Horizon Resource Management

A Comparison of Cover Sampling Methods

Presented by Richard Bonine at OSM Interactive Forum/
Approaching Bond Release

The Methods

1. Point-Intercept 50m
2. Continuous Cover 50m
3. Ten-Point Frame

The Concerns:

1. Transect Length - Sample Not Homogenous

The Concerns:

2. Observations not representative of population.

The Concerns:

3. Not all species present in the transect are observed.

The Concerns:

3. Not all species present in the transect are observed.

The Concerns:

4. Difficult to repeat

The Results

Perennial Ground Cover

Method	Mean	Median	Variance
Continuous Cover	62.5	65.4	6.2
Point Intercept	71.2	68.0	8.3

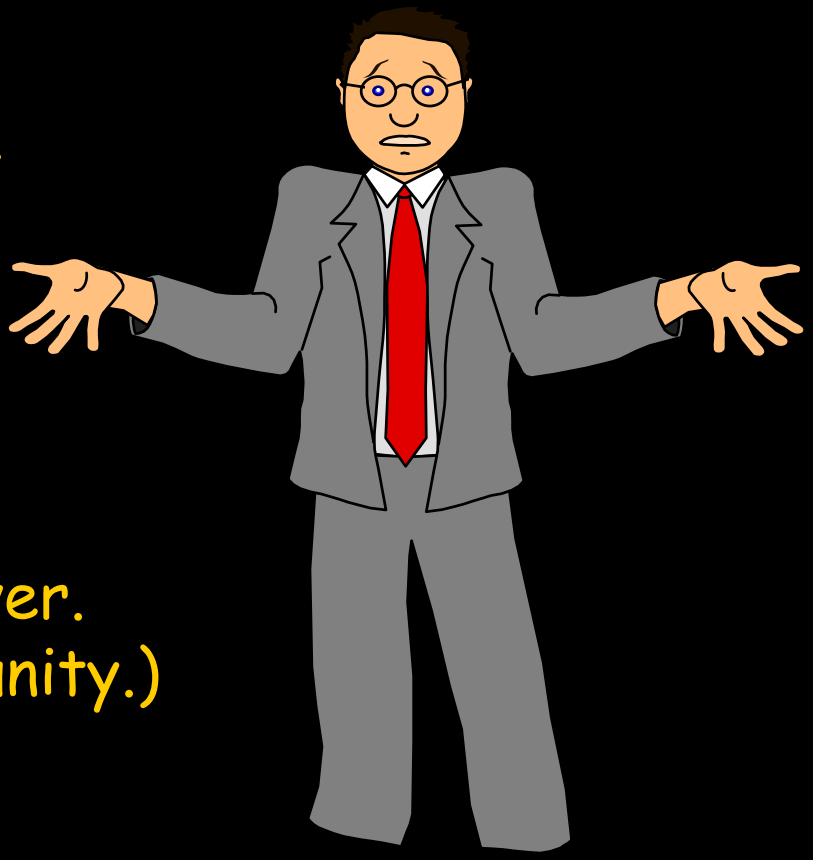
The Results

	1		2		3		4		5	
	CC	PI	CC	PI	CC	PI	CC	PI	CC	PI
AGEL3	1.00									
AGINI	16.60	24.00	6.40		13.40	10.00			15.40	14.00
AGSM	8.00	20.00	36.40	48.00	31.80	34.00	24.80	20.00	14.60	18.00
AGTR	0.40				0.60		33.50	44.00		
AGTR2	6.60	14.00	10.40	6.00	11.00	4.00	0.40		15.40	28.00
FEAR2									0.40	
ORHYH							0.80		1.80	2.00
ASFL									1.20	
ERDI					0.40					
GRSQ			0.20							
HEMI			11.40	10.00					4.60	6.00
MESA							0.20	4.00	1.80	
OVNI							2.00			
PECR							1.00		3.00	
SELO							0.40		6.80	
ATCA	3.80	2.00	12.20	20.00	22.00	20.00			7.00	6.00
CHNAN	1.20	2.00								
GUSA									0.60	
CANU									0.20	
CIAR									1.00	
BARE	66.40	22.00	21.20	8.00	18.00	18.00	35.10	24.00	19.00	18.00

Conclusions??

- Continuous Cover Method Appears to better measure the presence of all species in the transect.

- Point-Intercept Method appears to overestimate Total Perennial Ground Cover. (May depend on veg community.)



Conclusions??

- More evaluation warranted
- Method adaptive to type of vegetation being evaluated, rather than a one-size fits all approach.
- Non-Parametric Approach

Thanks for your time & attention

COMPUTING AND COMPARING DIVERSITIES

Richard Prodgers
Bighorn Environmental Services
Butte MT

John W. Kern
Western Ecosystems Technology Inc
Cheyenne WY

Presented at OSM Interactive Forum/ Approaching Bond Release

- **Diversity is a requirement of surface mine revegetation (SMCRA 1977),**

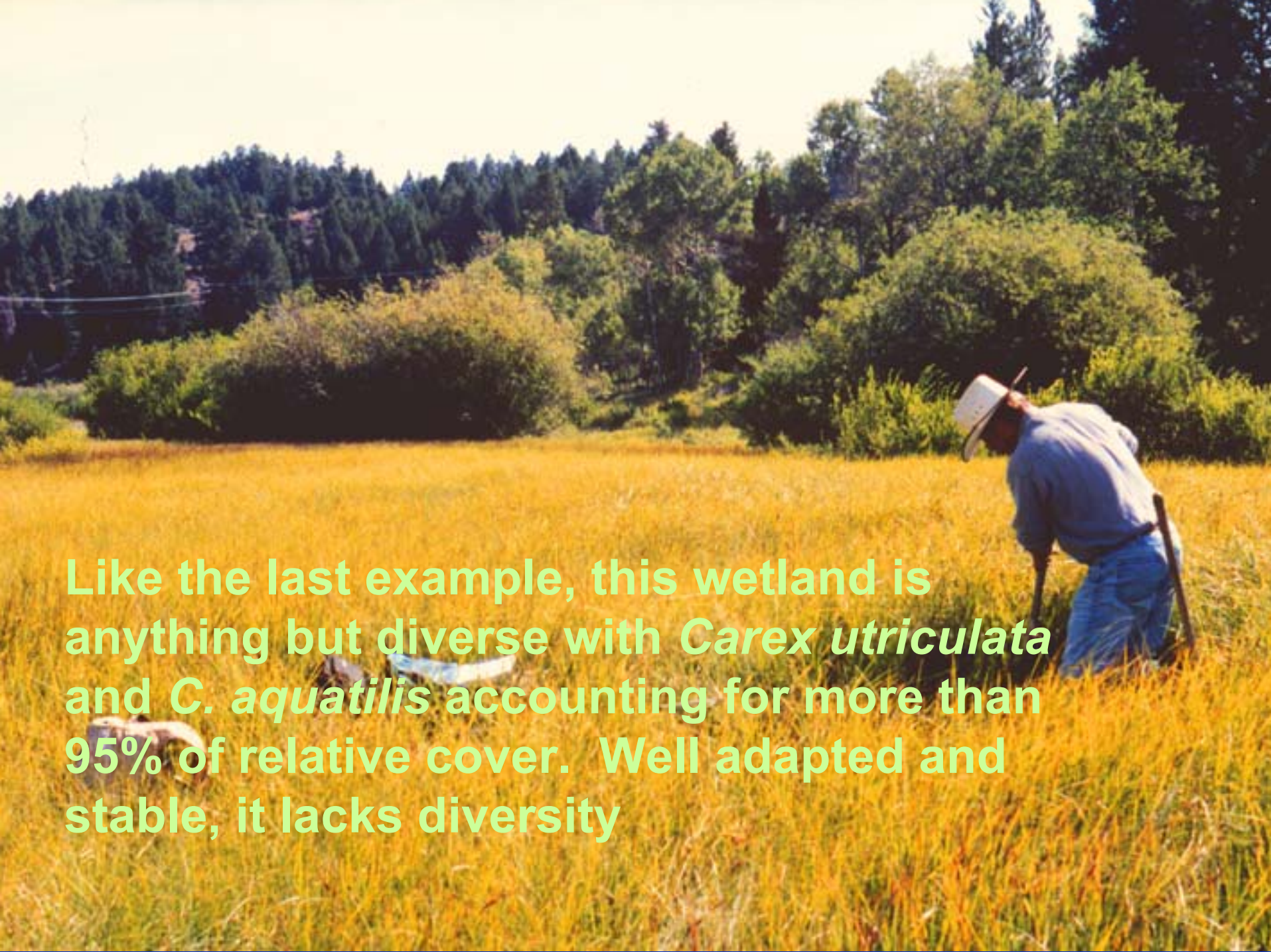
- **The authors apparently did not agree with Daniel Goodman's (1975) crushing review of the Diversity-Stability Hypothesis (MacArthur in 1955).**
- ***" …there is no simple relationship between diversity and stability in ecology…"***

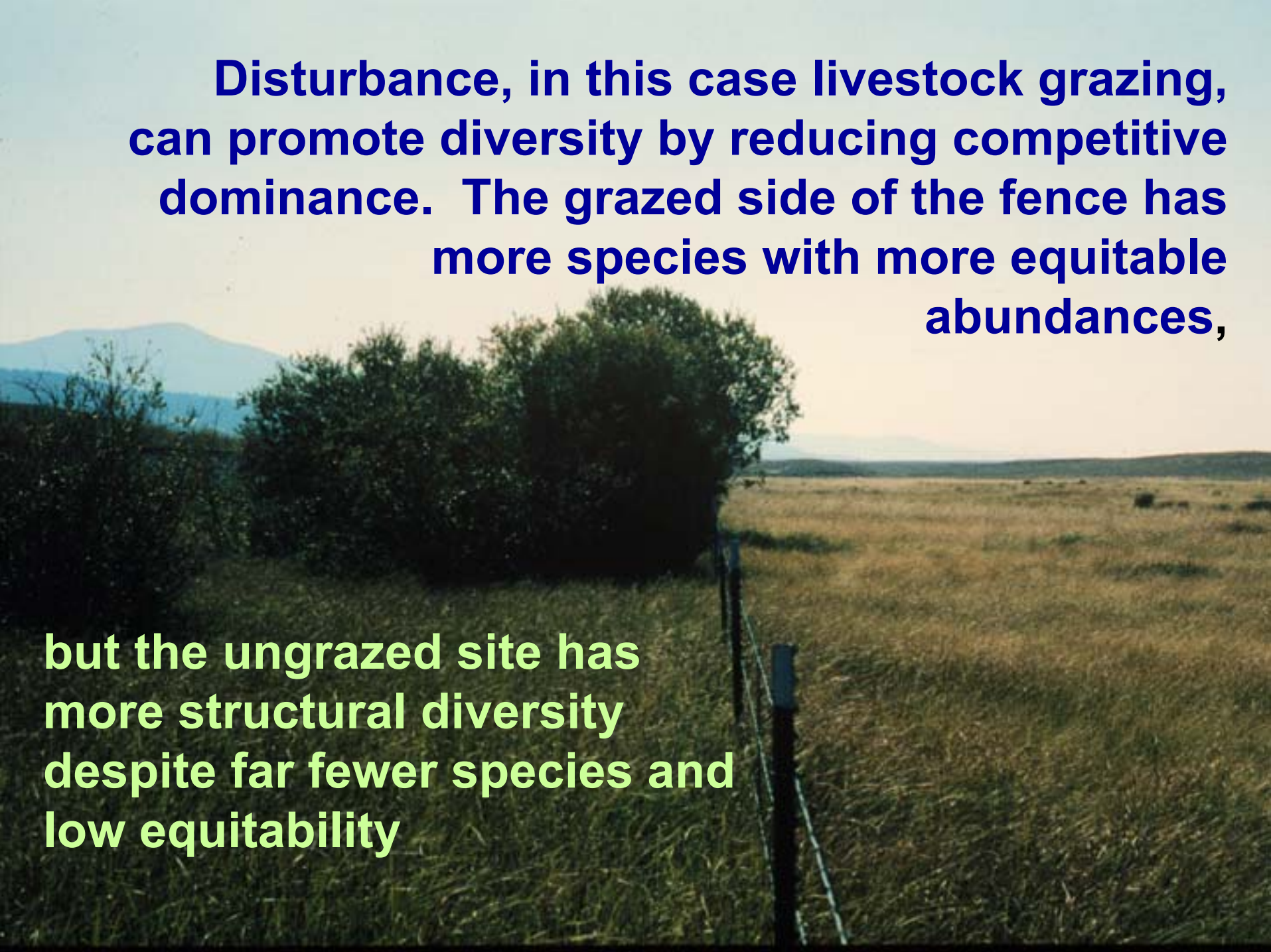
- At core, diversity is a concept, usually intuitive, to which ecologists have given mathematical expression. (Some ecologists aren't very intuitive.)

- DIVERSITY IS NOT A FUNDAMENTAL FUNCTION OF PLANT COMMUNITES AS IS PRODUCTIVITY.

- Since it is a concept, it is only natural that we should argue about what diversity is, how to measure it, and which community properties, if any, it accounts for.

Riparian Relict Along the Headwaters
of the Clark Fork of the Columbia
Thickspike wheatgrass is dominant. Western wheatgrass
and Baltic rush subdominant. Few other species present.
This community predates the
arrival of introduced weeds
such as spotted knapweed.


Like the last example, this wetland is anything but diverse with *Carex utriculata* and *C. aquatilis* accounting for more than 95% of relative cover. Well adapted and stable, it lacks diversity


Disturbance, in this case livestock grazing, can promote diversity by reducing competitive dominance. The grazed side of the fence has more species with more equitable abundances,
but the ungrazed site has more structural diversity despite far fewer species and low equitability

- Diversity is interesting and attracts strong minds. Opinions abound. But since comparisons are desired within the context of bond release, we will focus on established methods of measuring diversity and the statistics that apply.

WHERE TO BEGIN?

- A fixed pool of species in a single region apart from weedy invaders.
- SCALE: Small, local, usually community-level.
- DATA: Sample-based (STATISTICAL INFERENCE REQUIRED).

ACTUAL DIVERSITIES MAY NOT BE REVEALED BY SMALL SAMPLES.

- Calculating diversity from a small sample can make areas with unlike diversities appear similar, even leading one investigator to conclude that Australian heathlands were as rich in species as tropical rain forests! (See Rosensweig 1995 for an interesting discussion.)
- Appropriate quadrat size may be debatable

IT'S A HABITAT CONTINUUM OUT THERE.

LIKE OTHERS, WE DISTINGUISH
LEVELS OF DIVERSITY:

within-habitat
between-habitat
and landscape diversity

ATTENTION TO HABITAT MAY HELP TO CLARIFY
DIVERSITY RELATIONS.

You will no sooner discover differences in diversity between two areas than someone will ask if it can be explained by differences in size of area or differences in habitat variety.

WITHIN-HABITAT (Alpha) DIVERSITY: Sounds good. What could be simpler? But wait! What is a habitat?

- It's the physical and chemical elements of a plant's (or plant community's) environment….

- What defines a habitat in the landscape? How do we know if one or two or several are present in an area, even a reclaimed landscape?

