818

Second Edition

SOIL EROSION RESEARCH METHODS

R. Lal, Editor
Associate Professor
Department of Agronomy
Ohio State University
Columbus

SOIL AND WATER CONSERVATION SOCIETY

S^{t}L

Renard

Copyright © 1994 by the Soil and Water Conservation Society and St. Lucie Press

All rights reserved. No part of this publication may be reproduced, stored in a retrieval system or transmitted in any form or by any means, electronic, mechanical, photocopying, recording or otherwise, without the prior written permission of the publisher.

Printed and bound in the U.S.A. Printed on acid-free paper.

Library of Congress Cataloging-in-Publication Data

Soil Erosion Research Methods / edited by Rattan Lal.—2nd ed.
p. cm.
Includes bibliographical references
ISBN 1-884015-09-3 : $39.95
1. Soil erosion—Research—Methodology. 2. Soil conservation—Research—Methodology. I. Lal, R.
S626.S65 1994 93-45352
631.4'5'072—dc20 CIP

All rights reserved. Authorization to photocopy items for internal or personal use, or the personal or internal use of specific clients, is granted by St. Lucie Press, provided that $.50 per page photocopied is paid directly to Copyright Clearance Center, 27 Congress Street, Salem, MA, 01970 USA. The fee code for users of the Transactional Reporting Service is ISBN 1-884015-09-3 3/94/$100/$.50. The fee is subject to change without notice. For organizations that have been granted a photocopy license by the CCC, a separate system of payment has been arranged.

The copyright owner's consent does not extend to copying for general distribution, for promotion, for creating new works, or for resale. Specific permission must be obtained from St. Lucie Press for such copying.

Direct all inquiries to St. Lucie Press, Inc., 100 E. Linton Blvd., Suite 403B, Delray Beach, Florida 33483.
Phone: (407) 274-9906/Fax: (407) 274-9927

St. Lucie Press
100 E. Linton Blvd., Suite 403B
Delray Beach, FL 33483

Soil and Water Conservation Society
7515 Northeast Ankeny Road
Ankeny, IA 50021

CON

D. V. Armbrust
Soil Scientist, Wind Erosion Resc
Unit, Agricultural Research Servi
U.S. Department of Agriculture,
Manhattan, Kansas

A. A. Durar
Research Assistant, Department c
Agronomy, Kansas State Univers
Manhattan, Kansas

W. Elliot
Project Leader, Intermountain Re:
Station, USDA, Forest Service, I

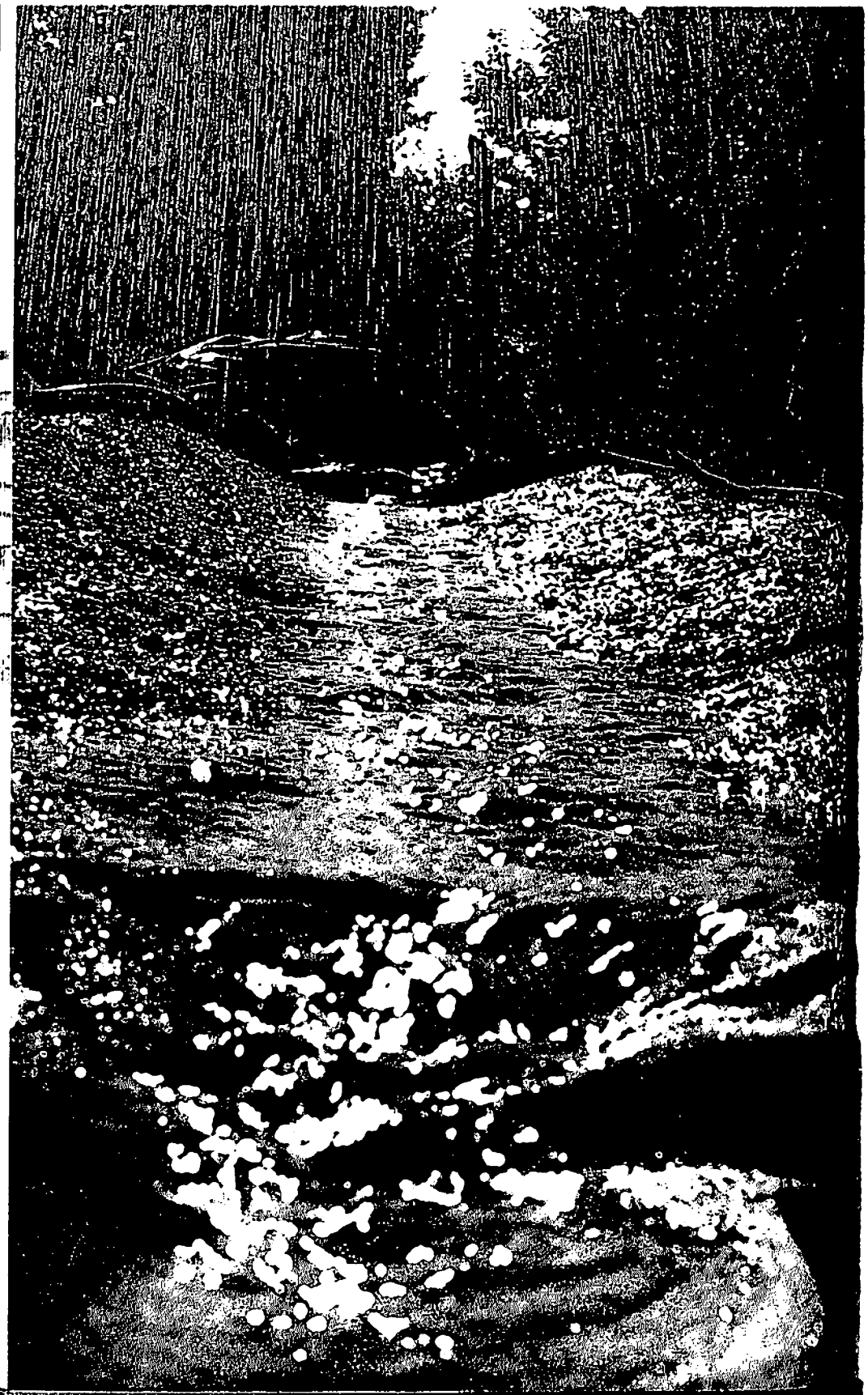
G. R. Foster
Director, National Sedimentation
Laboratory, Agricultural Researc
vice, U.S. Department of Agricul
Oxford, Mississippi

D. W. Fryrear
Research Leader, Conservation
Systems Research Laboratory,
Agricultural Research Service, U
Department of Agriculture, Big
Spring, Texas

L. J. Hagen
Agricultural Engineer, Wind Ero
Research Unit, Agricultural Resc
Service, U.S. Department of Agr
ture, Manhattan, Kansas

J. M. Laflen
Research Leader, National Soil I
sion Research Laboratory, Agric
Research Service, U.S. Departm
Agriculture, West Lafayette, Ind

R. Lal
Associate Professor, Department
Agronomy, Ohio State Universit
Columbus



Chapter 5

The REVISED UNIVERSAL SOIL LOSS EQUATION

K. G. Renard, J. M. Laflen,
G. R. Foster, and D. K. McCool

The Universal Soil Loss Equation (USLE) (*6*), has been the workhorse of erosion prediction and conservation planning technology in the U.S. and even worldwide. In 1985, at a meeting of U.S. Department of Agriculture (USDA) and other erosion researchers, it was decided that the USLE should be revised to incorporate additional research and technology developed after the 1978 USLE handbook. Work on the revision was initiated seriously late in 1987, and resulted in a new handbook and technology called RUSLE, the Revised USLE.

