estimation. Data bases were improved, particularly the one relating to rangelands (Renard did not like the range data base Laflen had put together – that is what happens when a farmer does rangeland!). Adjustments necessary for improved C values in the northwestern part of the United States related to moisture deficits were also incorporated.

In 1992, Yoder left the NSERL for the University of Tennessee, and Foster returned to ARS at Oxford MS. Yoder was supported by ARS at Tennessee to perform the work on RUSLE. Renard remained RUSLE leader until his retirement in 1994. Foster became RUSLE leader until his retirement in 1998. The present leader is M.J.M. Romkens, director of the National Sedimentation Laboratory at Oxford, Mississippi. A new version of RUSLE, named RUSLE2 is under development by Yoder and G.R. Foster at the University of Tennessee.

While there is a considerable overlap in scientists involved in both RUSLE and WEPP, the technologies are virtually independent as far as the science and approaches are concerned. Almost all ARS scientists and action agency personnel involved in RUSLE were also involved in WEPP. These include Foster, McCool, Young, Weesies and Laflen. Whittemore developed the first interface for WEPP, released in 1995. Porter had been employed to assist in the WEPP field experiments, but when it was apparent that his skills were needed in RUSLE, he was moved to RUSLE in the fall of 1987.

But, regardless of the technologies, they all rest heavily on the work of those that went before. Walt Wischmeier would likely support both the RUSLE and WEPP efforts because they more accurately reflect the interactions, and hence better predict soil erosion for specific sites — an outcome he would surely support. Ellison, in 1944, was enunciating erosion concepts that are embodied in WEPP, and it can be done only because of the computer. Those erosion plots, the old and new, serve to anchor all the technologies in something close to reality. And, none of this would have taken place, at least the way it has, without the pioneering work of M.F. Miller, D.D. Smith, G.W. Musgrave, and A.W. Zingg, and a host of others. And, it could not have been possible without the support of the public raised by H.H. Bennett, and without the political support of F.D. Roosevelt, the 32nd

President of the United States, who was trying to bring the United States out of the depths of the Great Depression.

SUMMARY

The USLE came into existence because of the remarkable evolutionary work of a series of research scientists and technology users. It was initiated prior to 1920 by a small group of state scientists that began to raise questions and present data that indicated the threat to the USA if soil erosion continued unabated. This caught the attention of a remarkable figure, H.H. Bennett, who used knowledge and events to build political support for controlling soil erosion. And, it occurred at a time when an American president was trying to raise this country from the depths of depression. And, this American president, despite being born to a life of privilege, knew of agriculture and soil and water conservation, and supported its funding as part of the national program for economic recovery.

And, of great importance, in the 1940s, a remarkable individual was trained in statistics, and given the opportunity to develop his skills in managing data sets and in analyzing these to establish empirical relationships — followed by a period of nearly 30 years to further develop the data sets and relationships to build the USLE as it is today.

W.H. WISCHMEIER

Walt Wischmeier graduated from High School in Lincoln, Missouri in 1928, and attended summer school at Missouri Central State College from 1928 to 1935, accumulating about 2 years of college credit. He was the valedictorian of his High School graduating class. He apparently taught in rural, one-room public schools near Lincoln from high school graduation until 1940 while he continued his college education during the summers. In 1940, he became an employee of the USDA-SCS at the University of Missouri in Columbia, Missouri. From 1940-1953, he worked as a clerk in support of SCS scientists at Columbia. He served in WWII during part of this period. From 1951-1953, he also attended the University of Missouri, receiving a BS degree in 1953, majoring in Statistical Theory. After his transfer to Purdue (Indiana) to lead the USLE work, he attended graduate school at Purdue, receiving a MS in Applied Statistics and Agricultural Economics in 1957.

At the 10th ISCO Conference, May 1999 (Purdue University, West Lafayette, Indiana, USA).