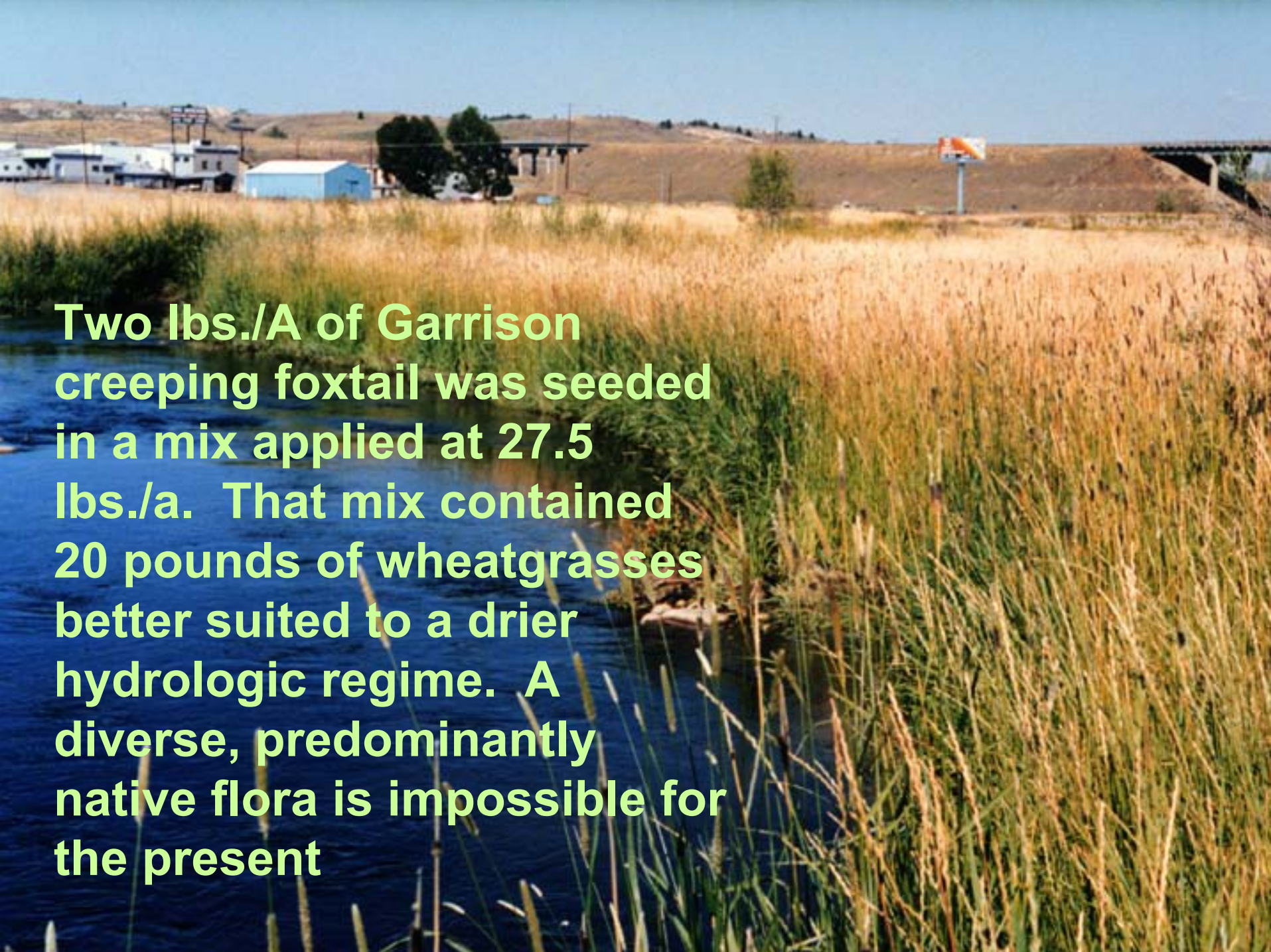
- Habitats are not inelastic and pre-defined. In some cases, habitats remain undifferentiated until many competing species treat them differently. Or worse: habitat and resource are co-evolved responses of organisms. DAMN

Does that mean that a region with little habitat variety can have a diverse flora?

- That is exactly what it means.
- Diversity is a product of evolution resulting in resource partitioning and niche packing.

- In reclamation, we are more likely to see the opposite. The combination of heavily seeded eurytopic species and gentle environmental gradients makes for few habitat distinctions.

- 5 lbs. Per Acre Slender wheatgrass out of a total of 22 lbs. seed/Acre.

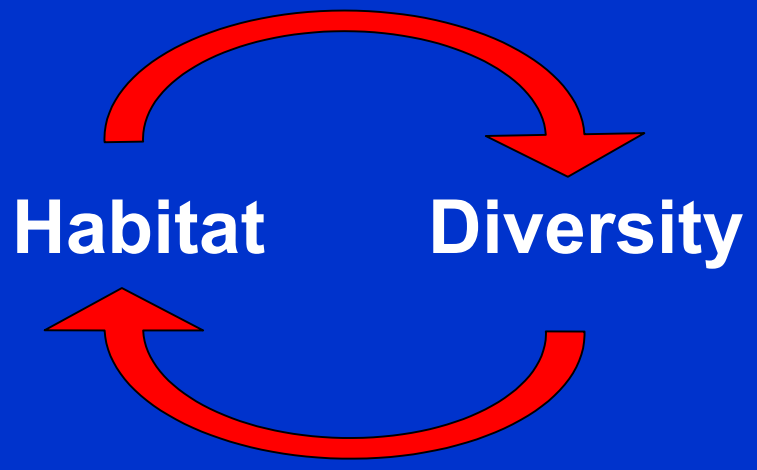


Two lbs./A of Garrison creeping foxtail was seeded in a mix applied at 27.5 lbs./a. That mix contained 20 pounds of wheatgrasses better suited to a drier hydrologic regime. A diverse, predominantly native flora is impossible for the present

- This needn’t deter us from identifying useful plant habitats and thresholds, as has been done for animals.
- In 1964, MacArthur hypothesized that the structural diversity defined as the relative densities of three layers of foliage (roughly: grasses, shrubs, and trees) were the elements of bird habitat.
- YES, HE USED A PROPORTIONAL ABUNDANCE INDEX, THE SHANNON FUNCTION. AND HE USED STRUCTURE, NOT SPECIES. (From this he was able to reliably predict bird diversity.)

- His predictions were only slightly improved when he used plant species rather than a simple measure of vegetational structure. This relationship has been substantiated pretty much worldwide. In fact, it is such a sound relation that it was used to establish that species or guilds on islands recognize fewer habitats than on mainlands. WOW!

- We know of no analogy in plant ecology. Plant ecologists are more likely to say that species distributions or community boundaries indicate habitat boundaries….which is hardly useful at all in revegetation planning



- So....within-habitat diversity is not so simple. Why not define plant habitats based on soils, hydrology, and topography?

- This may be fertile ground for experimentation in applied ecology.

- Luckily, environmental factors that matter to plants are largely co-linear, seldom varying independently.
- For example, the change from floodplain to sideslope usually involves not just a change in slope and aspect, but also soil type and hydrology.
- A single habitat factor, such as soil type, is likely to denote a slope position, perhaps even an aspect and elevational range, as well as hydrologic regime

A distinct habitat (seep from a road cut)
Three species: Sandbar willow (bank),
Nebraska sedge (bluish), Baltic rush (dark green)
This area wasn't seeded
with adapted species

- **BETWEEN-HABITAT (Beta) DIVERSITY also suffers from lack of habitat definition, not to mention mapping.**

- **LANDSCAPE DIVERSITY can apply to a collection of reclaimed fields….or a natural region. The region acts as the species bank from which organisms are recruited naturally for reclaimed areas….in a hopeful scenario**

- **Our point is that, since diversity is a concept and specific habitats are a lot less concrete than we might wish,**
  ***it can be difficult even to identify the level of diversity at which study (or regulation) is focused*.**
- **If diversity relations are being attributed to causes, we must define habitats and relate plant and animal diversity to habitats first – then other factors.**

UNITS:

- **The SPECIES is the fundamental unit of TAXONOMY.**

- **It does not follow that it is, or should be, the fundamental unit of DIVERSITY. (Remember that MacArthur, previously cited, related bird diversity to diversity of vegetation structure.)**

In combining taxonomy and mathematics, there is an assumption that species are equally different.

COMMUNITY A	COMMUNITY B
Wheatgrass A	Wheatgrass A
Wheatgrass B	Cottonwood Z
Wheatgrass C	
N = 3	2

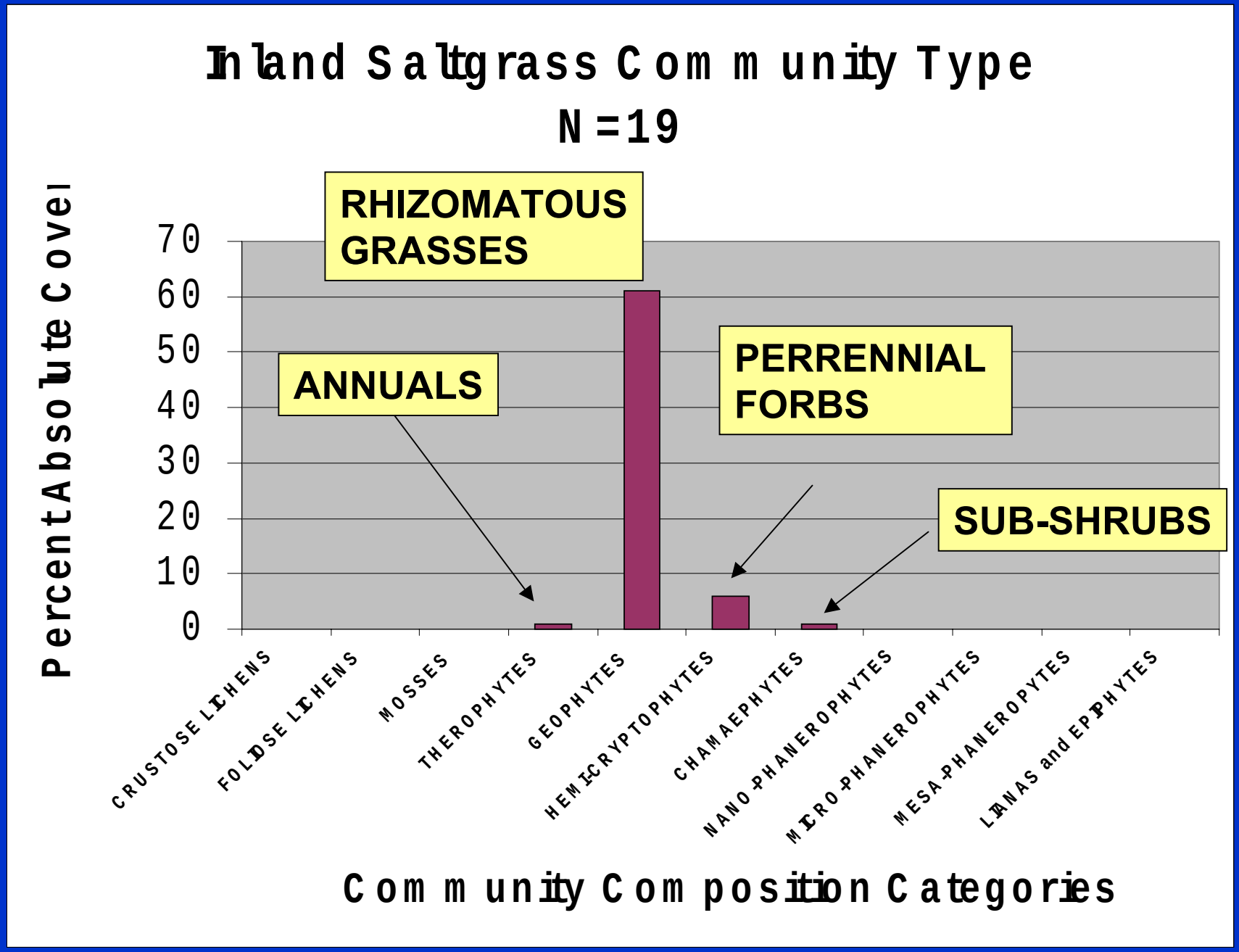
Is Community A 1.5X more diverse than Community B?

- Even though data is collected by species, diversities can be calculated for species groupings, and in many cases this would provide more meaningful diversity appraisals.

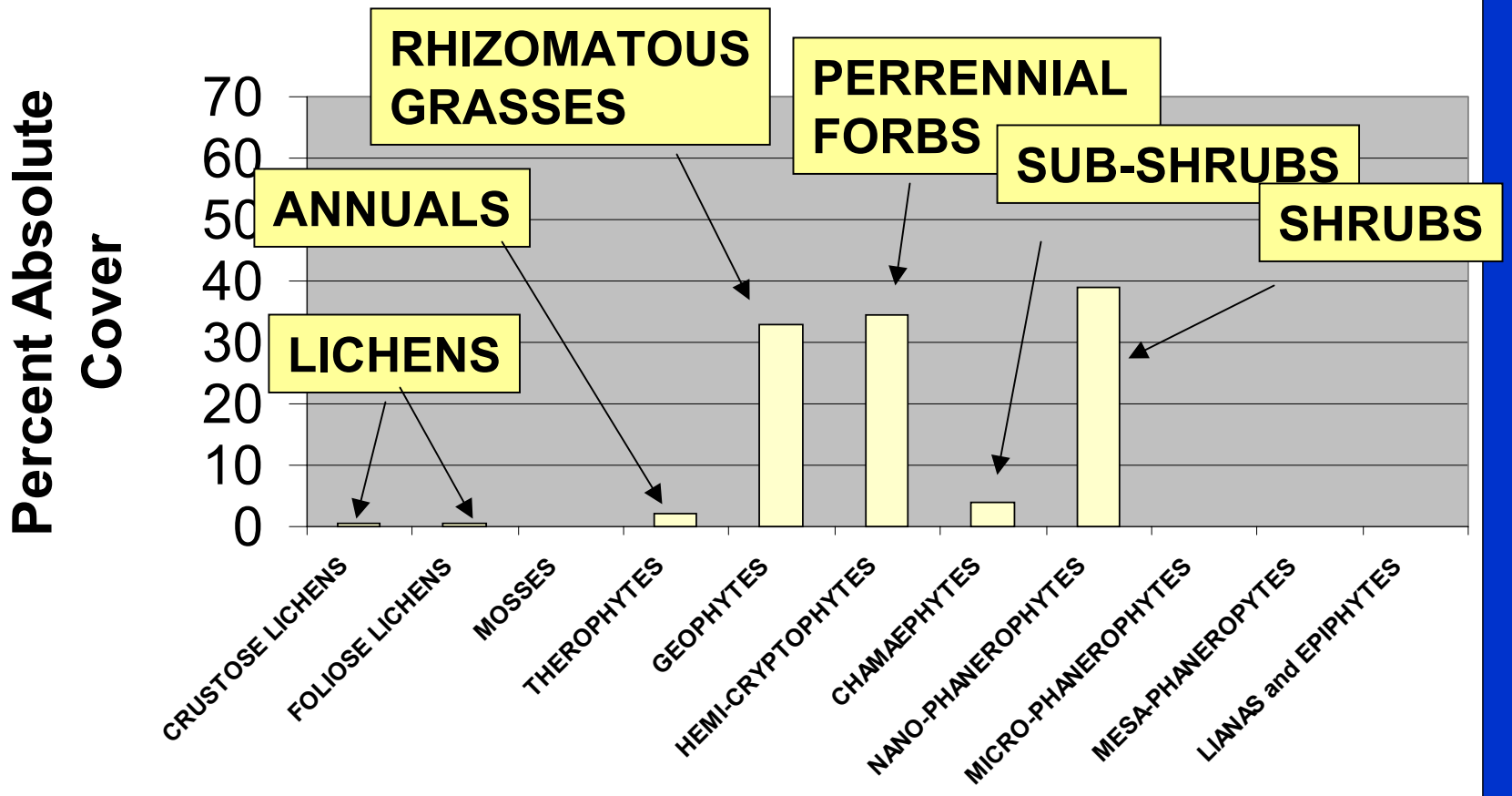
- SO LET'S DO IT

- In addition to showing the structure of various prairie communities, the following histograms introduce the concept of proportional abundance of life-forms graphically.