RUSLE maintains the basic structure of the USLE, namely

$$A = R\,K\,L\,S\,C\,P \qquad [1]$$

where A is the computed soil loss, R is the rainfall-runoff erosivity factor, K is the soil erodibility factor, L is the slope length factor, S is the slope steepness factor, C is the cover-management factor, and P is the supporting practices factor. This empirically-based equation, derived from a large mass of field data, computes sheet and rill erosion using values representing the four major factors affecting erosion. These factors are climate erosivity represented by R, soil erodibility represented by K, topography represented by LS, and land use and management represented by CP.

Whereas the basic USLE structure has been retained, the algorithms used to calculate the individual factors have been changed significantly in RUSLE. Perhaps most important has been the computerization of the technology to assist with individual factor determinations.

R-FACTOR

The rainfall-runoff erosivity term in RUSLE is calculated as the product of storm kinetic energy times the maximum 30-minute storm depth and summed for all storms in a year. The R-factor represents the input that drives the sheet and rill erosion processes. Thus differences in R values represent differences in erosivity of the climate. Of the RUSLE factors, R is the one most exactly computed from input data.

In the western U.S. (Figures 5.1, 5.2, and 5.3), new R values have been calculated using over 1000 point values, a significant addition to the information available in *Agriculture Handbook 537* (*6*). Whereas the old R isoerodent maps for the west had maximum point values of about 50 units (hundreds of foot · tonforce · inch/acre · hour · year), new values are as large as 350 units along the Pacific coastal areas (Figure 5.3). Some changes are also involved in the eastern states (east of the 105th meridian) (Figure 5.4). Another change in the R-factor is to reduce R values where flat slopes occur in regions of long intense rainstorms. Ponded water on the soil reduces the erosivity of the rain. Finally, an R equivalent approach is being used in the frozen soil areas of the Pacific Northwest to reflect the combined effect of rain or snowmelt on frozen or partly-thawed soil.

Part of the R-factor calculation involves a seasonal distribution to permit weighting of the soil erodibility value, K, and the cover-management factor, C. To facilitate these calculations, climate data files have been developed (called a city code) for climatically homogeneous areas. These computer files include information such as the frost-free duration in days, monthly precipitation and temperature, and 15-day distributions of R. Typical values are included in the computer program for at least one station in each of 120 climatic regions (Figure 5.5) of the contiguous 48 states plus numerous stations in Hawaii. The computer program includes a provision for addition of new climate data sets using data provided by the user. This also allows easy use of RUSLE in other regions of the world.

K-FACTOR

The K-factor is a measure of the inherent erodibility of a given soil under the standard condition of the unit USLE plot maintained in continuous fallow. Values for K typically range from about 0.10 to 0.45 (U.S. customary units), with high-sand and high-clay content soils having the lower values and high-silt content soils having the higher values. Users have little difficulty choosing a K-factor value because the Soil Conservation Service (SCS) has identified K values for all major soil mapping units

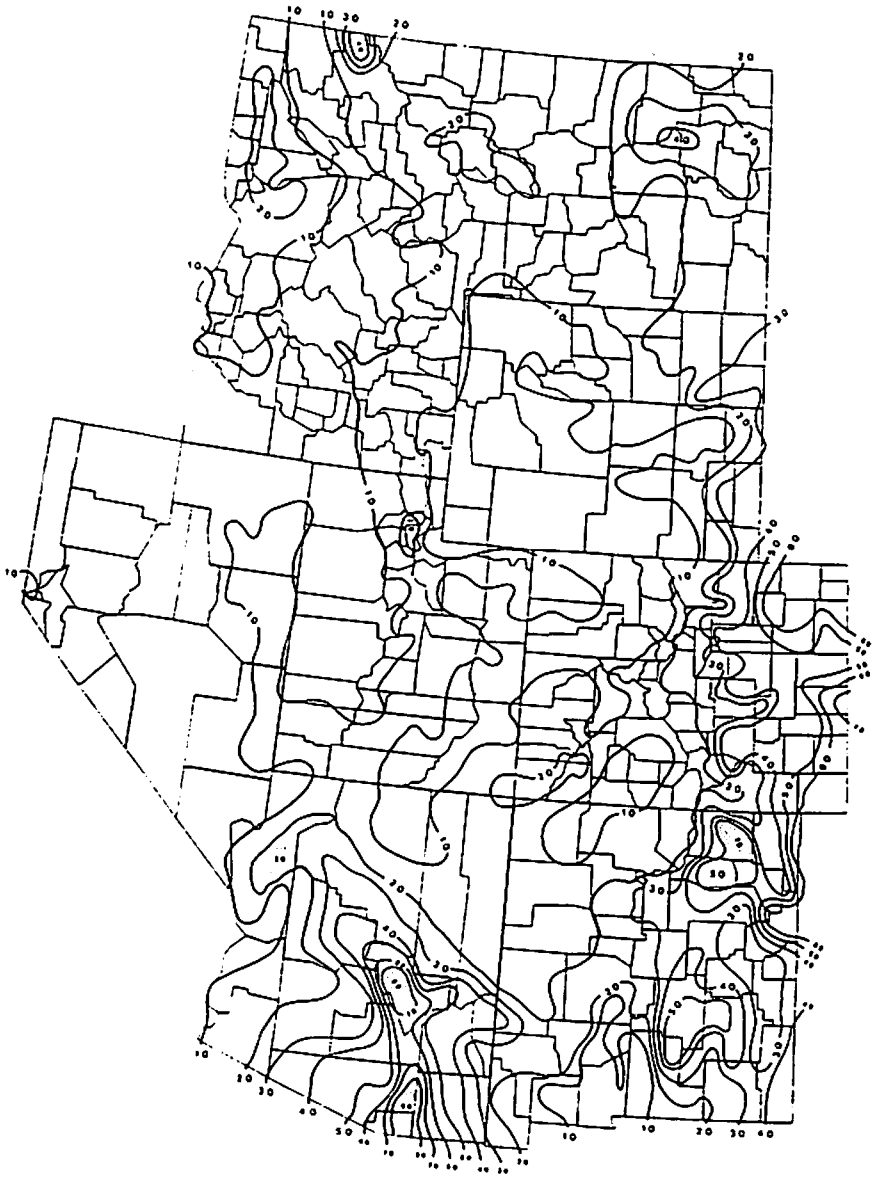


Figure 5.1 Western U.S. isoerodent map.