Walt surely demonstrated exceptional ability in the work at Columbia (Missouri) under the direction of Dwight Smith. Wischmeier was the person that supported much of Smith’s work in the latter half of the 1940s dealing with erosion prediction. Walt gives considerable credit to Smith's work, calling the

USLE "an extension of Dwight's pioneering work in the 1940s that led to the Corn Belt Slope-Practice Method". Smith was leader of USDA soil erosion research in the eastern part of the U.S. in the 1950s, and was the administrator mostly responsible in setting up the project at Purdue, and in selection of Wischmeier to lead that work, based on his personal knowledge of Wischmeier's abilities and accomplishments.

While at Missouri working under Smith, Wischmeier gained considerable familiarity with the erosion data sets being collected in the U.S. Wischmeier was probably directly involved in handling all the Missouri data sets. Many of the techniques used in developing various factors were evolutionary in nature, and Dwight Smith was heavily involved in these. Wischmeier was involved in much of the work at a support level. This experience, along with the training in statistics while at the University of Missouri, and again at Purdue, was surely instrumental in his success in developing the USLE. Wischmeier's first scientific publications began after completion of his MS degree at Purdue. His leadership began to be clear as the work progressed at Purdue in developing a coherent data set useful for the many analyses. From 1953 onward, little in ARS soil erosion research occurred without the involvement of Wischmeier either as a scientist or as a leader. During the next 25 years, Wischmeier was the major leader in ARS soil erosion research, and in transferring the technology to users.

Much of the success of the USLE can be directly attributed to Wischmeier's work with users of the USLE technology. Wischmeier regularly enhanced the technology to meet new needs. He participated in workshops with SCS in use of the USLE, and in development of supporting data sets.

In a conversation Laflen had with Walt in the late 1980s about the USLE and RUSLE, the interactions between the various factors in the USLE were discussed. It was clear from the writings that the scientists well understood the erosion processes, and the fact that these interactions were present. Walt indicated that the reason these were ignored in the USLE was that a technology was needed at the field level, and it could not be too complicated. It had to be delivered in manuals and field guides. If they had tried to incorporate these interaction effects (for example erodibility and climate), the technology would have been so complicated, using dozens of tables and charts, it would not have been used. It was this focus on providing technology for the user that made the USLE, and the group that developed it, so successful.

Walt Wischmeier was the first ARS Scientist in Soil and Water Conservation inducted into ARS's Hall of Fame. Walt retired in 1977. He passed away in 2001.

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The Authors

John M. Laflen

John Laflen was born in 1936 on a Southwest Missouri farm near Milo. He graduated from the University of Missouri with a BS degree in Agricultural Engineering in 1959, and with an MS degree in Agricultural Engineering in 1960. He began his research career in 1960 with the USDA-Agricultural Research Service in Baton Rouge, Louisiana. In 1967, he transferred to Ames, Iowa, and initiated a research program related to terraces, soil erosion and water quality. It was there that his and Bill Moldenhauer's long association began. In 1972, he received a PhD from Iowa State University in Agricultural Engineering with a minor in Statistics. He redirected his research program toward soil erosion and water quality related to conservation tillage. In 1980, he became Research Leader of a conservation tillage research unit in Ames, Iowa. In 1987, he was named Laboratory Director of the USDA's National Soil Erosion Research Laboratory at Purdue University. In 1989, he was named project leader for the Water Erosion Prediction Project (WEPP). In 1995, he transferred to the Soil Tilth Laboratory at Ames, Iowa, where he continued his WEPP activities until his retirement from the USDA-ARS in 2000. Since then, he has remained involved in soil erosion prediction activities, working as a visiting professor at Purdue in WEPP activities, presenting workshops on WEPP, and consulting and writing in the area of soil erosion prediction.

Laflen has received the highest awards the USDA offers with a Superior Service award for his work as a member of the EPIC modeling team, and a Distinguished Service award as a member of the WEPP modeling team. In 1994, he was invited to bring a small research team to China to transfer soil erosion research and prediction technology. In 1997, he was co-chair of a symposium on soil erosion and dryland farming held in Xi'an, China. He was also an editor of the proceedings of that symposium.