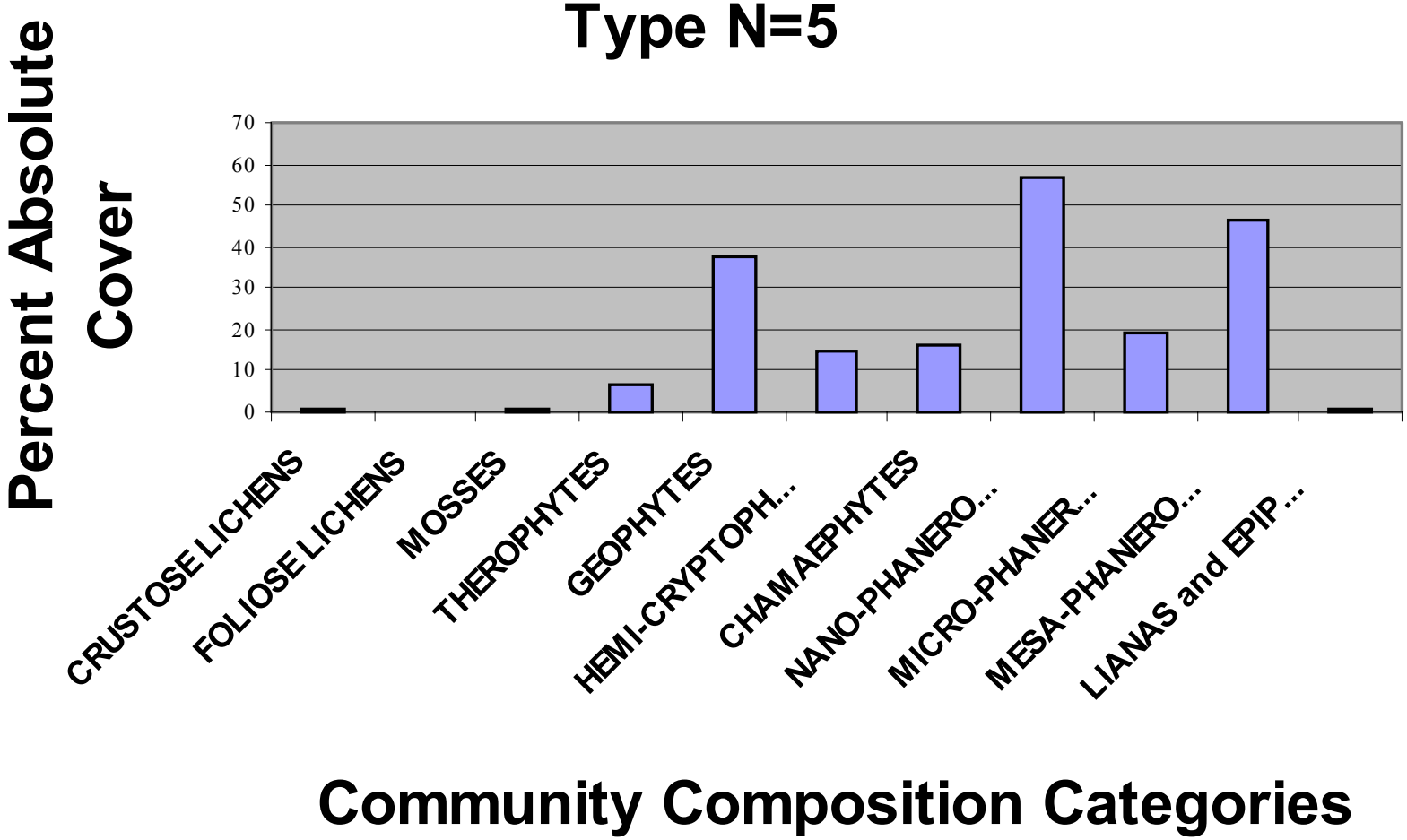
- Life-forms are based on the location of perennating tissues.


Inland Saltgrass Community Type
N=19
Percent Absolute Cover
70
60
50
40
30
20
10
0
RHIZOMATOUS GRASSES
ANNUALS
PERRENNIAL FORBS
SUB-SHRUBS
CRUSTOSE LICHENS
FOLIOSE LICHENS
MOSSES
THEROPHYTES
GEOPHYTES
HEMICRYPTOPHYTES
CHAMAEPHYTES
NANO-PHANEROPHYTES
MICRO-PHANEROPHYTES
MESA-PHANEROPYTES
LIANAS and EPIPHYTES
Community Composition Categories

Silver sagebrush/western wheatgrass/blue grama Community Type N=31



Plains Cottonwood/Rosa spp./Symphoricarpos occidentalis Community Type N=5



DATA REQUIREMENTS

- Just as comparisons of cover, productivity, density, etc. require a confidence interval, and power is bolstered when minimal statistical sample adequacy standards are met…..

- Species diversity evaluations require that the flora (fauna) be inventoried above some minimal level, i.e., all common and well-represented species should be represented in the data, along with some uncommon species.

- Even for vascular plants, this can take a lot of point-intercept transects.

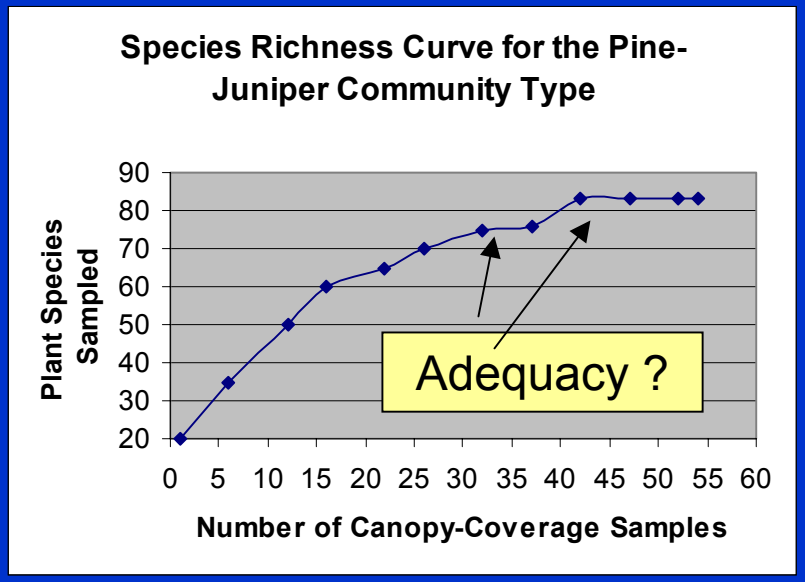
- Each sample or set of sub-samples (quadrats, transects, etc.) represents a community or set of similar communities. The level of sampling must be adequate for floral inventory.

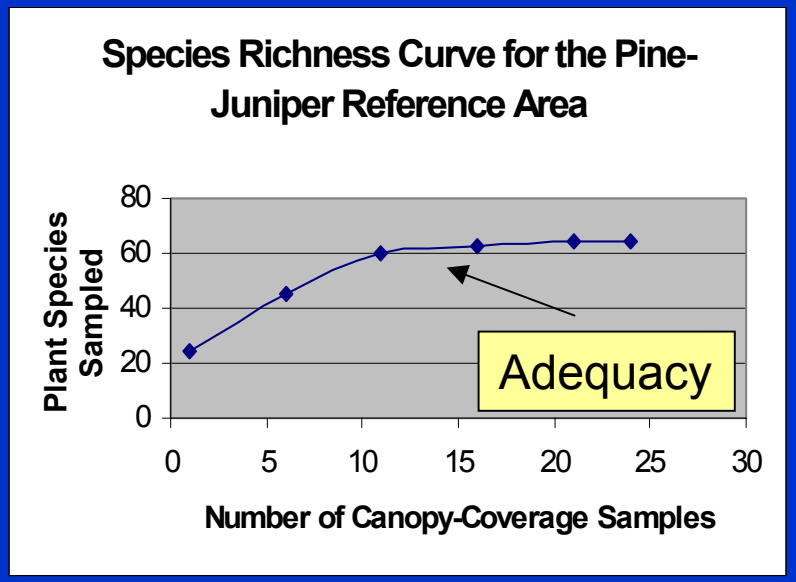
- What is sample adequacy for diversity?

THE SPECIES AREA CURVE:

Plot the number of species (Y-axis) as a function of number of samples or area sampled.

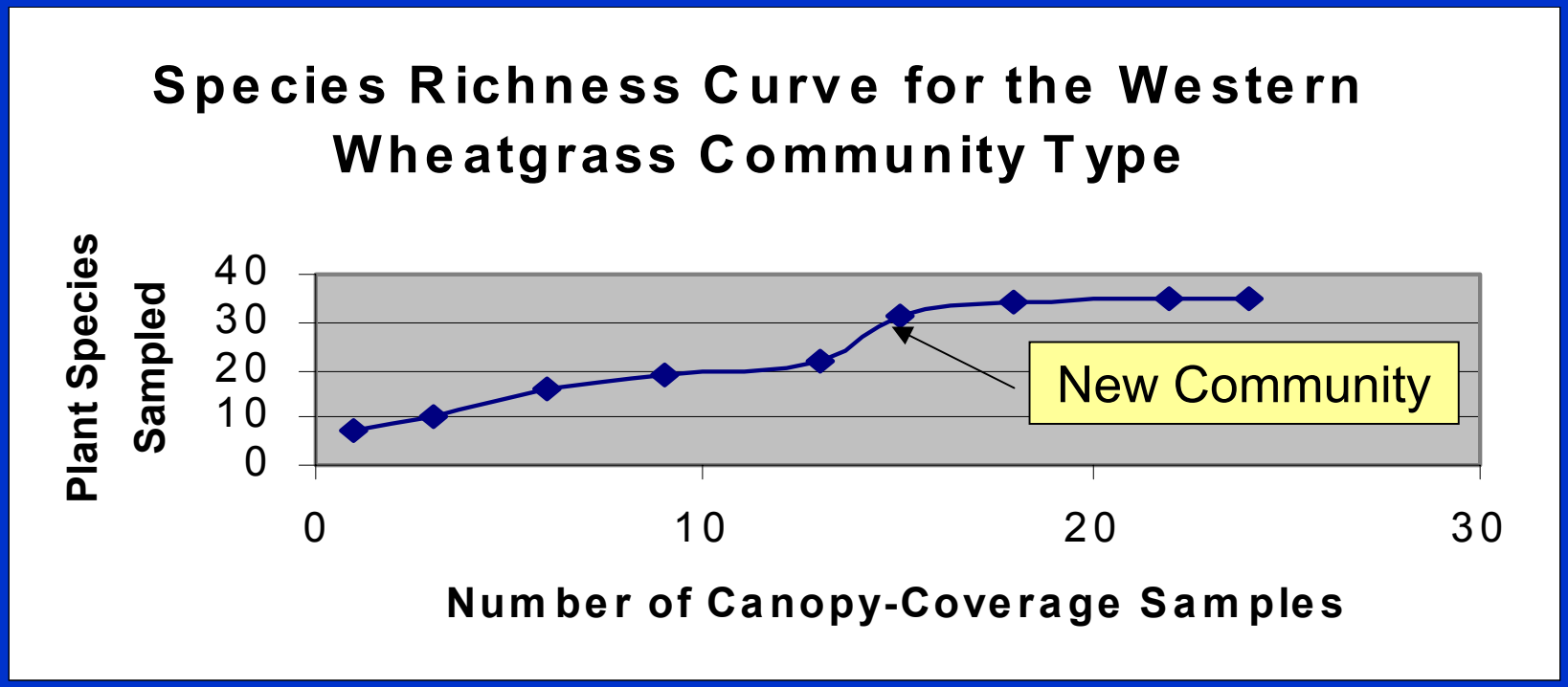
We are looking for a flattening of the curve. You can only see this in the rear view mirror – a degree of "oversampling" is inevitable.





Identifying the point of adequate floristic sampling is subjective and, in extreme cases, arbitrary.

CAUTION: Even when sample locations are randomly located, sampling may proceed uni-directionally for purely utilitarian reasons (e.g., to minimize travel time).



RESULT: The graph flattens, only to rise again as the boundary is crossed.

WHAT TO DO?

- **Randomize the order in which samples are entered into the graph, or use the original order in which locations were chosen, not the order in which they were sampled. (Perfectly legitimate).**

- **SPECIES RICHNESS: The number of species in a community, or community type, or some *area*.**

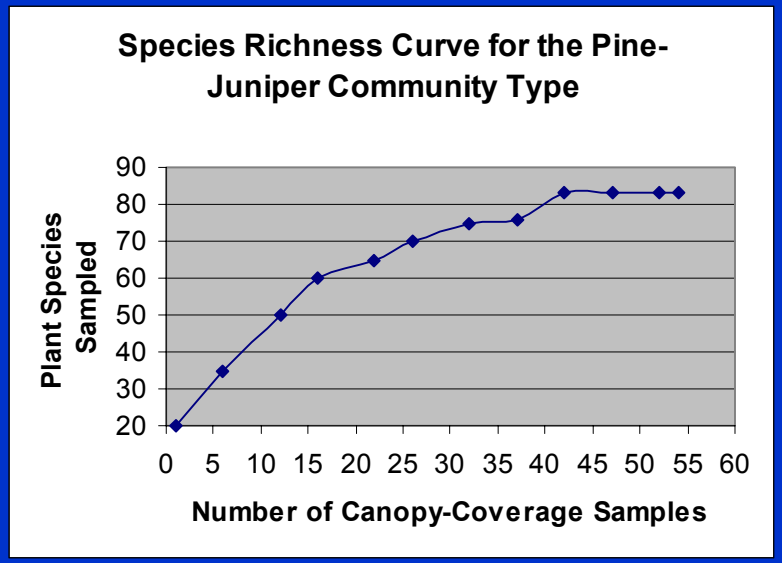
- **There's the rub.**

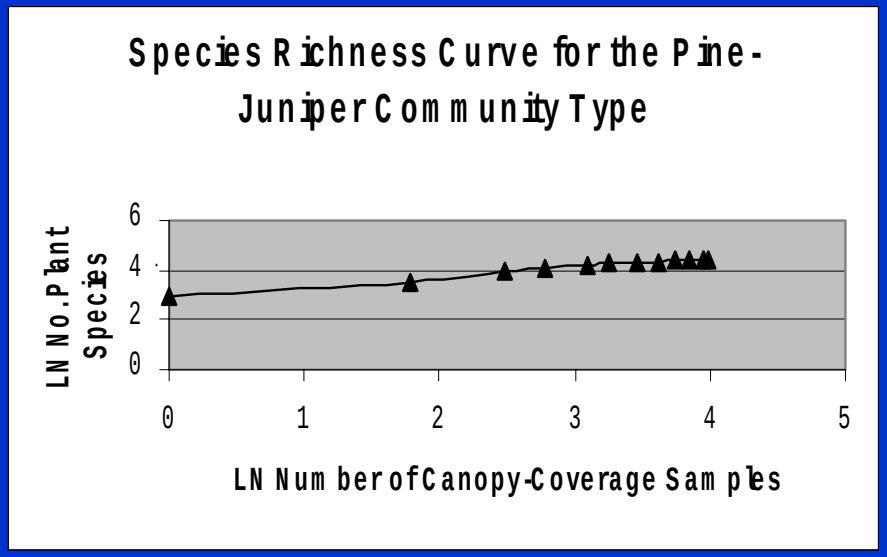
- **The most pervasive relation in diversity: LARGE AREAS HAVE MORE SPECIES THAN SMALL ONES.**

- Even the simplest comparison, the number of species in two units (reclaimed v.s. reference area), becomes problematic when study areas or areas sampled are not equal.

- Can we put a confidence interval on richness?
- Can you correct for sample size?
- How about data from a single area vs. a set of quadrats?)

For large areas, the log of species vs. log of area is a straight line, the slope of which has the property of a diversity index as long as a fairly large area was inventoried. (Long recognized.)





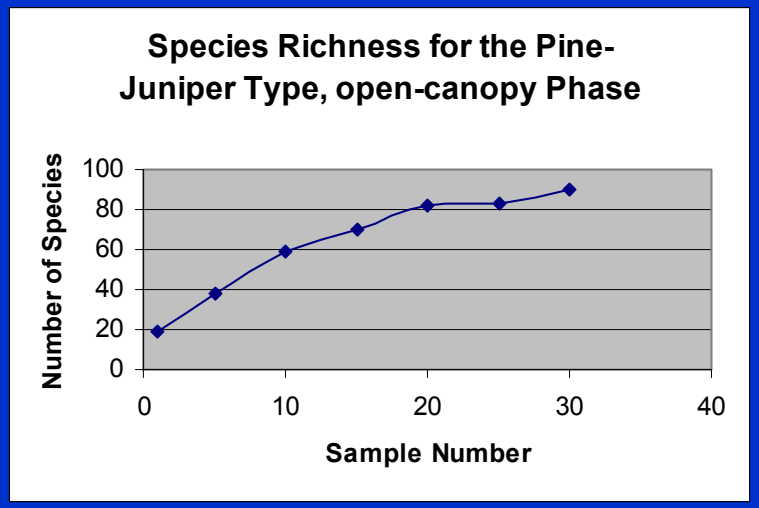
- **Dubious Comparison:**
- **PRODGERS COMPARED THE AVERAGE NUMBER OF SPECIES SAMPLED IN RECLAIMED COLSTRIP FIELDS BASED ON 20 1/2 M^2 PLOTS RANDOMLY DISTRIBUTED THROUGHOUT EACH FIELD**
- **TO: SOME OF WALT MUEGGLER'S RICHNESS DATA FOR RANGE TYPES COLLECTED FROM SINGLE O.1 HA AREAS.**
- **WAS THIS A SPURIOUS COMPARISON? ANY WAY TO VALIDLY COMPARE?** ***Technical Standard?***

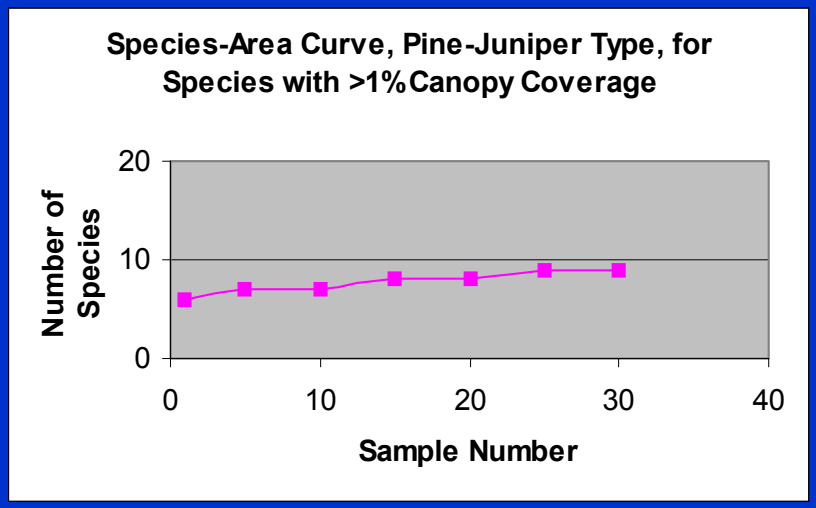
- Some states tally the number of species with >1.0% average coverage, disregarding those with <1.0%.