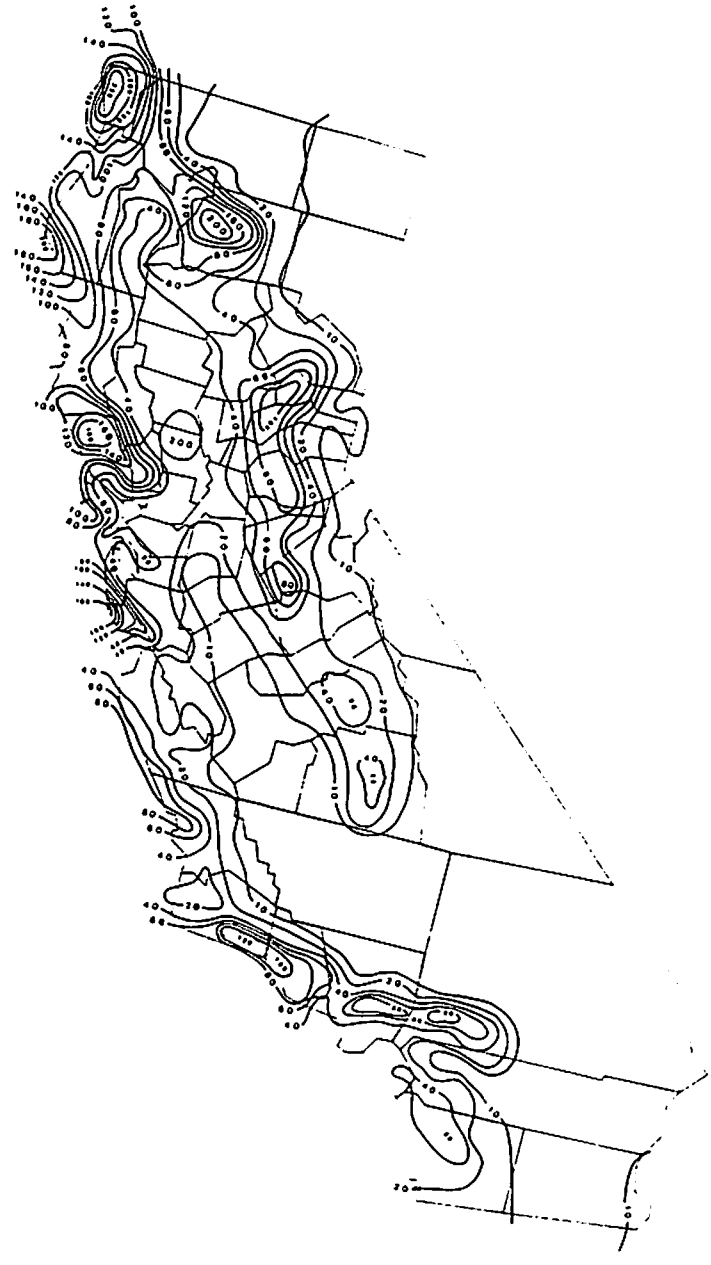


Figure 5.2 California isoerodent map.

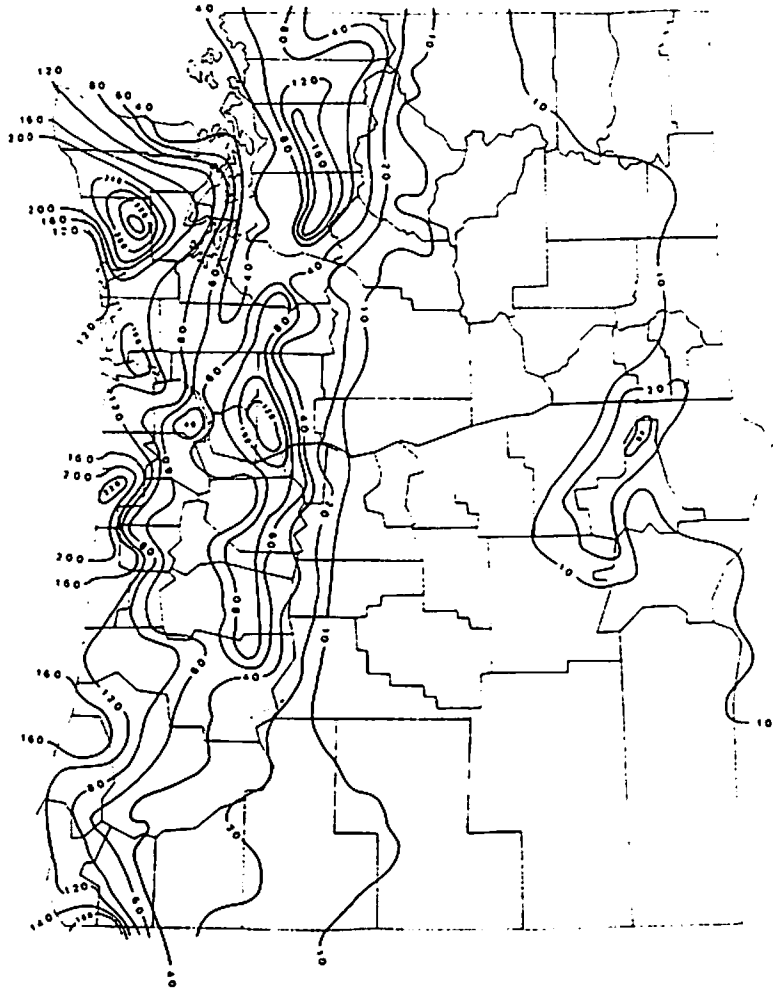


Figure 5.3 Isoerodent map of Oregon and Washington.

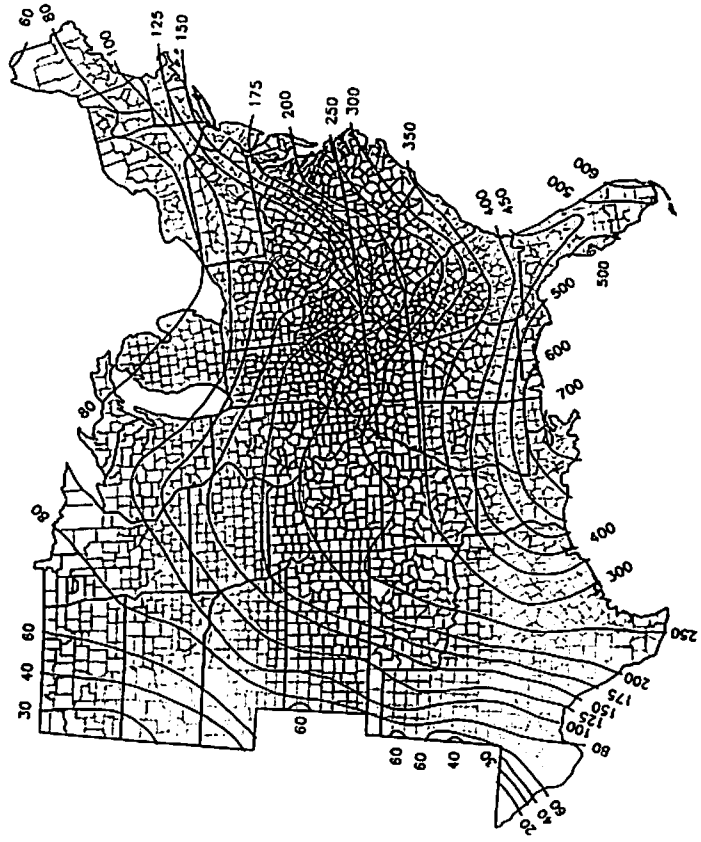


Figure 5.4 Isoerodent map of eastern United States.