Laflen is a fellow of the American Society of Agricultural Engineers and received their Hancor Soil and Water Engineering Award in 1987. He is also a fellow of the Soil and Water Conservation Society, has chaired its publication committee, and has received SWCS Presidential Citation Awards for his work related to soil erosion and conservation tillage and for his leadership in Publications.

William C. Moldenhauer

William Moldenhauer was born in 1923 on a crop and livestock farm near New Underwood, South Dakota, USA. In 1941 he graduated from New Underwood High School and began a major in chemistry at South Dakota State College (SDSC) at Brookings, South Dakota, USA. World War Two intervened and he worked in the Bremerton Navy Yard in Washington State, was drafted into the military and served in New Caledonia and Leyte and Luzon in the Philippines. On his discharge from military service he resumed studies and received a BS in Agronomy at SDSC in 1949. In 1951 he received an MS degree and in 1956 a PhD, both in Soil Science at the University of Wisconsin, Madison, Wisconsin, USA.

He began his soil science career in Soil Survey for the South Dakota Experiment Station from 1948 to 1954. In 1954 he joined the U.S. Department of Agriculture, Agriculture Research Service (USDA-ARS) at Big Spring, Texas, USA, to work on wind erosion problems. He remained with ARS until his retirement in 1985. In 1957 he moved to Ames, Iowa, and worked with Iowa State University in research on soil management and control of wind and water erosion. In 1972 he moved to Morris, Minnesota and in 1975 to West Lafayette, Indiana where he was Research Leader working with Purdue University. During his tenure as Research Leader, USDA's National Soil Erosion Research Laboratory was approved and built on the Purdue Campus at West Lafayette.

He was active in the Soil and Water Conservation Society (SWCS) throughout his career. He served as President in 1979 and received its Hugh Hammond Bennett Award. He served on the founding committees of the International Soil Conservation Organization (ISCO) and the World Association of Soil and Water Conservation (WASWC). He served as first President of WASWC (l983-85) and as Executive Secretary from 1985-2003. He is Professor Emeritus of Purdue University and a Fellow of the American Society of Agronomy, Soil Science Society of America and the Soil and Water Conservation Society. He has been author or co-author of 125 publications as well as editor or coeditor of a number of books, booklets and proceedings.

World Association of Soil and Water Conservation WASWC

By Bill Moldenhauer and David Sanders

The World Association of Soil and Water Conservation (WASWC) was established in 1983 with the help and support of the Soil and Water Conservation Society (SWCS) of the USA. The original purpose was to support international activities of both SWCS and the International Soil Conservation Organization (ISCO). The world was divided into nine regions with at least one Vice President from each region. Since there was little contact among ISCO participants from one biennial conference to the next, our first priority was to publish a quarterly newsletter with meeting announcements, international conservation news, book reviews, member news, etc. From the beginning, we tried to give recognition to, and a forum for, workers in the international field who had published mainly in the "gray literature" (company, Government (GOV) and non-governmental (NGO) agency and organization reports that had had very small circulation). This continues to be one of our most vital functions.

By 1986 there was great interest in the Food and Agriculture Organization (FAO) of the United Nations and many GOV and NGOs in just how effective their international programs were in solving problems in developing countries. WASWC and SWCS organized a workshop in Puerto Rico with the help of several donor organizations and invited speakers to address the success (or failure) of donor sponsored soil and water conservation and land husbandry programs in developing countries worldwide. This was a very successful conference and resulted in two publications published by SWCS, *Conservation Farming on Steep Lands* and *Land Husbandry: A Framework for Soil and Water Conservation*.

Since our Puerto Rico workshop we have held a workshop in Taiwan in 1989, one in Solo, Central Java, Indonesia, in 1991, and one in Tanzania and Kenya in 1993. These have all been published and were circulated by SWCS.