- WHOA! In most cases, the number of samples we take is inadequate to quantify the abundance of uncommon taxa.

- The confidence intervals are enormous relative to the means by virtue of many zeroes and usually a few moderately high values.

- The number of species was around 90, but only 9 w/>1% cover.
- Sample adequacy is hardly an issue.
- Comparisons to reference sites are almost guaranteed to be non-significant





- Can we use data from sets of small, standard samples while holding area constant to simplify comparisons?

- **SPECIES DENSITY:** The number of species per standard-size small sample, e.g., per quadrat or per set of quadrats along a transect, or (less desirable) per point-intercept transect. If the name weren't already taken, it might be termed a measure of equitability, and a simple one at that.

- Standard confidence intervals apply for moderate sample sizes, (e.g. N > 20) and a reasonably flat species area curve.

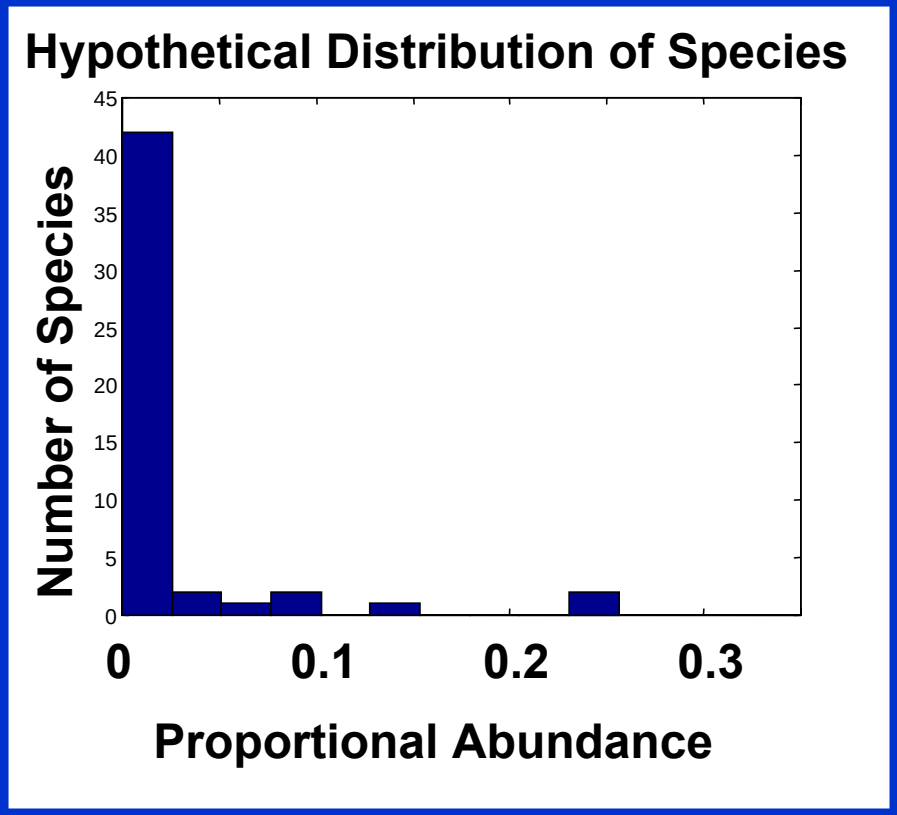
- Proportional abundance matters.

- Recall the histograms of community structure shown earlier. For example, given two communities, each with only two species.

- One community has 50% species A and 50% of species B. The other community has 99% of A and 1% of B. Or it could be life forms instead of species. Most people think the first community is more diverse.

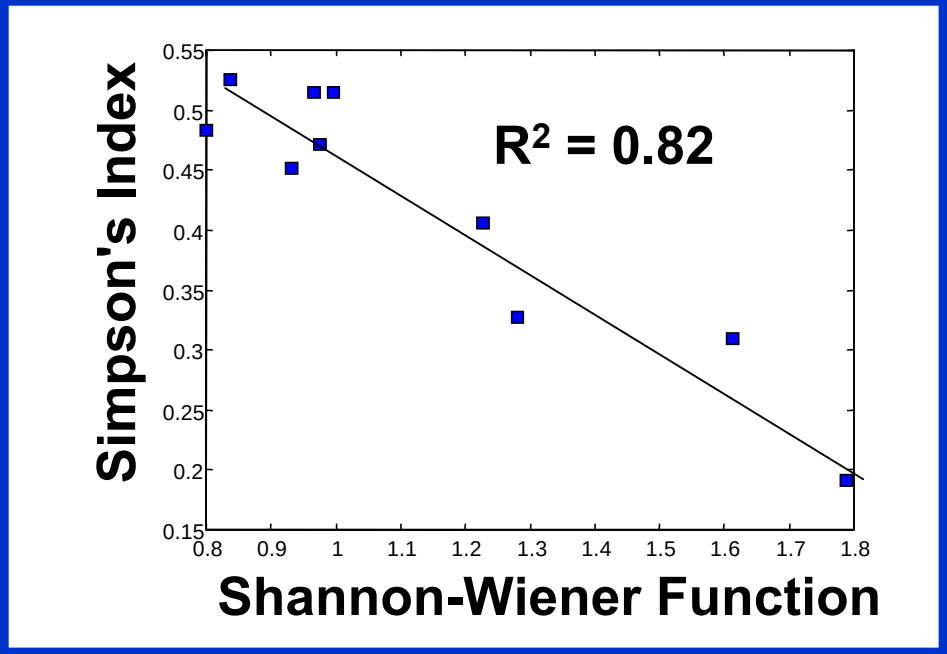
- **INDEX** **FORMULA**
- **Simpson** $$D = \sum p_i^2$$
- **Shannon** $$H = -\sum p_i \log(p_i)$$
- **Fisher's Alpha** $$S = \alpha \log\left(1 + \frac{N}{\alpha}\right)$$
- **The reciprocal of the Simpson index and the exponentiated forms of the Shannon index sometimes are used.**

- Much has been written about the merits, or more often disadvantages, of the Simpson index (a probability index) and the Shannon index (an information theory index). The Simpson index supposedly emphasizes abundant species (true) whereas the Shannon index supposedly emphasizes the rare (false). Numerous taxa of rather low abundance can have a significant effect, but no realistic number of species of truly low abundance (e.g., 0.1 or 0.2% cover) make much difference



For western arid regions the Shannon and Simpson indices should provide similar information.

Variances and confidence intervals can be estimated by bootstrap or jackknife resampling.



- The Simpson function is simpler and easier to work with, but the Shannon function has been applied to more data. Fisher's Alpha is rarely seen but corrects for sample area. So too Simpson's index of concentration.

- We should adopt one formula and one log base to facilitate comparisons.

- Empirical studies should be conducted using existing data from the semi-arid west to determine the most appropriate index or indices.

- By calculating diversities for old data as well as new, we can explore diversity-time curves for revegetation. How exciting!!

- Revegetation development can be documented in terms of diversity changes as well as compositional changes, soil genesis, etc.

- We should be creating a database of diversity measurements for revegetation and reference areas even as we devise strategies to foster diversity.

- In the long run, quality data may be more enduring than today's explanations for what we observe.

- **WHAT CAN YOU DO WITH THE DATA?**

- **If sample data are collected on equal numbers of equal size REPLICATE experimental units (quadrats or transects), bootstrapping and jackknifing can be used to estimate variances and confidence intervals (See Krebs 1989 for a review)**

- **Permutation tests (Manly 1991) can be used to test for differences although confidence intervals may be more appropriate than tests of hypothesis. The power of tests and sample adequacy are open questions….**

Sampling

- Careful sampling designs may be the most important aspect in comparing diversity.
- Apples to apples comparisons are difficult to achieve given the sensitivity of diversity measures to identification of similar types and numbers of habitats.
- When diversity differs are we measuring a difference in diversity in similar habitats or misidentification of habitats?

Proportional abundances for two areas can be compared if the taxa of both were sampled adequately and the number of habitats was equal (preferably just one).

But you cannot compare data from a *community type*, comprised of *numerous communities* sampled throughout the landscape as in a baseline study, to a single revegetation unit.

Because data from the summary composition for the community type will have more total species and more species of moderate abundance and usually fewer species of high abundance than any single community. These factors result in higher proportional abundance.

- We reject purely comparative approaches to diversity such as similarity indices.
- They don’t measure diversity.
- Neither do they contribute to our understanding of it.
- In SMCRA, there would be no point in enumerating cover, production, seasonality, and utility if we put back exactly what was present before mining.

CONCLUSION: WE RECLAMATORS NEED AN ATTITUDE ADJUSTMENT.

"Papers about species diversity -- particularly from the 1980s and 1990s -- rarely reach conclusions. They perpetuate controversies...Do you believe that science boils down to a continual poll on an ever-lengthening questionnaire?"

M. Rosenzweig

Formal evaluations of diversity in revegetation have been too long ignored. The prospect of bond release has forced the issue. Don't worry about grand models. Let's raise the level of investigation rather than reiterate our reservations or cite those of others. We now need to identify diversity relations in revegetation at specified scale based on adequate data

- To progress in bringing diversity into bond release calculations, we need:
- SOUND SAMPLE DESIGNS, RIGOROUSLY EXECUTED.
- FLORISTIC SAMPLE ADEQUACY, IN PARALLEL WITH QUANTITATIVE SAMPLE ADEQUACY.
- DISTINGUISH WHETHER THE DATA DESCRIBES WITHIN-HABITAT, BETWEEN HABITAT, OR LANDSCAPE DIVERSITY. Compare like to like. Do some work at the landscape level to get the big picture.
- USE THE MOST APPROPRIATE BIOLOGICAL UNITS, e.g., it could be growth-forms or guilds rather than species.

- Define a scale at which diversity will be regulated.
- Agree upon a small set of indices to evaluate (preferably one).
- Develop data quality objectives from which sample adequacy can be determined.
- The data quality objectives will determine appropriate statistical analysis. Many options are available.
- Decision Criteria!!

- A landscape can be divided into any number of habitats. Before deciding what we should change in reclamation to promote habitat and thereby biodiversity, it would be nice to identify the habitat components that matter most at scales appropriate to surface mine reclamation. In other words, build an index of habitat variety that correlates well with important biological diversities.

Extreme Surface Roughening:

A Technique for Establishing Natives on Arid Lands and Slopes

Presented by Susan White,
Utah Division of Oil, Gas, and Mining
at OSM Interactive Forum/Approaching Bond Release

Gouging, pitting, and cleat marking have been used on reclamation sites for decades in arid land seeding.

Need to concentrate water for germination and growth

Known that smoothed slopes are undesirable

- Severe erosion on smooth surfaces
- Results in little germination and vegetation establishment

Conventional gouging methods difficult to apply on steep slopes

- Gouges and cleat marks too small
- Gouges not continuous
- Packs soil and doesn’t leave in loose condition
- Difficult in rocky soils

Cleat marks too small, erosion on smooth surface

Furrows and Terraces

- Difficult to install correctly
- Leaves visual scars for decades
- Rodent burrows cause failures
- Failures are catastrophic

Terraces leave visual scars on the landscape

Extreme Surface Roughening

- Trackhoe shovel to dig, poke, and/or push
- Microbasins 1½ to 2 feet deep by 4 feet wide
- Placed in a random overlapping pattern
- Can incorporate amendments (biosolids, hay, rock)
- Difficult to walk over when finished

Sunnyside Coal Mine with Surface Roughening and Hydromulch

Extreme Surface Roughening

Can be used on most all soil surface

- Perfect for rocky soils
- Fine silt or clay gouges should be extreme
- Fill in a short time period

1990

1994

1997

Extreme Surface Roughening

Is used as the primary sediment control treatment on many reclaimed sites

Extreme Surface Roughening

- Broadcast Seeding (hand or hydroseed)
- Mulch with tackifier to reduce wind erosion

Two Brief Case Studies

- J. B. King Mine
- Hidden Valley Mine

J. B. King Mine

- Operated periodically 1930's to 1981
- Salt desert shrub community
- 6300 feet elevation
- 8 to 10 inches annual precipitation
  - mainly winter, except for past several years

J. B. King Mine

- Reclaimed in 1985
- Refuse pile, about 8 acres
- Reclaimed to rolling 4h:1v slope
- 4 feet soil material on top
- Contour furrows
- Seeded, fertilized, and mulched

J. B. King Mine, 1985, smooth contour furrowed and drill seeded

- Recurring drought, erosion, and south westerly exposure limited vegetation establishment
- Approximately 5% vegetative cover

Late fall 1994 the refuse pile was reworked

- Applied 20 tons per acre (dry wt.) biosolids
- Applied approximately 184 cubic yds. Per acre rocky borrow material
- Soil, biosolids, and rock mixed to a 2 to 3 foot depth
- Extreme surface roughening applied as worked down the slope

Five years later

- Approximately 70% of the surface covered with rock
- Vegetation has excellent establishment
- Approximately 20 % vegetative cover
- Erosion minimized

J. B. King Mine refuse pile showing surface roughening and rocks

Excellent vegetation establishment

Hidden Valley Mine

- Unmined coal
- Permitted under Permanent Coal Program

Hidden Valley Mine

- 15 miles north of J. B. King Mine
- Salt desert shrub
- 7 to 9 inches annual precipitation
- Silty loam soils

Hidden Valley Mine

Reclaimed 1986 and reworked several times thereafter

- Used contour furrows
- Used coconut matting

Hidden Valley Mine in 1986

Hidden Valley Mine in 1986

Hidden Valley Mine ,1995, non-weedy cover 7%

Hidden Valley Mine

A portion reworked again in 1997

- Steepened, but shortened slope
- Flattened gentle slopes
- Applied rocky soil
- No organic amendment applied

Hidden Valley, 1998

Hidden Valley Mine

Results

- Roughening filled-in during operation and subsequent rains
- No runoff from the site
- Vegetation establishing

Hidden Valley Mine, 1999

Horizon Resource Management

Resource Monitoring & Management

Non-Parametric Vegetation Evaluation for Bond Release

Presented by Richard Bonine at OSM Interactive Forum/ Approaching Bond Release

Horizon Resource Management

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The US Standard railroad gauge (distance between the rails) is 4 feet8.5 inches. That's an exceedingly odd number. Why was that gauge used?

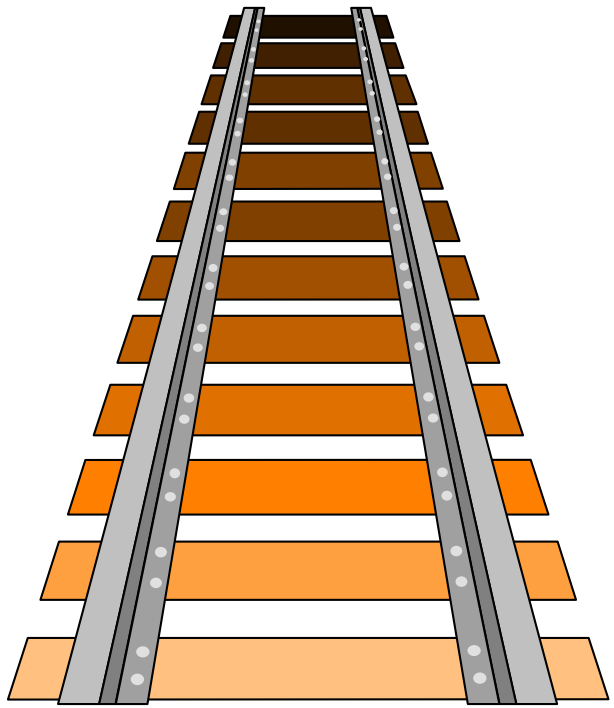
Because that's the way they built them in England, and the US railroads were built by English expatriates.