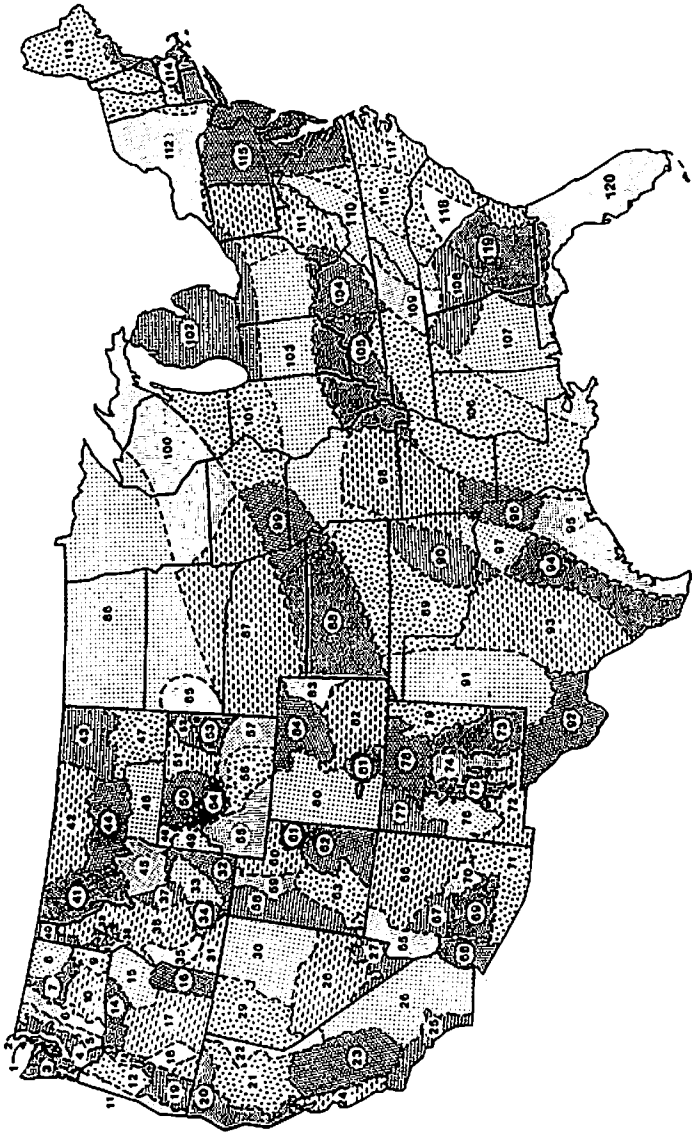


Figure 5.5 EI distribution zones for the counterminious U.S.

in the United States. However, the site-specific K value, and its seasonal variation, can be quite different from the K value given in soil survey information.

The soil erodibility nomograph is a popular tool for estimating K values, but it does not apply to some soils. Updating the K-factor for RUSLE involved developing guides so the user could identify soils where the nomograph does not apply and estimate K using alternative methods. Erodibility data from around the world have been reviewed, and an equation has been developed that gives an estimate of K as a function of an "average" diameter of the soil particles. K-values for volcanic soils of Hawaii are also estimated with an alternative algorithm to the erodibility nomograph.

RUSLE also varies K seasonally, a major change over the USLE procedure. Experimental data show that K is not constant but varies with season, being highest in early spring and lowest in mid-fall or when the soil is frozen. The seasonal variability is addressed by weighing the instantaneous estimate of K in proportion to EI (the percent of annual R) for twice monthly intervals. Instantaneous estimates of K are made from equations relating K to the frost-free period and the annual R-factor.

An additional change incorporated in RUSLE is to account for rock fragments on and in the soil, a common occurrence on western rangelands. Rock fragments on the soil surface are treated like mulch in the C-factor, while K is adjusted for rock in the soil profile to account for effects on runoff.

An example output from the computer program which weights the instantaneous K values in proportion to the distribution of twice monthly EI values is given in Table 5.1. For this illustration, the nomograph K was given as 0.28 (customary U.S. units) and the average weighted K was 0.25. The maximum K was estimated to be 0.707 with a minimum of 0.104. Note that the corresponding observed K values were somewhat lower. In other instances the difference between the nomograph and weighed K go in the opposite directions from this example. K_{max} and K_{min} are determined with regression equations relating K_i to the annual R factor and the frost free period.

L- AND S-FACTOR

More questions and concerns are expressed over the L-factor than any of the other USLE factors. One reason is that the choice of a slope length involves judgment; different users choose different slope lengths for similar situations. RUSLE includes improved guides for choosing slope length values to give greater consistency among users.

Table 5.1 Measured and calculated monthly K values for a Barnes loam soil near Morris, Minnesota ($R=100$, $K_{nom}=0.28$).

Date	% of annual EI	t_i	T_{av}(°F)	K_i^*(cal)	$\%(EI_i)K_i$	K_i^*(obs.)
01/01-03/15	0	37	15	0.104	0	0
03/16-03/31	1	82	31	0.612	0.612	
04/01-04/15	1	98	40	0.707	0.707	0.404
04/16-04/30	1	113	40	0.672	0.672	
05/01-05/15	3	128	57	0.548	1.644	0.393
05/16-05/31	5	143	57	0.447	2.235	
06/01-06/15	12	159	66	0.360	4.317	0.229
06/16-06/30	13	174	66	0.293	3.814	
07/01-07/15	13	189	72	0.239	3.11	0.328
07/16-07/31	14	204	72	0.195	2.733	
08/01-08/15	14	220	71	0.157	2.199	0.205
08/16-08/31	13	235	71	0.128	1.665	
09/01-09/15	5	251	60	0.105	0.525	0.042
09/16-09/30	3	266	60	0.120	0.360	
10/01-10/15	1	281	50	0.137	0.137	0.065
10/16-10/31	1	296	50	0.157	0.157	
11/01-11/15	0	312	34	0.182	0	0
11/16-12/31	0	342	20	0.104	0	
Total	**100**				**24.888**	

$K_{av} = \Sigma(EI_i)K_i/100=0.25$

$t_{max} = 110$ $t_{min} = 250$

$K_{max}/K_{nom} = 2.5$ $K_{max} = 0.700$

$K_{max}/K_{min} = 6.7$ $K_{min} = 0.104$

*K_i values are given in tons/acre per erosion index unit. For SI-units of t·ha·h/ha·MJ·mm, mulitply K_i values by 0.1317.

t_i = Julian day for date interval used in calculation (interval midpoint)

K_i = soil erodibility for day t_i

K_{nom} = nomograph soil erodibility

The attention given to the L-factor is not always warranted because soil loss is less sensitive to slope length than to any other USLE factor. For typical slope conditions, a 10 percent error in slope length measurement results in a 5 percent error in computed soil loss.

RUSLE uses four separate slope length relationships (Tables 5.2, 5.3, 5.4, and 5.5). Three are functions of slope steepness as in the USLE, and

Table 5.2 Values for topographic factor, LS, for low ratio of rill to interrill erosion, such as for rangeland and other consolidated soil conditions with cover (applicable to thawing soil where both interrill and rill erosion are significant).