Our Vice President for Europe, Dr. Martin Haigh, has initiated a series of meetings on Environmental Regeneration in Headwaters in various parts of the globe. Our Vice President for the Pacific Region, Dr. Samir El-Swaify, has initiated a series on Multiple Objective Decision Making for Land, Water and Environmental Management. Four of our Council members—Samran Sombatpanit, Michael Zoebisch, David W. Sanders, and Maurice Cook have edited a book titled, *Soil Conservation Extension: From Concepts to Adoption*. David Sanders, Paul Huszar, Samran Sombatpanit and Thomas Enters have edited a book titled, *Incentives in Soil Conservation: From Theory to Practice.* Lately, Samran Sombatpanit has edited a voluminous book, *Response to Land Degradation,* with five other editors.

Besides the above publications, past WASWC President Hans Hurni initiated a long-term program, World Overview of Conservation Approaches and Technologies (WOCAT), based in Berne, Switzerland in 1992. WASWC has supported Jim Cheatle's Organic Matter Management Network based in Nairobi, Kenya. WASWC is also closely allied with Reseau Erosion, a project of Vice President Eric Roose, based in Montpellier, France, and operating mainly in Africa. WASWC is closely allied to ISCO and cooperates fully with planning and conducting its biennial conferences. WASWC is requested and very willing to co-sponsor conferences, symposia and workshops it feels will further its philosophy and objectives.

The WASWC Philosophy

WASWC philosophy is that the conservation and enhancement of the quality of soil and water are a common concern of all humanity. We strive to promote policies, approaches and technologies that will improve the care of soil and water resources and eliminate unsustainable land use practices.

The Objectives of WASWC

The basic objective of WASWC is to promote the wise use of our soil and water resources. In doing so WASWC aims to:

- Facilitate interaction, cooperation and links among its members.
- Provide a forum for the discussion and dissemination of good soil and water conservation practices.
- Convene and hold conferences and meetings and conduct field studies connected with the development of better soil and water conservation.
- Assist in developing the objectives and themes for ISCO conferences and collaborate in their running.
- Produce, publish and distribute policies, guidelines, books, papers and other information that promote better soil and water conservation.
- Encourage and develop awareness, discussion and consideration of good conservation practices among associated organizations.
- Liaise, consult and work in conjunction with environmental organizations on the development and promulgation of global environmental and conservation policies, strategies and standards.

Recent Developments

The WASWC has had to face some serious problems in recent years and, as a result, some important changes have taken place. The cost of running WASWC has increased over the years and, at the same time, membership numbers dropped to below 400. The drop in numbers was partly because a membership fee of even US$10 per year is a considerable amount of money for many members from developing countries. Added to this, is the problem of paying in dollars and transferring relatively small sums of money internationally. To overcome these problems, a number of important steps have been taken. *First,* a concerted effort has been made to recruit new members. As part of this campaign, an effort has been made to improve the services provided to members. This has included improving the quality and length of the quarterly newsletter and distributing it by e-mail. *Second,* a flexible system of membership fees has been introduced which means that members can join for as little as US$5 per year. *Third,* a program of decentralization has also been launched with the appointment of several more Vice Presidents and the establishment of National Representatives. This program is not only bringing our association closer to members but has also provided other advantages including a system whereby it is now possible for local organizations to collect membership fees in local currencies and to pay the secretariat in bulk. *Fourth,* the WASWC council has become more actively involved in encouraging regional and local meetings, conferences and other useful activities. As a result of these measures, membership has risen to more than 800.

Another major change has been the move of the WASWC secretariat from the SWCS in the USA to Beijing in China, on April 1, 2003. It is now hosted by the Department of Soil and Water Conservation in the Ministry of Water Resources. The WASWC appreciates the generous help that it received from the SWCS over the 20 years that the SWCS ran its secretariat and intends to maintain a close association with it in the future. However, the Council believes that this move will have a number of advantages. Our Chinese hosts have offered very generous terms for the running of the secretariat; we will have the opportunity to work in a country where running costs are likely to be low and where there is considerable technical expertise available and of interest to many of our members.