Horizon Resource Management

Resource Monitoring & Management

Why did the English people build them like that?

Because the first rail lines were built by the same people who built the pre-railroad tramways, and that's the gauge they used.



Horizon Resource Management

Resource Monitoring & Management

Why did "they" use that gauge then?

Because the people who built the tramways used the same jigs and tools that they used for building wagons, which used that wheel spacing.

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Why did the wagons use that odd wheel spacing?

Well, if they tried to use any other spacing, the wagons would break on some of the old, long distance roads, because that's the spacing of the old wheel ruts.

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So who built these old rutted roads?

The first long distance roads in Europe were built by Imperial Rome for the benefit of their legions. The roads have been used ever since.

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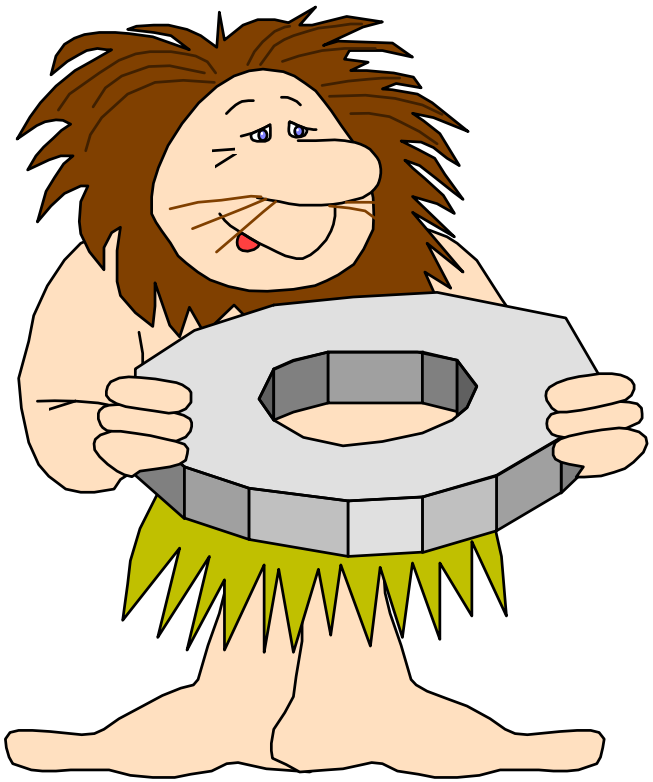
And the Ruts?



The initial ruts, which everyone else had to match for fear of destroying their wagons, were first made by Roman war chariots. Since the chariots were made for or by Imperial Rome they were all alike in the matter of wheel spacing.

Thus, we have the answer to the original question. The United States' standard railroad gauge of 4 feet 8.5 inches derives from the original specification for an Imperial Roman army war chariot.

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Specs and Bureaucracies live

forever!!!

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So, the next time you are handed a specification and wonder what schmick came up with it, you may be exactly right: Because the Imperial Roman chariots were made to be just wide enough to accommodate the back ends of two war horses.

Horizon Resource Management

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Now the twist to the story... There's an interesting extension of the story about railroad gauge and horse's behinds.

When we see a space shuttle sitting on the launch pad, there are two big booster rockets attached to the sides of the main fuel tank. These are the solid rocket boosters, or SRBs. The SRBs are made by Thiokol at a factory in Utah. The engineers who designed the SRBs might have preferred to make them a bit fatter, but the SRBs had to be shipped by train from the factory to the launch site.

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The railroad line to the factory runs through a tunnel in the mountains. The SRBs had to fit through that tunnel. The tunnel is slightly wider than a railroad track, and the railroad track is about as wide as two horses' behinds.

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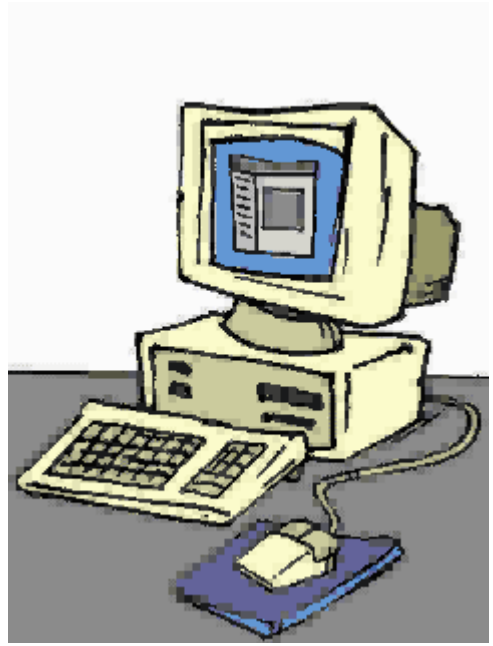
Resource Monitoring & Management

So a major design feature of what is arguably the world's most advanced transportation system was determined by the width of a horse's rear end.



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Paradigms!

Horizon Resource Management

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For those of you that forgot what is presentation is about...

Non-Parametric Vegetation Evaluation for Bond Release

Horizon Resource Management

Resource Monitoring & Management

Why a new approach to Bond Release is necessary.

Horizon Resource Management

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Why a new approach to Bond Release is necessary.

- Operators were using limited number of species in their seed mixes. (FEAR,OGDL,AGCR,ELJU)

- Congress understood the need for vegetative diversity in the plant community. There should be some similarity with pre-mine vegetation.

Horizon Resource Management

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Why a new approach to Bond Release is necessary.

- Post-Mine land uses in mid-west focused on production.
- Soil diversity was not desirable.
- Vegetation data "more" normally distributed, allowing the use of parametric statistical methods.

Horizon Resource Management

Resource Monitoring & Management

Why a new approach to Bond Release is necessary.

But in the west things are different…

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Why a new approach to Bond Release is necessary.

- Post-mine land uses and vegetation are more diverse.
- Vegetation data is NOT normally distributed.
- Pre-mine soils are highly variable.

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Why a new approach to Bond Release is necessary.

The current process used to evaluate reclamation success in the west is much like the story about the US Standard Railroad Gauge:

- It is developed from a time when our post-mine land uses were different.

- Even if we want to redesign our reclamation for current uses, we still have to get it through "old tunnels" to get it off the "launch-pad".

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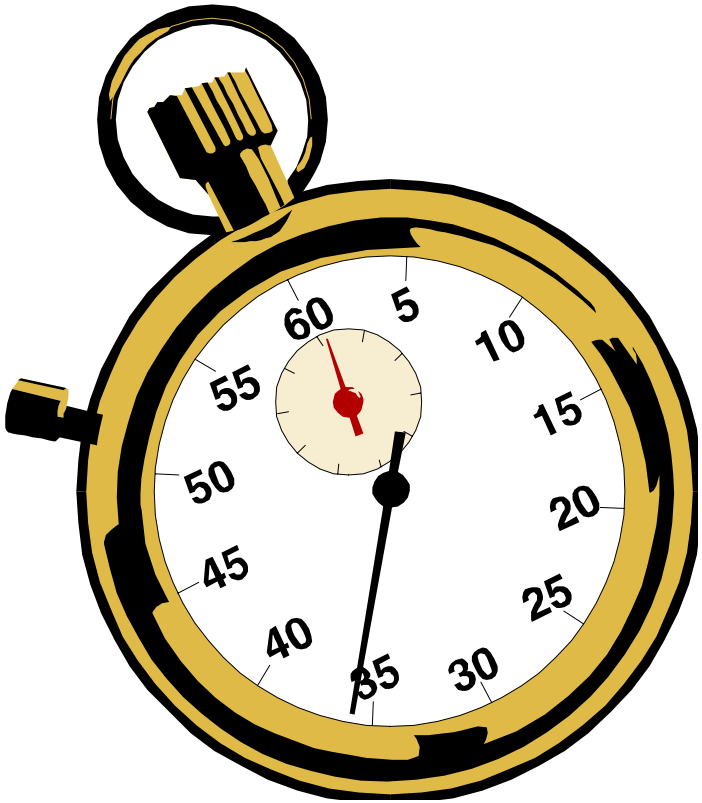

It's time for a change!

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What if, rather than measuring cover directly, we qualitatively evaluate the success or failure of a piece of reclamation based the presence or absence of attributes that "cover" would provide? (i.e. rills, water flow patterns, pedestals, wind scoured areas)

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If the soil site is stable, there is biotic integrity, and the watershed is functional, does it REALLY matter what the percentage of cover is?

Horizon Resource Management

Resource Monitoring & Management

Non-Parametric Revegetation Evaluation

- Rangeland Trend
- Rangeland Similarity
- Rangeland Health

Horizon Resource Management

Resource Monitoring & Management

Ecological Site Descriptions

A distinctive kind of land with specific physical characteristics which differs from other kinds of land in its ability to produce a distinctive type and amount of vegetation and in its response to management.

Horizon Resource Management

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Ecological Site Descriptions

Product of all environmental factors responsible for development.

- Soils
- Topography
- Climate
- Natural Disturbances
  - Herbivore
  - Drought
  - Fire

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Rangeland Trend

Apparent Trend: One point in time determination of the direction of change of the plant community.

Measured Trend: Requires that one or more trend indicators are measured over a period of time.

Planned Trend: Direction of change relative to management objectives.

Rated by desired plant community

- Positive
- Not apparent
- Negative

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Rangeland Trend

An ecological rating of the direction of change that is occurring on the site:

- Toward
- Not Apparent
- Away from

Very dynamic: Can and does change rapidly.

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Rangeland Trend

Trend Indicators:

- Composition changes
- Abundance of seedlings or new plants
- Plant residues
- Plant vigor
- Conditions of the soil surface

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Resource Monitoring & Management

Rangeland Similarity Index

How was Range Condition calculated in the past?

The range condition of areas within a range site was determined by comparing the present plant community with that of the **climax plant community**, as indicated by the RSD.

Practically speaking, climax plant communities exist in the past and are utopian in nature.

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Rangeland Similarity Index

Compares existing plant community to a **Steady State** community for the site (i.e. ESD).

Reported as an Index number. (0%-100%)

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Rangeland Similarity Index

Indicators:

- Total above-ground biomass produced annually.
- Species composition by weight.

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Rangeland Similarity Index

The purpose of the similarity index is to provide a basis for describing the extent and direction of changes that have taken place. Also to predict those changes that can take place in the plant community because of a specific treatment, disturbance, or management.

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Rangeland Health

The degree to which the integrity of the soil, vegetation, and water, as well as the ecological process of the rangeland ecosystem is balanced, sustained, and stable.

Integrity = maintenance of the structure & functional attributes that are characteristic of a particular locale.

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Rangeland Health

How are the ecological processes functioning?

- Soil/site stability
- Water cycle & hydrology
- Nutrient Cycle
- Plant species functional diversity

Horizon Resource Management

Resource Monitoring & Management

Rangeland Health

Areas of Evaluation:

- Soil & site stability
- Hydrologic Function
- Integrity of the biotic community

Horizon Resource Management

Resource Monitoring & Management

Rangeland Health

No one area of evaluation, or attribute will place a site into a health category. It is the preponderance of evidence that indicates the health status of a site.

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Resource Monitoring & Management

Rangeland Health

Currently there are seventeen rangeland health indicators to be evaluated. Individual indicator data can be analyzed and maintained. Indicators can be grouped for purposes of analysis and reporting.

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Rangeland Health

Indicators:

- Rills
- Water Flow Patterns
- Pedestals or Terracetes
- Bare Ground
- Gullies
- Wind Scoured Areas
- Litter Movement
- Physical & Chemical Soil Crusts

Horizon Resource Management

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Rangeland Health

Indicators:

- Soil Surface Organic Matter
- Plant Community Composition & Distribution
  -relative to infiltration and runoff
- Compaction Layers

Horizon Resource Management

Resource Monitoring & Management

Rangeland Health

Indicators:

- Plant Functional Groups
- Plant mortality
- Litter Amount
- Annual Production
- Noxious & Invasive Plants
- Perennial Plant Reproductive Capability

Horizon Resource Management

Resource Monitoring & Management

Rangeland Health

Soil Site Stability	Not Stable	At Risk	Stable
Biotic Integrity	Not In Tact	At Risk	In Tact
Watershed Function	Not Functioning	At Risk	Functioning

Horizon Resource Management

Resource Monitoring & Management

Non-Parametric Revegetation Evaluation

- Rangeland Trend- Measures direction of change.
- Rangeland Similarity Index- Evaluates current plant community.
- Rangeland Health- Process oriented evaluation of ecological processes.

Horizon Resource Management

Resource Monitoring & Management

Non-Parametric Revegetation Evaluation

Three distinct and different ratings!

- Not Interchangeable
- Not Always Correlated
- Not Mutually Exclusive
- All Needed

Horizon Resource Management

Resource Monitoring & Management

Non-Parametric Revegetation Evaluation

Believe that this integrated approach is simple, yet comprehensive, and will provide all stake-holders with an assurance of permanent, diverse, and effective reclamation.

Horizon Resource Management

Resource Monitoring & Management

Non-Parametric Revegetation Evaluation

Believe that the time is right to develop a new "gauge" that will allow our reclamation to reach the Bond Release "launch-pad".

Thanks for your time & attention!!

Resource Monitoring & Management

Terrace Design Using RUSLE and SEDCAD 4

by

Dr. Richard C. Warner, University of Kentucky

Dr. Daniel C. Yoder, University of Tennessee

Presented by Dr. Richard C. Warner at OSM Interactive Forum/ Approaching Bond Release

Functions of a Terrace

- Reduce Erosion along a Slope
- Reduce Down-Gradient Sediment Load
- Establish Vegetation

Slope Length

- Slope Length is Distance Between Terraces
  - reduce slope length
  - reduce erosion
  - reduce sediment load

Deposition Along a Terrace

- Reduces Down-Gradient Sediment Load

Benefits of Reduced Down-Gradient Sediment Load

- Smaller Sediment Basin
  - less area disturbed
  - lower sediment removal costs
- Reduces
  - frequency of sediment clean out
  - amount of sediment removed
  - potential for NOVs

Terrace Design Considerations

- Location
- Size
- Gradient
- Outlet
- Length
- Installation
- Cost
- Other On-Slope Controls
- Runoff
- Transport Capacity
- Deposition

Terrace Location

- Slope Configuration
- Uniform Spacing
- Non-Uniform Spacing
- Failure Potential

Terrace Size

- Height
- Storage Volume
  - storm
  - sediment
- Cross Dikes
- Failure Potential

Terrace Gradient

- Increase / Decrease Sediment Deposition
- Erosion / Deposition
- Uniform / Variable Slope
- Cross Dikes

Terrace Outlet

- Spillway Types / Size
  - porous rock
  - perforated riser
  - siphon
  - gradient siphons
  - combination
- Retention Time
- Sediment Deposition
- Backwater

Terrace Length

- Number and Size of Downdrains
- Failure Potential

Terrace Installation

- During Final Topsoil / Spoil Placement
- Quality Control
  - gradient
  - height
  - compaction

Terrace Cost

- Installation
- Maintenance
- Inspection
- Reduced Down-Gradient Cost
- Establishment of Vegetation
  - slope
  - terrace

Other On-Slope Controls

- Effect Sediment Load
- Example Controls
  - ripping
  - contour furrows
  - strip vegetation
  - mulch

Terrace Runoff

- Geographic Area
- Design Storm
  - amount of rainfall / return period
  - multiple storms
- Hydrograph
  - peak flow
  - runoff volume

Terrace Transport Capacity

- If Transport Capacity > Sediment Load
  - no deposition
- Transport Capacity >> Sediment Load
  - possible erosion along terrace
- Soil
  - eroded particle size distribution
  - soil texture
    - cohesive
    - aggregates

RUSLE Predictions

- Terrace Gradient & Sediment Load
- Terrace Gradient & Soil Texture
- Soil Texture & Geographical Location

RUSLE Design Inputs

- Geographical Location
- Soils
- LS Inputs
- C-Factor Inputs
- Terrace Inputs

Geographical Location

- CITY file
  - average annual R
  - distribution of R (bi-monthly)
  - EI (10-yr)

Soils

- Soil Texture
  - particle size distribution
  - organic material
  - permeability
  - structure
- K
- Hydrologic Soil Group
- % Surface Rock Cover

LS Inputs

- Length Between Terraces (L)
- Slope Gradient (S)
- Multi-Segments for Non-Uniform Slopes
  - L
  - S
  - Cover Condition

C-Factor Inputs

- Roughness
- Mechanically Disturbed (Y/N)
- Number of Years for Soil Consolidation
- % Surface Rock Cover (Transferred)
- Surface Cover Function

Terrace Inputs

- Graded Terrace (Open or Closed Outlet)
- Distance Between Terraces
- Soil Texture
- Gradient of Terrace

Sediment Delivery Ratios, Trap Efficiency, and Tons Discharged for Alternative Graded Terrace Slopes on Sandy Loam Soil with Hillslope Length 300 ft and 10% Gradient at Lexington Kentucky

Terrace Grade (%)	6 tons per acre per year			15 tons per acre per year			28 tons per acre per year		
	DR	TE	Tons	DR	TE	Tons	DR	TE	Tons
0.1	0.2	80	1.2	0.12	88	1.80	0.1	90	2.8
0.2	0.32	68	1.92	0.18	82	2.70	0.13	87	3.64
0.5	0.78	22	4.68	0.36	64	5.40	0.23	77	6.44
0.75	1	0	6	0.53	47	7.95	0.32	68	8.96
1	1	0	6	0.71	29	10.65	0.42	58	11.76
1.5	1	0	6	1	0	15.00	0.62	38	17.36
2	1	0	6	1	0	15.00	0.83	17	23.24
2.5	1	0	6	1	0	15.00	1	0	28
3	1	0	6	1	0	15	1	0	28

DR = Sediment Delivery Ratio
TE = Trap Efficiency (%)
Tons = Tons Discharged

Sediment Delivery Ratios, Trap Efficiency, and Tons Discharged for Graded Terrace Slopes as a Function of Soil Textures based on a Hillslope Length 300 ft and 10% Gradient at Lexington Kentucky.