	Slope length in feet																
Slope	<3	6	9	12	15	25	50	75	100	150	200	250	300	400	600	800	1000
%																	
0.2	0.05	0.05	.0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
0.5	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09
1.0	0.12	0.12	0.12	0.12	0.12	0.13	0.13	0.14	0.14	0.15	0.15	0.15	0.15	0.16	0.16	0.17	0.17
2.0	0.20	0.20	0.20	0.20	0.20	0.21	0.23	0.25	0.26	0.27	0.28	0.29	0.30	0.31	0.33	0.34	0.35
3.0	0.26	0.26	0.26	0.26	0.26	0.29	0.33	0.36	0.38	0.40	0.43	0.44	0.46	0.48	0.52	0.55	0.57
4.0	0.33	0.33	0.33	0.33	0.33	0.36	0.43	0.46	0.50	0.54	0.58	0.61	0.63	0.67	0.74	0.78	0.82
5.0	0.38	0.38	0.38	0.38	0.38	0.44	0.52	0.57	0.62	0.68	0.73	0.78	0.81	0.87	0.97	1.04	1.10
6.0	0.44	0.44	0.44	0.44	0.44	0.50	0.61	0.68	0.74	0.83	0.90	0.95	1.00	1.08	1.21	1.31	1.40
8.0	0.54	0.54	0.54	0.54	0.54	0.64	0.79	0.90	0.99	1.12	1.23	1.32	1.40	1.53	1.74	1.91	2.05
10.0	0.60	0.63	0.65	0.66	0.68	0.81	1.03	1.19	1.31	1.51	1.67	1.80	1.92	2.13	2.45	2.71	2.93
12.0	0.61	0.70	0.75	0.80	0.83	1.01	1.31	1.52	1.69	1.97	2.20	2.39	2.56	2.85	3.32	3.70	4.02
14.0	0.63	0.76	0.85	0.92	0.98	1.20	1.58	1.85	2.08	2.44	2.73	2.99	3.21	3.60	4.23	4.74	5.18
16.0	0.65	0.82	0.94	1.04	1.12	1.38	1.85	2.18	2.46	2.91	3.28	3.60	3.88	4.37	5.17	5.82	6.39
20.0	0.68	0.93	1.11	1.26	1.39	1.74	2.37	2.84	3.22	3.85	4.38	4.83	5.24	5.95	7.13	8.10	8.94
25.0	0.73	1.05	1.30	1.51	1.70	2.17	3.00	3.63	4.16	5.03	5.76	6.39	6.96	7.97	9.65	11.04	12.26
30.0	0.77	1.16	1.48	1.75	2.00	2.57	3.60	4.40	5.06	6.18	7.11	7.94	8.68	9.99	12.19	14.04	15.66
40.0	0.85	1.36	1.79	2.17	2.53	3.30	4.73	5.84	6.78	8.37	9.71	10.91	11.99	13.92	17.19	19.96	22.41
50.0	0.91	1.52	2.06	2.54	3.00	3.95	5.74	7.14	8.33	10.37	12.11	13.65	15.06	17.59	21.88	25.55	28.82
60.0	0.97	1.67	2.29	2.86	3.41	4.52	6.63	8.29	9.72	12.16	14.26	16.13	17.84	20.92	26.17	30.68	34.71

Table 5.3 Values for topographic factor, LS, for moderate ratio of rill to interrill erosion, such as for row-cropped agricultural and other moderately consolidated soil conditions with little to moderate cover (not applicable to thawing soil).

	Slope length in feet																
Slope	<3	6	9	12	15	25	50	75	100	150	200	250	300	400	600	800	1000
%																	
0.2	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.06	0.06	0.06
0.5	0.07	0.07	0.07	0.07	0.07	0.08	0.08	0.08	0.09	0.09	0.09	0.09	0.09	0.10	0.10	0.10	0.10
1.0	0.11	0.11	0.11	0.11	0.11	0.12	0.13	0.14	0.14	0.15	0.16	0.17	0.17	0.18	0.19	0.20	0.20
2.0	0.17	0.17	0.17	0.17	0.17	0.19	0.22	0.25	0.27	0.29	0.31	0.33	0.35	0.37	0.41	0.44	0.47
3.0	0.22	0.22	0.22	0.22	0.22	0.25	0.32	0.36	0.39	0.44	0.48	0.52	0.55	0.60	0.68	0.75	0.80
4.0	0.26	0.26	0.26	0.26	0.26	0.31	0.40	0.47	0.52	0.60	0.67	0.72	0.77	0.86	0.99	1.10	1.19
5.0	0.30	0.30	0.30	0.30	0.30	0.37	0.49	0.58	0.65	0.76	0.85	0.93	1.01	1.13	1.33	1.49	1.63
6.0	0.34	0.34	0.34	0.34	0.34	0.43	0.58	0.69	0.78	0.93	1.05	1.16	1.25	1.42	1.69	1.91	2.11
8.0	0.42	0.42	0.42	0.42	0.42	0.53	0.74	0.91	1.04	1.26	1.45	1.62	1.77	2.03	2.47	2.83	3.15
10.0	0.46	0.48	0.50	0.51	0.52	0.67	0.97	1.19	1.38	1.71	1.98	2.22	2.44	2.84	3.50	4.06	4.56
12.0	0.47	0.53	0.58	0.61	0.64	0.84	1.23	1.53	1.79	2.23	2.61	2.95	3.26	3.81	4.75	5.56	6.28
14.0	0.48	0.58	0.65	0.70	0.75	1.00	1.48	1.86	2.19	2.76	3.25	3.69	4.09	4.82	6.07	7.15	8.11
16.0	0.49	0.63	0.72	0.79	0.85	1.15	1.73	2.20	2.60	3.30	3.90	4.45	4.95	5.86	7.43	8.79	10.02
20.0	0.52	0.71	0.85	0.96	1.06	1.45	2.22	2.85	3.40	4.36	5.21	5.97	6.68	7.97	10.23	12.20	13.99
25.0	0.56	0.80	1.00	1.16	1.30	1.81	2.82	3.65	4.39	5.69	6.83	7.88	8.86	10.65	13.80	16.58	19.13
30.0	0.59	0.89	1.13	1.34	1.53	2.15	3.39	4.42	5.34	6.98	8.43	9.76	11.01	13.30	17.37	20.99	24.31
40.0	0.65	1.05	1.38	1.68	1.95	2.77	4.45	5.87	7.14	9.43	11.47	13.37	15.14	18.43	24.32	29.60	34.48
50.0	0.71	1.18	1.59	1.97	2.32	3.32	5.40	7.17	8.78	11.66	14.26	16.67	18.94	23.17	30.78	37.65	44.02
60.0	0.76	1.30	1.78	2.23	2.65	3.81	6.24	8.33	10.23	13.65	16.76	19.64	22.36	27.45	36.63	44.96	52.70

Table 5.4 Values for topographic factor, LS, for high ratio of rill to interrill erosion, such as for freshly prepared construction and other highly disturbed soil conditions with little or no cover (not applicable to thawing soil).