WASWC Council

(For the period up to December 2004)

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Deputy President: Michael Zöbisch, AIT, P.O. Box 4 Klong Luang, Pathumthani 12120, Thailand.

Executive Secretary: Jiao Juren, ICRTS, DSWC/MWR, Jia 1, Fuxinglu, Beijing 100083, Beijing, China.

Treasurer: Maurice G. Cook, 3458 Leonard Street, Raleigh, North Carolina 27607, USA.

Immediate Past President: David W. Sanders, Flat No. 1, Queen Quay, Welsh Back, Bristol BS1 4SL, UK.

Past Presidents:
1983-1985: William C. Moldenhauer, USA
1986-1988: Norman W. Hudson, UK
1989-1991: Rattan Lal, USA
1992-1997: Hans Hurni, Switzerland
1997-2001: David W. Sanders, UK

WASWC Secretariat

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Assistants: Tu Xiaoning, Xu Tao, Chen Xuechun

WASWC Publications
– published in association with other institutions –

1988

- Conservation Farming on Steep Lands. Edited by W.C. Moldenhauer and N.W. Hudson, ISBN 0935734198

1989

- Land Husbandry – A Framework for Soil and Water Conservation. by T.F. Shaxson, N.W. Hudson, D.W. Sanders, E. Roose and W.C. Moldenhauer, ISBN 0935734201

1990

- Soil Erosion on Agricultural Land. Edited by J. Boardman, I.D.L. Foster and J.A. Dearing, ISBN 0471906027 (From a meeting co-sponsored by WASWC)

1991

- Development of Conservation Farming on Hillslopes. Edited by W.C. Moldenhauer, N.W. Hudson, T.C. Sheng and San-Wei Lee, ISBN 0935734244
- Soil Management for Sustainability. Edited by R. Lal and F.J. Pierce, ISBN 0935734236

1992

- Conservation Policies for Sustainable Hillslope Farming. Edited by S. Arsyad, I. Amien, Ted Sheng and W.C. Moldenhauer, ISBN 0935734287
- Soil Conservation for Survival. Edited by K. Tato and H. Hurni, ISBN 0935734279
- Erosion, Conservation and Small-Scale Farming, Edited by H. Hurni and K. Tato, ISBN 3906290700
- Environmental Regeneration in Headwaters. Edited by J. Krecek and M.J. Haigh

1993

- Working with Farmers for Better Land Husbandry. Edited by N. Hudson and R.J. Cheatle, ISBN 1853391220

1995

- Adopting Conservation on the Farm: An International Perspective on the Socioeconomics of SWC. Edited by T.L. Napier, S.M. Camboni and S.A. El-Swaify, ISBN 0935734317

1996

- Hydrological Problems and Environmental Management in Highlands and Headwaters. Edited by J. Křeček, G.S. Rajwar and M.J. Haigh, ISBN 8120410483

1997

- Soil Conservation Extension: From Concepts to Adoption. Edited by S. Sombatpanit, M. Zöbisch, D. Sanders and M.G. Cook, ISBN 8120411897

1999

- Multiple Objective Decision Making for Land, Water and Environmental Management. Edited by S.A. El-Swaify and D.S. Yakowitz, ISBN 1-57444-091-8
- Incentives in Soil Conservation: From Theory to Practice. Edited by D.W. Sanders, P. Huszar, S. Sombatpanit and T. Enters, ISBN 1-57808-061-4

2000

- Reclaimed Land: Erosion Control, Soils and Ecology. Edited by M.J. Haigh, ISBN 90 5410 793 6

2001

- Response to Land Degradation. Edited by E.M. Bridges, I.D. Hannam, L.R. Oldeman, F. Penning de Vries, S.J. Scherr and S. Sombatpanit, ISBN 812041942

Forthcoming

2003

- Asia-Pacific Ground and Water Bioengineering for Erosion Control & Slope Stabilization

2004

- Living Land: Productive Conservation in the Tropics
- Monitoring and Evaluation of Soil Conservation and Watershed Development Projects