Soil Loss on Inter-Terrace Interval = 6 tons/acre/year

Soil Texture	Terrace Grade at 0.1%			Terrace Grade at 0.5%		
	DR	TE	Tons	DR	TE	Tons
Sand	0.14	86	0.84	0.77	23	4.62
Sandy Loam	0.2	80	1.2	0.78	22	4.68
Silt Loam	0.32	68	1.92	0.82	18	4.92
Silt	0.43	57	2.58	0.85	15	5.1
Clay	0.25	75	1.5	0.8	20	4.8

DR = Sediment Delivery Ratio
TE = Trap Efficiency (%)
Tons = Tons Discharged

Sediment Delivery Ratios, Trap Efficiency, and Tons Discharged for the Same Conditions of a 300 ft Hillslope with a 10% Gradient and a Terrace Grade of 0.1% at Three Locations with Different Climates

Soil Texture	Lexington, KY (A= 6t/ac/yr)			Huron, SD (A= 1.8t/ac/yr)			Dallas, TX (A= 10.1t/ac/yr)		
	DR	TE	Tons	DR	TE	Tons	DR	TE	Tons
Sand	0.14	86	0.84	0.17	83	0.306	0.12	88	1.212
Sandy Loam	0.2	80	1.2	0.2	80	0.36	0.2	80	2.02
Silt Loam	0.32	68	1.92	0.27	73	0.486	0.36	64	3.636
Silt	0.43	57	2.58	0.32	68	0.576	0.49	51	4.949
Clay	0.25	75	1.5	0.27	73	0.486	0.24	76	2.424

DR = Sediment Delivery Ratio
TE = Trap Efficiency (%)
Tons = Tons Discharged

SEDCAD 4 Design Inputs

- Design Storm
- Eroded Particle Size Distribution
- Networking
- SubWatershed
- Structure Design

Design Storm

- Duration
- Rainfall Depth
- Type-Storm (or Actual Storm)

Eroded Particle Size Distribution

- Diameter (mm)
- % Finer

Networking (options)

- For 1 Terrace
  - S1 - 0
  - structure type - pond
- For Terraces and Down-Drain
  - S1 - S2 - 0 (longest terrace)
  - structure types - pond, rock riprap channel

SubWatershed

- Area (inter-terrace area)
- Time of Concentration (Tc)
- NRCS Curve Number (CN)
- Unit Hydrograph Shape (UHS)
- K
- L (length between terraces)
- S (gradient)
- C

Structure Design

- Capacity
  - elevation
  - area
- Discharge
  - spillway type(s)
  - inputs
  - example
    - perforated riser
    - broad crested weir

SEDCAD 4 Example Inputs

- Storm - 10 yr-24 hr, 4.2”, Type-II
- Soil - Sandy Loam
- SubWatershed - 5.74 Ac
- CN = 79, Tc = 0.157 hr, UHS = Fast
- K = 0.24, L = 300 ft, S = 10%, C = 0.50
- Terrace:
  - Triangular
  - Slope Gradient = 0.50, 1, 2%

SEDCAD 4 Results

Terrace Gradient (%)	0.5	1	2
Peak Flow In (cfs)	11.21	11.21	11.21
Peak Flow Out (cfs)	1.11	9.38	11.09
Peak Stage	4.01	4.13	4.16
Sediment In (tons)	105.2	105.2	105.2
Sediment Out (tons)	8.4	22.3	31.7
Peak Sediment In (mg/l)	141000	141000	141000
Peak Sediment Out (mg/l)	21000	34000	48000
Peak Sediment In (ml/l)	75.6	75.6	75.6
Peak Sediment Out (ml/l)	0	0.4	0.7
Trap Efficiency	92	78.8	69.8

Structure Design

Help

Click on Row to View SWS and Structure Information...

Type	No.	Description
Pond	#1	

Subwatershed

Structure Design

OK

Hydrograph

Graph

Sedimentgraph

Add

SWS

Remove

Hydrology

			SWS Routing			
SWS	Area (ac)	Tc (hrs)	MK (hrs)	MX	Curve Number	H'graph Response
1	5.74	0.157	0.000	0.000	79.0	Fast

Sedimentology

SWS	K	Rep. Length (ft)	Rep. Slope (%)	C Factor	P Factor	PS Distribution	Disturbed?
1	0.240	300.000	10.00	0.5000	1.0000	sandyloam	☐

Structure Design

Help

Click on Row to View SWS and Structure Information...

Type	No.	Description
Pond	# 1	

Subwatershed

Structure Design

OK

Pond Design

Capacity — Defined from Elev 0 to Elev 5

Discharge — 1 Perforated Riser(s), 1 Weir(s)

SEND TO

Permanent Pool Elev: 2.50

☐ Override

Pond Sedimentology

Sediment Capacity:

- ◉ Do not Reset Zero
- ○ Avg Annual R
- ○ Disturbed Acre
- ○ Contributing Acre
- ○ Inflow Sediment Tons
- ○ User-defined

Storage Elevation:

Dead Space (%): 20.00

Design Results:

	IN	OUT
Peak Discharge (cfs):	11.210	9.379
Runoff Volume (ac-ft):	1.0174	0.9084
Peak Elevation:	4.13	
Dewatering Time (days):	2.63	

Graph

(Dewatering Time was extrapolated beyond the 50 hour hydrograph limit)

Peak Sediment Concentration (mg/l):	141,015	34,391
Peak Settleable Concentration (ml/l):	75.63	0.39
24 hr Vol Weight'd Avg Settleable Conc (ml/l):	40.56	0.23
Trap Efficiency (%):	78.8	

Graph

SEDCAD 4 for Windows

File Utilities Help

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General | Design | Reports

- Networking
- PS Distribution-Structu
- Structure Summary
- [Structure Details:]
  - All Structures (1)
  - Structure #1
- [Subwatershed Details
  - All Structures (1) SW:
  - Structure #1 SWS's
- All Reports

Page Orientation
- Portrait
- Landscape

Save Report

SEDCAD 4 for Windows

Copyright 1998 Pamela J. Schwab
Civil Software Design

Structure Summary:

		Immediate Contributing Area (ac)	Total Contributing Area (ac)	Peak Discharge (cfs)	Total Runoff Volume (ac-ft)	Sediment (tons)	Peak Sediment Conc. (mg/l)	Peak Settleable Conc. (ml/l)	24VW (ml/l)
#1	In	5.740	5.740	11.21	1.02	105.2	141,015	75.63	40.56
	Out			9.38	0.91	22.3	34,391	0.39	0.23

Page: 4 Zoom: 80 Print Range: All From: 1 to 8

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SEDCAD 4 for Windows

File Utilities Help

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General | Design | Reports

- Networking
- PS Distribution-Structu
- Structure Summary
- [Structure Details:]
  - All Structures (1)
  - Structure #1
- [Subwatershed Details
  - All Structures (1) SW
  - Structure #1 SWS's
- All Reports

Page Orientation
- (•) Portrait
- ( ) Landscape

Save Report

Perforated Riser

Riser Diameter (in)	Riser Height (ft)	Barrel Diameter (in)	Barrel Length (ft)	Barrel Slope (%)	Manning's n	Spillway Elev	Number of Holes per Elev
2.00	3.50	2.00	10.00	1.00	0.0150	3.50	2

Broad-crested Weir

Weir Width (ft)	Spillway Elev
32.00	4.00

Pond Results:

Peak Elevation:	4.13
H'graph Detention Time:	5.55 hrs
Pond Model:	CSTRS
Dewater Time:	2.63 days
Trap Efficiency:	78.77 %

Dewatering time is calculated from peak stage to lowest spillway

Page: 6 Zoom: 80 Print Range: (•) All ( ) From: 1 to 8

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RUSLE Version 1.06

Application for:

mine lands
construction sites
and reclaimed lands

Short Course: September 20-21, 1999

by

Dr. Richard C. Warner ü University of Kentucky
Mike Anderson ü Surface Mining Institute

Presented at OSM Interactive Forum/Approaching Bond Release

Interactive Forum

Approaching Bond Release:

Revegetation, Native Plants, Native American Culturally Significant/ Historical Plants used in Reclamation and Surface Mining Applications in the Arid, Semi-Arid West

Little America Hotel
Flagstaff, Arizona

Sponsored by the Office of Technology Transfer
Western Regional Coordinating Center
Office of Surface Mining
Denver, Colorado

Revised Universal Soil Loss Equation (RUSLE)

mine lands
construction sites
reclaimed lands

Terrance J. Toy and George R. Foster
Co-editors

Joe R. Galetovic
Publishing Editor

August 1998

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- **George Foster** Co-Editor of RUSLE Guidelines. Adapted RUSLE for mined lands, construction sites, reclamation lands. U.S. Department of Agriculture (USDA), Agriculture Research Service (ARS).

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RUSLE

- Estimates Soil Loss
  - Undisturbed Lands experiencing overland flow
  - Disturbed Lands
  - Reclaimed Lands new or established
- Assists Permitting
  - Prepare Permit Applications
  - Assess Reclamation Success in support of Bond Release

Terminology

- **Erosion** a group of processes by which earth materials are entrained and transported across a given surface.

- **Soil loss** material actually removed from a hillslope or hillslope segment.

- **Sediment Yield** the sum of the soil losses minus deposition in macro-topographic depressions such as the toe of the hillslope, along field boundaries, or in terrances and channels.

RUSLE Does

- Estimate soil loss from a hillslope caused by:
  - raindrop impact
  - overland flow (interrill erosion)
  - rill erosion

RUSLE Does Not

- Estimate soil loss from a hillslope caused by:
  - gully erosion
  - stream-channel erosion

The RUSLE Model

- Estimates average annual soil loss and sediment yield from interrill and rill erosion.
- Derived from over 100,000 plot years of data from natural rainfall plots and numerous rainfall-simulation plots

RUSLE Eq. $A = R\ K\ LS\ C\ P$

A = Average annual soil loss in tons per acre per year

R = Rainfall/runoff erosivity

K = Soil erodibility

LS = Hillslope length and steepness

C = Cover-management

P = Support practice

The RUSLE Model

A = R K LS C P

- R factor = Erosivity of rainfall and runoff.
- “R” increases as amount and intesity of rainfall increases.
- “R” data contained in CITY database file provided within the RUSLE program
- Additional “R” data may be obtained from the USDA and NRCS

The RUSLE Model

A = R **K** LS C P

- “K” factor = the inherent erodibility of the soil
- “K” is a function of particle-size distribution, organic-matter content, structue, and permeability
- Additional “K” values for undisturbed lands may be obtained from NRCS soil surveys.
- “K” values for disturbed soils are embedded within the RUSLE program.

The RUSLE Model

A = R K **LS** C P

- “LS” factor = an expression of topography specifically, hillslope length and steepness.
- “LS” increases as hillslope length and steepness increases.
- “LS” assumes runoff accumulates and accelerates in the downslope direction.

The RUSLE Model

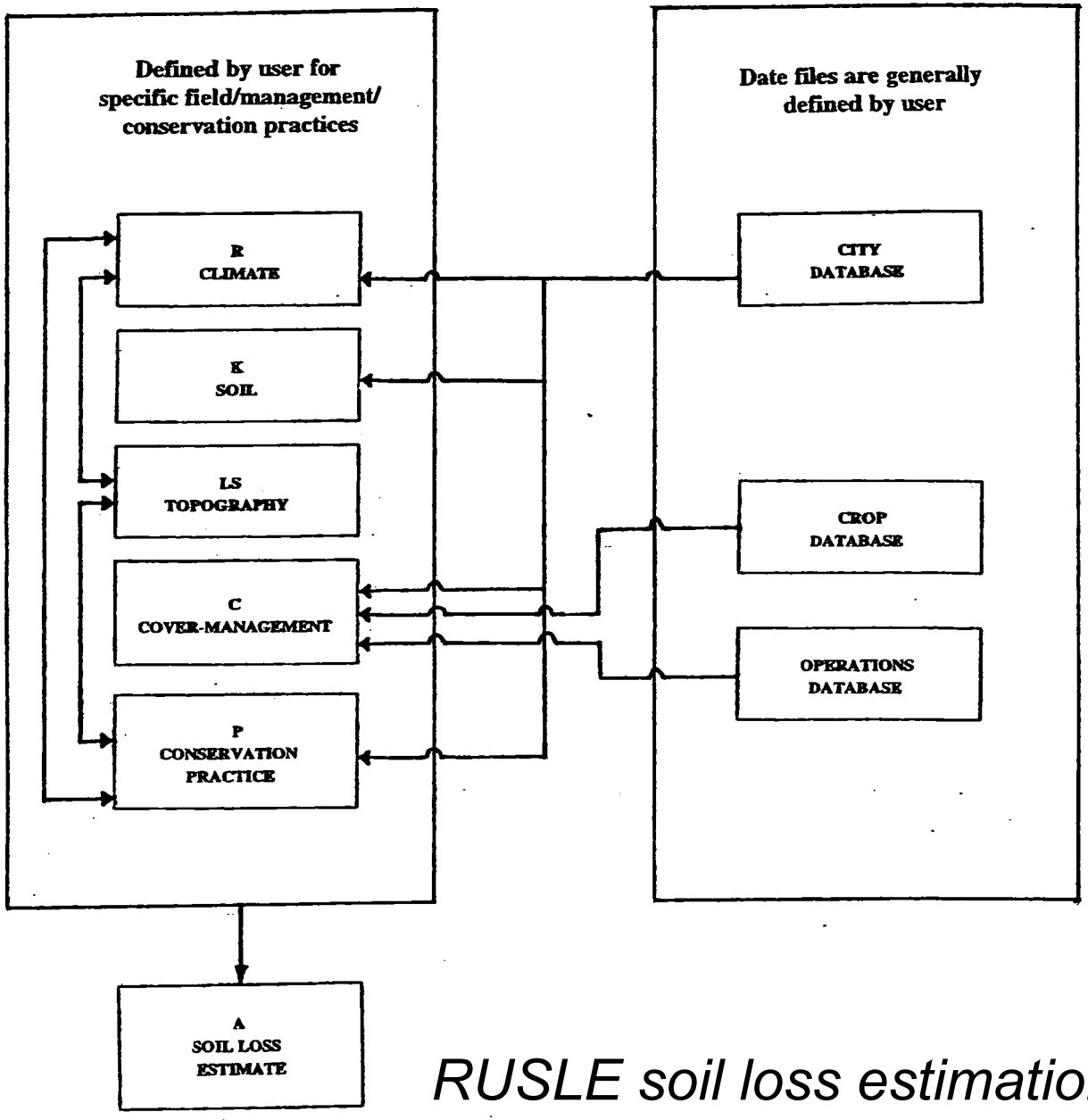
A = R K LS **C** P

- “C” factor = an expression of the effects of surface covers, roughness, soil biomass, and soil-disturbing activities.
- “C” decreases as surface cover and biomass increase.
- RUSLE uses a sub-factor method to compute “C”.
  - Based on changing “C” as a result of dynamic vegetation.
- “C” values are provided in RUSLE with customizing capabilities.