	Slope length in feet																
Slope	<3	6	9	12	15	25	50	75	100	150	200	250	300	400	600	800	1000
%																	
0.2	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.06	0.06	0.06	0.06	0.06	0.06	0.06
0.5	0.07	0.07	0.07	0.07	0.07	0.07	0.08	0.08	0.09	0.09	0.10	0.10	0.10	0.11	0.12	0.12	0.13
1.0	0.09	0.09	0.09	0.09	0.09	0.10	0.13	0.14	0.15	0.17	0.18	0.19	0.20	0.22	0.24	0.26	0.27
2.0	0.13	0.13	0.13	0.13	0.13	0.16	0.21	0.25	0.28	0.33	0.37	0.40	0.43	0.48	0.56	0.63	0.69
3.0	0.17	0.17	0.17	0.17	0.17	0.21	0.30	0.36	0.41	0.50	0.57	0.64	0.69	0.80	0.96	1.10	1.23
4.0	0.20	0.20	0.20	0.20	0.20	0.26	0.38	0.47	0.55	0.68	0.79	0.89	0.98	1.14	1.42	1.65	1.86
5.0	0.23	0.23	0.23	0.23	0.23	0.31	0.46	0.58	0.68	0.86	1.02	1.16	1.28	1.51	1.91	2.25	2.55
6.0	0.26	0.26	0.26	0.26	0.26	0.36	0.54	0.69	0.82	1.05	1.25	1.43	1.60	1.90	2.43	2.89	3.30
8.0	0.32	0.32	0.32	0.32	0.32	0.45	0.70	0.91	1.10	1.43	1.72	1.99	2.24	2.70	3.52	4.24	4.91
10.0	0.35	0.37	0.38	0.39	0.40	0.57	0.91	1.20	1.46	1.92	2.34	2.72	3.09	3.75	4.95	6.03	7.02
12.0	0.36	0.41	0.45	0.47	0.49	0.71	1.15	1.54	1.88	2.51	3.07	3.60	4.09	5.01	6.67	8.17	9.57
14.0	0.38	0.45	0.51	0.55	0.58	0.85	1.40	1.87	2.31	3.09	3.81	4.48	5.11	6.30	8.45	10.40	12.23
16.0	0.39	0.49	0.56	0.62	0.67	0.98	1.64	2.21	2.73	3.68	4.56	5.37	6.15	7.60	10.26	12.69	14.96
20.0	0.41	0.56	0.67	0.76	0.84	1.24	2.10	2.86	3.57	4.85	6.04	7.16	8.23	10.24	13.94	17.35	20.57
25.0	0.45	0.64	0.80	0.93	1.04	1.56	2.67	3.67	4.59	6.30	7.88	9.38	10.81	13.53	18.57	23.24	27.66
30.0	0.48	0.72	0.91	1.08	1.24	1.86	3.22	4.44	5.58	7.70	9.67	11.55	13.35	16.77	23.14	29.07	34.71
40.0	0.53	0.85	1.13	1.37	1.59	2.41	4.24	5.89	7.44	10.35	13.07	15.67	18.17	22.95	31.89	40.29	48.29
50.0	0.58	0.97	1.31	1.62	1.91	2.91	5.16	7.20	9.13	12.75	16.16	19.42	22.57	28.60	39.95	50.63	60.84
60.0	0.63	1.07	1.47	1.84	2.19	3.36	5.97	8.37	10.63	14.89	18.92	22.78	26.51	33.67	47.18	59.93	72.15

Table 5.5 Values for topographic factor, LS, for thawing soils where most of the erosion is caused by surface flow.

	Slope length in feet												
Slope	15	25	50	75	100	150	200	250	300	400	600	800	1000
%													
0.2	0.02	0.03	0.04	0.05	0.06	0.07	0.09	0.10	0.10	0.12	0.15	0.17	0.19
0.5	0.04	0.05	0.07	0.09	0.10	0.12	0.14	0.16	0.17	0.20	0.24	0.28	0.31
1.0	0.06	0.08	0.11	0.14	0.16	0.20	0.23	0.26	0.28	0.32	0.40	0.46	0.51
2.0	0.11	0.14	0.20	0.25	0.29	0.35	0.41	0.46	0.50	0.58	0.71	0.82	0.91
3.0	0.16	0.21	0.29	0.36	0.42	0.51	0.59	0.66	0.72	0.83	1.02	1.17	1.31
4.0	0.21	0.27	0.38	0.47	0.54	0.66	0.77	0.86	0.94	1.08	1.33	1.53	1.71
5.0	0.26	0.33	0.47	0.58	0.67	0.82	0.94	1.06	1.16	1.34	1.64	1.89	2.11
6.0	0.31	0.40	0.56	0.69	0.79	0.97	1.12	1.26	1.38	1.59	1.95	2.25	2.51
8.0	0.41	0.52	0.74	0.91	1.05	1.28	1.48	1.65	1.81	2.09	2.56	2.96	3.31
10.0	0.48	0.62	0.88	1.08	1.25	1.53	1.77	1.98	2.16	2.50	3.06	3.54	3.95
12.0	0.54	0.70	0.98	1.21	1.39	1.71	1.97	2.20	2.41	2.78	3.41	3.94	4.40
14.0	0.59	0.76	1.08	1.32	1.53	1.87	2.16	2.41	2.64	3.05	3.74	4.31	4.82
16.0	0.64	0.82	1.17	1.43	1.65	2.02	2.33	2.61	2.86	3.30	4.04	4.67	5.22
20.0	0.73	0.94	1.33	1.63	1.88	2.30	2.66	2.97	3.25	3.76	4.60	5.31	5.94
25.0	0.83	1.07	1.51	1.85	2.13	2.61	3.02	3.37	3.69	4.27	5.23	6.03	6.75
30.0	0.91	1.18	1.67	2.05	2.36	2.89	3.34	3.73	4.09	4.72	5.78	6.68	7.47
40.0	1.07	1.38	1.95	2.39	2.75	3.37	3.90	4.36	4.77	5.51	6.75	7.79	8.71
50.0	1.19	1.54	2.18	2.67	3.08	3.77	4.35	4.87	5.33	6.16	7.54	8.71	9.74
60.0	1.30	1.67	2.37	2.90	3.35	4.10	4.74	5.30	5.80	6.70	8.20	9.47	10.59

of the susceptibility of the soil to rill erosion relative to interrill erosion. A slope length relationship has been developed specifically for the frozen soil area of the Pacific Northwest of the U.S. (*3, 4*). A guide in the computer program and users manual helps identify the appropriate relationship for the particular field conditions.

Soil loss is much more sensitive to changes in slope steepness than to changes in slope length. In the USLE, a 10 percent error in slope steepness gives about a 20 percent error in computed soil loss. Thus, special attention should be given to obtaining good estimates of slope steepness. RUSLE has a more nearly linear slope steepness relationship than the USLE. Computed soil loss for slopes less than 20 percent are similar in USLE and RUSLE. However, on steep slopes, RUSLE computed soil loss is reduced up to about half that with USLE. Experimental data and field observations, especially on rangelands, do not support the USLE quadratic relationship when extended to steep slopes. RUSLE also provides a slope steepness relationship for short slopes subject primarily to interrill erosion and a steepness relationship for the frozen soil area of the Pacific Northwest.