The RUSLE Model

A = R K LS C P

- “P” factor = an expression of the effects of supporting conservation practices such as contouring, buffer strips, and terracing.
- “P” decreases with practices responsible for reducing runoff volume and velocity and encourage deposition of sediment.
- Effectiveness of ‘practices’ varies due to local conditions.



RUSLE soil loss estimation

RUSLE Improvements

- Expanded to include weather bureau stations
- K factor modified for variable soil erodibility during the year
- LS factor can accommodate steeper hillslope gradients
- C factor modified using a sub-factor approach for main features of a cover management system
- RUSLE can be applied to many more field conditions
- More site specific C values
- New equations developed to estimate P values
- Estimates sediment yield for concave hillslopes

Rainfall/Runoff Erosivity (R)

- Soil loss is directly proportional to rainfall factor
- R is the average annual sum of ($E * I_{30}$) for storm events in last 22 years

  E = total storm kinetic energy

  I_{30} = maximum 30-min intensity
- R values exist in almost 200 eastern U.S. locations and over 1000 in western U.S.
- Maps of contoured R values may be obtained

Rainfall/Runoff Erosivity (R)

- R values typically derived from gauging locations such as airports
- Deriving R values for varying elevations:

$$R_{new} = R_{base} (P_{new}/P_{base})^{1.75}$$

R_{new} = the new value for R at desired new location when R value is not available from map

R_{base} = R value at base location where R is known

P_{new} = average annual precipitation at new location

P_{base} = average annual precipitation at base location

- Approximately plus 2 - 3 inches for each 1,000 ft

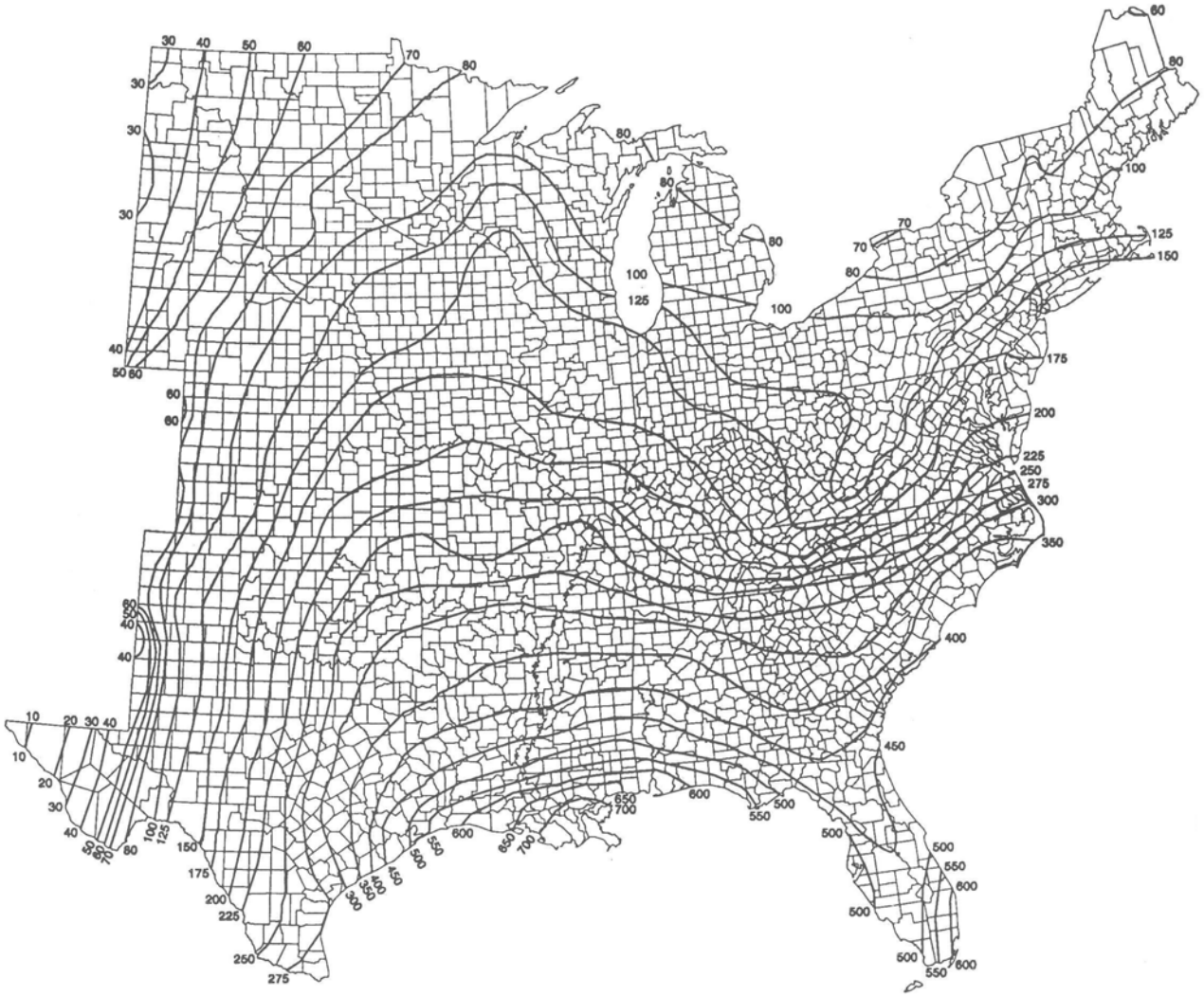


Fig. 2-1. Isoerodent map of eastern United States.
Units are hundreds ftCtonfCin(acChCyr)$^{-1}$

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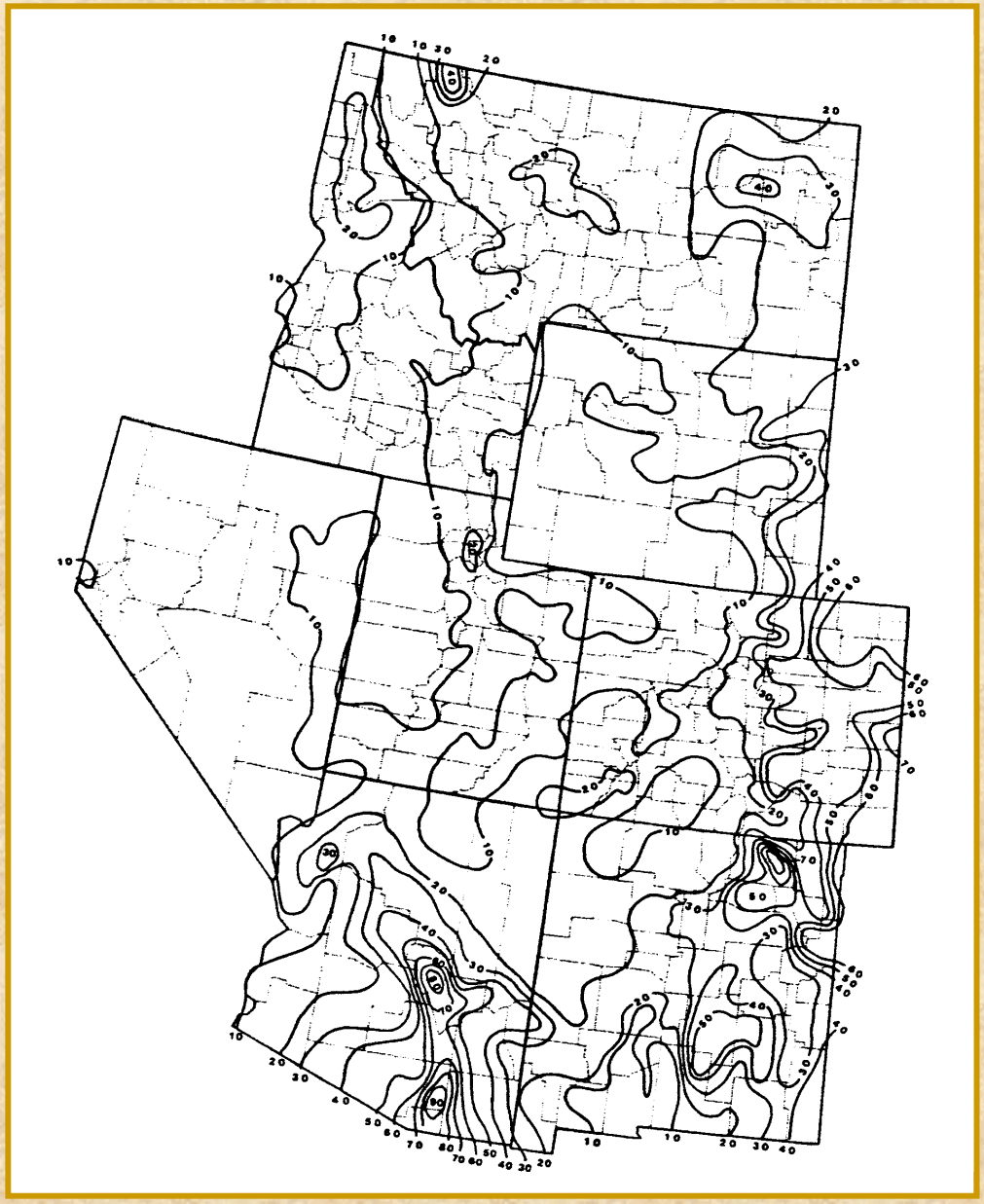
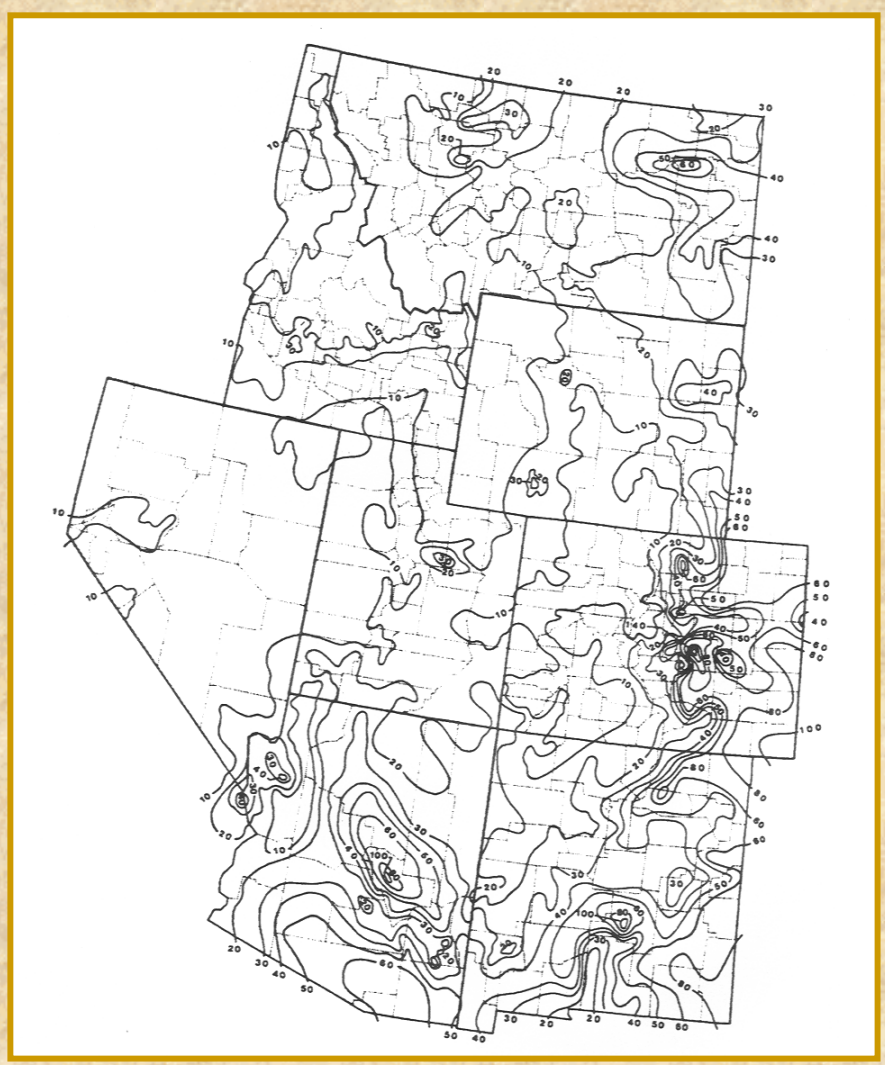
Rainfall/Runoff Erosivity (R)

- RUSLE uses 10 year frequency EI data to represent storm-rainfall depth (design storm) for calculation of conservation support practices (P).

- Runoff data used with fundamental sediment-transport relations to simulate effect of conservation support practices.



Isoerodent map of western U.S. Units ft*tonf*in(ac*h*yr)$^{-1}$



10yr-frequency single-storm erosion index.

Units are hundreds ft∗tonf∗in(ac∗h)$^{-1}$

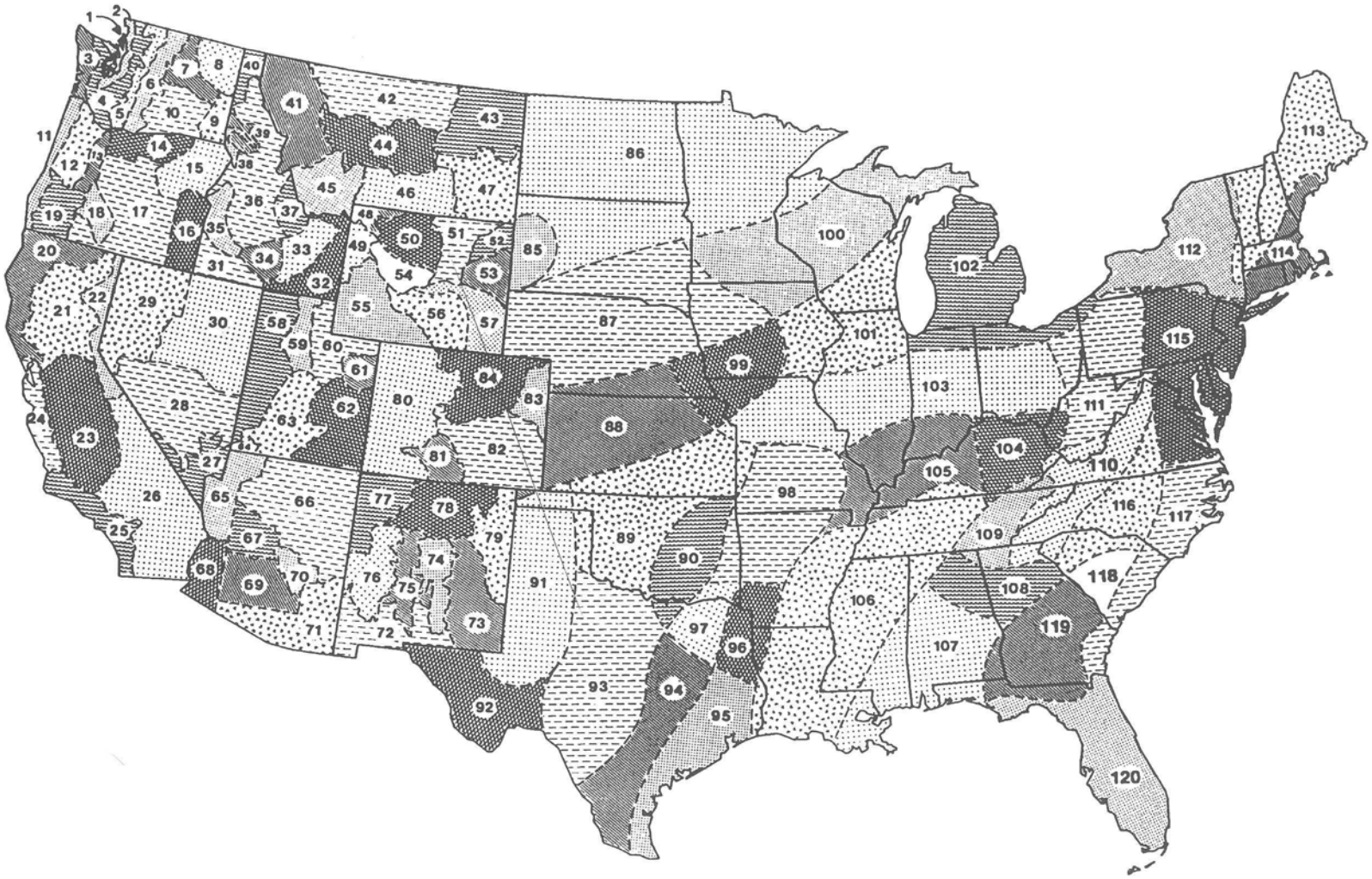


Fig. 2-7. EI distribution zones for contiguous United States

Table 2-1. EI as percentage of average annual value for geographic areas shown in figure 2-7