In most practical applications, a slope segment previously estimated as a single plane or uniform slope can be a poor representation of the topography. In RUSLE and its computer program, complex slopes can be readily represented to provide a better approximation of the topographic effect. For example, a 300-ft slope having three equal segments at 5 percent, 15 percent, and 10 percent slope has an LS value of 2.9 for a moderate rill to interrill ratio. The same slope described as 300 feet at 10 percent has a LS values of 2.44 or a 20 percent decrease.

C-FACTOR

The C-factor is perhaps the most important USLE/RUSLE factor because it represents conditions that can most easily be managed to reduce erosion. Values for C can vary from near zero for a very well protected soil to 1.5 for a finely tilled, ridged surface that produces much runoff and leaves the soil highly susceptible to rill erosion.

Values for C are a weighted average of soil loss ratios that represent the soil loss for a given condition at a given time, to that of the unit plot (a unit plot is one maintained in clean-tilled fallow). Thus, soil loss ratios vary during the year as soil and cover conditions change. To compute C, soil loss ratios (SLR) are weighted according to the distribution of erosivity during a year (i.e., from the information in the city code and climate data). In RUSLE, a subfactor method is used to compute SLRs as a function of four subfactors (2) given as

$$C = PLU \cdot CC \cdot SC \cdot SR \qquad [2]$$

where PLU is prior land use, CC is crop canopy, SC is surface or ground cover (including erosion pavement) and SR is the surface roughness. In the Pacific Northwest area where fallow is used to replenish soil moisture, an additional term is included reflecting the moisture status of the profile.

For cropland, CC and SC and the associated below-ground biomass are calculated from a crop and operation file. A residue decomposition calculation (*1*) is used to make estimates of the amount of residue cover on the soil surface and buried residue in the soil profile. The crop and operation file gives the amount of below ground living biomass, canopy cover, and canopy fall height by 15-day periods (see Figures 5.6 and 5.7). On rangeland, the user inputs ground cover, canopy cover; below-ground biomass is then estimated from above-ground biomass using ratios that are specific to different ecological zones (*5*). Surface roughness values are also specified by the user from a list of typical values for different rangeland cover conditions.

Ground (surface) cover is the term of the subfactors having the greatest effect on erosion. The inclusion of erosion pavements results in large changes in the value of the subfactor. Figure 5.8 illustrates the sensitivity of the elements considered in the subfactors on the final C-factor.

Grazed effects on rangelands, pasture, and meadows are reflected in the grazing-induced changes in canopy height, surface cover, and root biomass. Finally, surface cover, as used in the USLE, reflected vegetation and litter; in RUSLE, surface cover is given as 1.0 minus the amount of bare soil which reflects the addition of litter in the form of rock and stone to the conventional vegetative litter.

In *Agriculture Handbook 537*, SLRs were given in several tables for differing crops and crop growth periods. In many instances, the SLRs were developed for row spacing, crop varieties, and practices no longer used and in other instances, the SLRs were just not available. In the RUSLE approach, with a farming operation (Figure 5.6) and crop file (Figure 5.7) for which some fundamental data are available, SLRs can be calculated and weighted at 15-day intervals to obtain a crop or annual cover-management factor. Thus it is possible with the computer program to assemble SLRs for most agronomic crops used in modern agriculture.

P-FACTOR

Of the USLE/RUSLE factors, values for the P-factor are the least reliable. The P-factor mainly represents how surface conditions affect flow paths and flow hydraulics. For example, with contouring, runoff flows

Field operation: moldboard (5-7 inches)

Effect #1: 2—% dist.: 100 roughness: 1.3 % left: 30 depth: 6
Effect #2: 8
Effect #3: 1
Effect #4: 1
Effect #5: 1

enter effects in the order in which they occur

Operation effect list:

1. no effect
2. the soil surface is disturbed
3. crop residue is added to the surface
4. other residue is added to the surface
5. crop residue is removed from the field
6. the crop is harvested
7. the crop is planted
8. the crop is killed
9. call in a new crop growth file

Figure 5.6 Field operation example for a moldboard plow.

crop name: corn: _____ category: 1
weight per harvest unit: 56 residue-to-yield ratio: 1
carbon: nitrogen ration: 100 stem constant u/R: 0.00120
residue at 30% cover (#/A): 1250 harvest units: bushels

Days After Planting	*Root Mass (pounds/acre/inches)*	*Canopy Cover (%)*	*Fall Height (feet)*
15	0	0	0
30	23	10	.5
45	45	50	1.2
60	68	80	2.5
75	136	100	5
90	136	100	6
105	136	100	6
120	136	100	6

Figure 5.7 Crop file for corn as might be grown in Indiana.

around the slope in channels formed by tillage. The grade and flow velocities could be much lower than in up-and-down hill flow paths. There are many interacting variables that determine the effect of contouring. Size of storm, antecedent soil water, and tillage type to name a few of these variables, interact in such a way that a contouring factor may vary widely from storm to storm and field to field; these interactions have made it

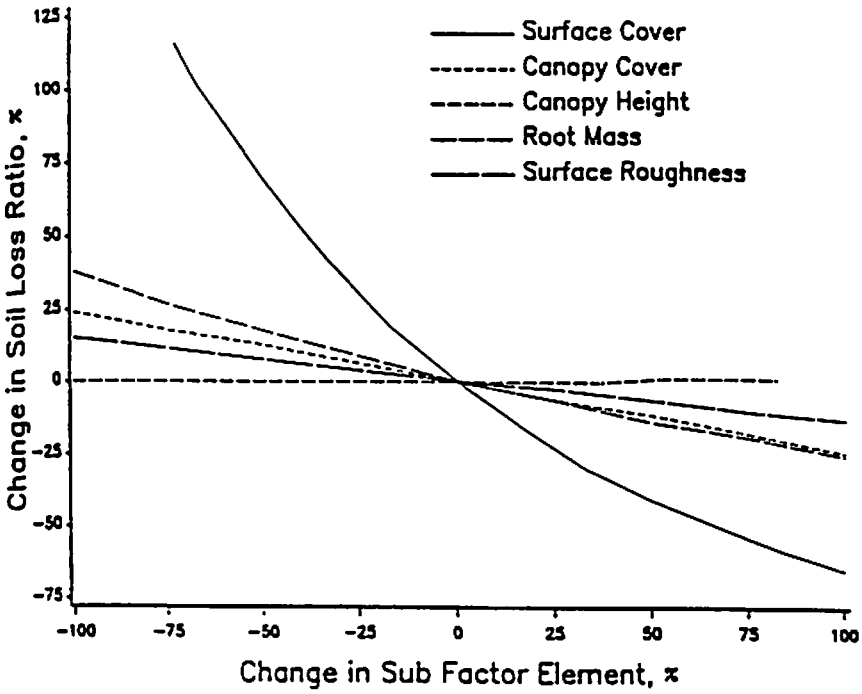


Figure 5.8 Sensitivity of soil loss ratio to subfactor elements.

difficult to document in the limited number of field studies dealing with contouring. Likewise, identifying these subtle characteristics in the field is difficult when applying RUSLE. Thus, P-factor values represent broad, general effects of such practices as contouring.

RUSLE P-factors are treated as the product of subfactors computed based on practices applied to the landscape. In RUSLE extensive data (both field and model) have been analyzed to reevaluate the effect of contouring. The results have been interpreted to give factor values for contouring as a function of ridge height, furrow grade, and climatic erosivity. New P-factor values for the effect of terracing account for grade along the terrace while a broader array of stripcropping conditions are considered in RUSLE than in USLE.

Finally, P-factors in RUSLE have been developed to reflect conservation practices on rangelands. The practices require estimates of surface roughness and runoff reduction.

COMPARISON OF RUSLE AND USLE

To illustrate some of the differences between RUSLE and USLE soil loss estimates, calculations were made for a continuous corn field with conventional tillage near Indianapolis, Indiana, and for a rangeland field near Tombstone, Arizona. Table 5.6 summarizes the comparison and illustrates differences in individual parameter values.

For these illustrations, the changes in R-values are relatively insignificant. K-factor changes using the time varying factor in RUSLE led to a smaller K value in Indianapolis and a larger value in Tombstone, a trend observed frequently in our experience to date. Breaking a 300-ft-long slope at 8 percent into three segments (top of slope to the bottom) of 100 ft at 6 percent, 150 ft at 10 percent and 50 ft at 6 percent (the same total elevation change) produced greatly different LS values.

On the Indianapolis location, the 1.72 LS value in the USLE increased to 1.94 in RUSLE, whereas the LS value for the RUSLE rangeland location decreased to 1.52, from 1.72, indicating the reduced rill to interrill erosion ratio on rangeland over that for cropland in addition to the slope segmenting.

The C-factor values in both instances were lower for the RUSLE estimates when compared to the values from *Agriculture Handbook 537*. In still other instances, the C-factor values have been observed higher from RUSLE than from the USLE.

The estimated soil loss for these two illustrations are both less with RUSLE than with USLE estimates from *Agriculture Handbook 537*. This should not be considered to be the case for all locations.

Of greatest significance is that C-factor values can be estimated with RUSLE for crops where SLRs were not available, i.e., there was no data in Table 5 and 10 of *Agriculture Handbook 537* to cover the particular crop and operation. Given that the user can obtain data for developing a crop file to cover the specific conditions encountered in his climatic conditions (data to describe at intervals after planting the root mass in the upper four in., canopy cover, fall height, carbon/nitrogen ratio, residue to yield ratio and characteristics of the residue stem), SLRs with which to calculate a C-factor can be made for any crop. Furthermore, new tillage implements can be added to the operations file to cover an infinite range of activities with which to simulate their effect on soil loss.

Table 5.6 Summary of RUSLE and USLE soil loss estimates for two locations.

	Location			
	Continuous corn/Indianapolis, IN		Rangeland/Tombstone, AZ	
Factor	RUSLE	USLE	RUSLE	USLE
R	180	175	65	70
*K	0.32	0.37	0.32	0.26
†LS	1.94	1.72	1.52	1.72
C	‡0.236	§0.252	††0.014	#0.038
P	1.0	1.0	1.0	1.0
A	26.4	28.1	0.44	1.19

*Used a Miami silt loam in Indianapolis and a Stronghold gravelly sandy loam in Tombstone.
†Used a 300 ft slope length at 8 percent in USLE and a three segment 100 ft at 6 percent, 150 ft at 10 percent, and 50 ft at 6 percent in RUSLE.
‡Used continuous corn with 8-in. deep moldboard plowing on 4/10, tandem disk on 4/15, row planter on 4/20, row cultivator on 5/15, and harvest on 10/13 with 120 bu/A yield.
§Used continuous corn with SLRs from line 1 of Table 5 in Agriculture Handbook 537.
††Used 0.8 roughness, 60 percent ground cover, 25 percent canopy cover, 4000 lb/A root biomass in the upper 4 in., and a canopy height of 1 ft.
#Used Table 10 of Agriculture Handbook 537 with grass, 25 percent cover, and 60 percent ground cover.

SUMMARY

RUSLE retains the basic structure of the USLE with soil loss estimated for a slope profile as the product of the terms reflecting the climatic erosivity represented by R, soil erodibility represented by K, topography represented by LS, and land use, and management and conservation support practices represented by CP. Incorporation of the technology in a computer program facilitates the calculations.

New climatic erosivity values have been calculated which reflect the variability of R in the mountainous conditions of the western U.S. Corrections have been introduced in high R-value areas with flat slopes. It is recognized that in these areas, ponded water on the soil reduces the erosivity of the rain.

The soil erodibility term K is varied seasonally being highest in spring and lowest in late fall synonymous with soil freezing. Although the K values are generally obtained from the erodibility nomograph, alternative methods are used for volcanic soils (such as dominate in Hawaii) and an alternative proposed for use as a function of average soil particle diameters.

The topographic factors L and S are evaluated using four separate slope length relationships. Three are a function of slope steepness and the susceptibility of the soil to rill erosion relative to interrill erosion. A specific slope length relationship has been developed for the frozen soil areas of the Pacific Northwest where rilling and freeze-thaw phenomenon dominate. In RUSLE, and its computer programs, complex slopes can be readily represented to provide a better approximation of the topographic effect.

Soil loss ratios are calculated with time dependent functions that address subfactors reflecting prior land use, crop canopy, surface or ground cover, and surface roughness. For time invariant conditions encountered on range and pasture land, the user inputs ground cover, canopy cover, and below-ground biomass. Grazing effects are reflected in the grazing induced changes in canopy height, surface cover, and root biomass.

The conservation practice value represents broad, general effects of such practices as contouring, strip cropping, subsurface drainage, and terracing. P-factors have also been developed to reflect conservation practices on rangeland and require the user to estimate surface roughness and runoff reductions.

REFERENCES

1. Gregory, J.M., T.R. McCarty, F. Ghidey, and E.E. Alberts. 1985. *Derivation and evaluation of a residue decay equation.* Transactions, American Society of Agricultural Engineers 28: 98-101, 105.
2. Laflen, J.M., G.R. Foster, and C.A. Onstad. 1985. *Simulation of individual-storm soil loss for modeling the impact of soil erosion on crop productivity.* In: S.A. El-Swaify, W.C. Moldenhauer, and A. Lo, (eds.) *Soil Erosion and Conservation.* Soil and Water Conservation Society, Ankeny, Iowa. pp. 285-295.
3. McCool, D.K., L.C. Brown, G.R. Foster, C.K. Mutchler, and L.D. Meyer. 1987. *Revised slope steepness factor for the universal soil loss equation.* Transactions, American Society of Agricultural Engineers 30: 1387-1396.
4. McCool, D.K., G.R. Foster, C.K. Mutchler, and L.D. Meyer. 1989. *Revised slope length factor for the universal soil loss equation.* Transactions, American Society of Agricultural Engineers 32(5): 1571-1576.
5. Weltz, M.A., K.G. Renard, and J.R. Simanton. 1987. *Revised universal soil loss equation for Western rangelands.* In: *U.S./Mexico Symposium on Strategies for Classification and Management of Native Vegetation for Food Production in Arid Zones*, U.S. Forest Service General Technical Report RM-150, pp. 104-111.
6. Wischmeier, W.H., and D.D. Smith. 1978. *Predicting rainfall erosion losses.* USDA Agriculture Handbook 537, U.S. Department of Agriculture.