EI number	Periods 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
101	0.0	0.0	0.0	1.0	2.0	3.0	4.0	6.0	9.0	14.0	20.0	28.0	39.0	52.0	63.0	72.0	80.0	87.0	91.0	94.0	97.0	98.0	99.0	100.0
102	0.0	0.0	1.0	2.0	3.0	4.0	6.0	8.0	11.0	15.0	22.0	31.0	40.0	49.0	59.0	69.0	78.0	85.0	91.0	94.0	96.0	98.0	99.0	100.0
103	0.0	1.0	2.0	3.0	4.0	6.0	8.0	10.0	14.0	18.0	25.0	34.0	45.0	56.0	64.0	72.0	79.0	84.0	89.0	92.0	95.0	97.0	98.0	99.0
104	0.0	2.0	3.0	5.0	7.0	10.0	13.0	16.0	19.0	23.0	27.0	34.0	44.0	54.0	63.0	72.0	80.0	85.0	89.0	91.0	93.0	95.0	96.0	98.0
105	0.0	1.0	3.0	6.0	9.0	12.0	16.0	21.0	26.0	31.0	37.0	43.0	50.0	57.0	64.0	71.0	77.0	81.0	85.0	88.0	91.0	93.0	95.0	97.0
106	0.0	3.0	6.0	9.0	13.0	17.0	21.0	27.0	33.0	38.0	44.0	49.0	55.0	61.0	67.0	71.0	75.0	78.0	81.0	84.0	86.0	90.0	94.0	97.0
107	0.0	3.0	5.0	7.0	10.0	14.0	18.0	23.0	27.0	31.0	35.0	39.0	45.0	53.0	60.0	67.0	74.0	80.0	84.0	86.0	88.0	90.0	93.0	95.0
108	0.0	3.0	6.0	9.0	12.0	16.0	20.0	24.0	28.0	33.0	38.0	43.0	50.0	59.0	69.0	75.0	80.0	84.0	87.0	90.0	92.0	94.0	96.0	98.0
109	0.0	3.0	6.0	10.0	13.0	16.0	19.0	23.0	26.0	29.0	33.0	39.0	47.0	58.0	68.0	75.0	80.0	83.0	86.0	88.0	90.0	92.0	95.0	97.0
110	0.0	1.0	3.0	5.0	7.0	9.0	12.0	15.0	18.0	21.0	25.0	29.0	36.0	45.0	56.0	68.0	77.0	83.0	88.0	91.0	93.0	95.0	97.0	99.0
111	0.0	1.0	2.0	3.0	4.0	5.0	6.0	8.0	11.0	15.0	20.0	28.0	41.0	54.0	65.0	74.0	82.0	87.0	92.0	94.0	96.0	97.0	98.0	99.0
112	0.0	0.0	0.0	1.0	2.0	3.0	4.0	5.0	7.0	12.0	17.0	24.0	33.0	42.0	55.0	67.0	76.0	83.0	89.0	92.0	94.0	96.0	98.0	99.0
113	0.0	1.0	2.0	3.0	4.0	5.0	6.0	8.0	10.0	13.0	17.0	22.0	31.0	42.0	52.0	60.0	68.0	75.0	80.0	85.0	89.0	92.0	96.0	98.0
114	0.0	1.0	2.0	4.0	6.0	8.0	11.0	13.0	15.0	18.0	21.0	26.0	32.0	38.0	46.0	55.0	64.0	71.0	77.0	81.0	85.0	89.0	93.0	97.0
115	0.0	1.0	2.0	3.0	4.0	5.0	6.0	8.0	10.0	14.0	19.0	26.0	34.0	45.0	56.0	66.0	76.0	82.0	86.0	90.0	93.0	95.0	97.0	99.0
116	0.0	1.0	3.0	5.0	7.0	9.0	12.0	15.0	18.0	21.0	25.0	29.0	36.0	45.0	56.0	68.0	77.0	83.0	88.0	91.0	93.0	95.0	97.0	99.0
117	0.0	1.0	2.0	3.0	4.0	5.0	7.0	9.0	11.0	14.0	17.0	22.0	31.0	42.0	54.0	65.0	74.0	83.0	89.0	92.0	95.0	97.0	98.0	99.0
118	0.0	1.0	2.0	3.0	5.0	7.0	10.0	14.0	18.0	22.0	27.0	32.0	37.0	46.0	58.0	69.0	80.0	89.0	93.0	94.0	95.0	96.0	97.0	97.0
119	0.0	2.0	4.0	6.0	8.0	12.0	16.0	20.0	25.0	30.0	35.0	41.0	47.0	56.0	67.0	75.0	81.0	85.0	87.0	89.0	91.0	93.0	95.0	97.0
120	0.0	1.0	2.0	4.0	6.0	7.0	9.0	12.0	15.0	18.0	23.0	31.0	40.0	48.0	57.0	63.0	72.0	78.0	88.0	92.0	96.0	97.0	98.0	99.0
[2]121	0.0	8.0	16.0	25.0	33.0	41.0	46.0	50.0	53.0	54.0	55.0	56.0	56.5	57.0	57.8	58.0	58.8	60.0	61.0	63.0	66.5	72.0	80.0	90.0
122	0.0	7.0	14.0	20.0	25.5	33.5	38.0	43.0	46.0	50.0	52.5	54.5	56.0	58.0	59.0	60.0	61.5	63.0	65.0	68.0	72.0	79.0	86.0	93.0
123	0.0	4.0	8.0	12.0	17.0	23.0	29.0	34.0	38.0	44.0	49.0	53.0	56.0	59.0	62.0	65.0	69.0	72.0	75.0	79.0	83.0	88.0	93.0	96.0
124	0.0	4.0	9.0	15.0	23.0	29.0	34.0	40.0	44.0	48.0	50.0	51.0	52.0	53.0	55.0	57.0	60.0	62.0	64.0	67.0	72.0	80.0	88.0	95.0
125	0.0	7.0	12.0	17.0	24.0	30.0	39.0	45.0	50.0	53.0	55.0	56.0	57.0	58.0	59.0	61.0	62.0	63.0	64.0	66.0	70.0	77.0	84.0	92.0

Special Erosion Situations

- Splash Erosion Reduction in Ponded Water
  - computes reduced R values based on hillslope gradient and 10-yr frequency EI
- Erosion from Snowmelt, Rain on Snow, and Thawing Soil
- Estimating R Factors from Limited Data by referring users to Renard and Freimund (1994)

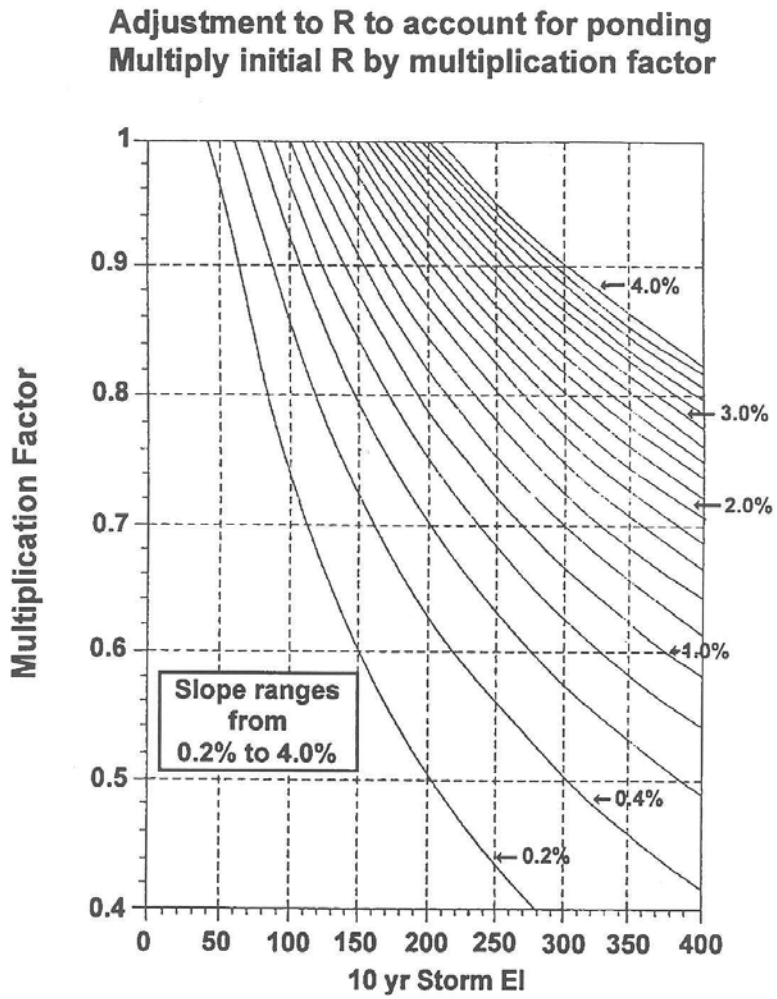
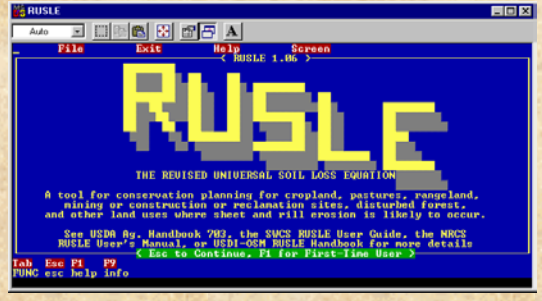


Fig. 2-6. Corrections for R factor for flat slopes and large R values to reflect amount of rainfall on ponded water.



RUSLE Exercises

Ex1: Fill Embankment Stabilization During Highway Construction

- **Scenario 1: No Erosion Control**
  - creating input files
  - selecting CITY codes
  - entering inputs
  - progress through input screens
  - run the program
  - save a file

Soil Erodibility (K)

- K is based on soil properties
- Obtained from Soil Surveys or Soil-Erodibility Nomograph Equations
- RUSLE computes adjusted K based on seasonal variation of climate for eastern 2/3 of the U.S.
- Relationship of K Factor to Soil Properties
  - clays have low K values (0.05-0.15)
  - sands have low K values (0.05-0.2)
  - loams have moderate K values (0.25-0.45)
  - silts have high K values (0.45-0.65)

Soil Erodibility (K)

- Organic matter reduces erodibility
  - binds particles together
  - increases aggregation
  - improves biological activity
  - increases infiltration rates
- Permeability dictates K
  - affects runoff rates
  - affects detachment and infiltration rates
  - mineralogy such as kaolinite, montmorillonite
  - sodic soils seal quickly thus reducing permeability

Table 3-3. Soil-water data for major USDA soil textural classes

Texture	Permeability code[1]	Saturated hydraulic conductivity[2] (in/hr)	Hydrologic soil group[3]
Silty clay, clay	6	<0.04	D
Silty clay loam, sand clay	5	0.04-0.08	C-D
Sandy clay loam, clay loam	4	0.08-0.2	C
Loam, silt loam[4]	3	0.2-0.8	B
Loamy sand, sandy loam	2	0.8-2.4	A
Sand	1	>2.4	A+

[1]Permeability codes used in figure 3-1. See National Soils Handbook No. 430 (USDA 1983) for permeability classes.
[2]Rawls et al. (1982)
[3]See National Engineering Handbook (USDA 1972).
[4]Note: Although silt texture is missing because of inadequate data, this should be in permeability class 3.

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Soil Erodibility (K)

Determining K Values

- Undisturbed Soils: Use NRCS soil-survey information
  - Check to see if K has been adjusted for Rock Fragments
  - (K_f) Fine-earth fraction = adjusted for soil fines less than 2mm in diameter and the effect of rock fragments
  - (Kw) Whole soil = adjusted for all soil-particle sizes and the effect of rock fragments

- Disturbed Soils: Compute K using the RUSLE soil-erodibility nomograph

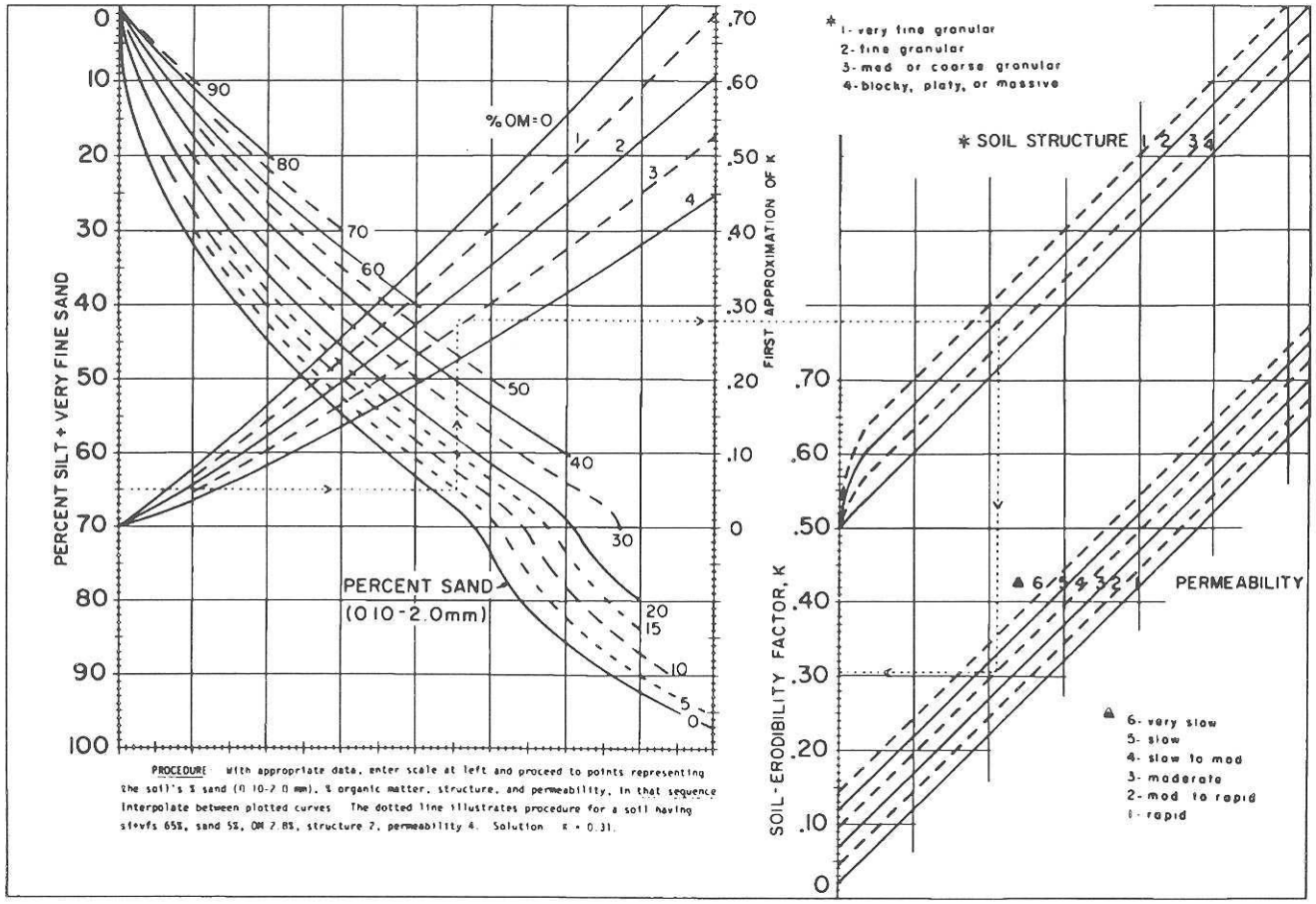

Fig. 3-1. Soil-erodibility nomograph (after Wischmeier and Smith 1978). For conversion to SI divide K values of this nomograph by 7.59. K is in U.S. customary units.

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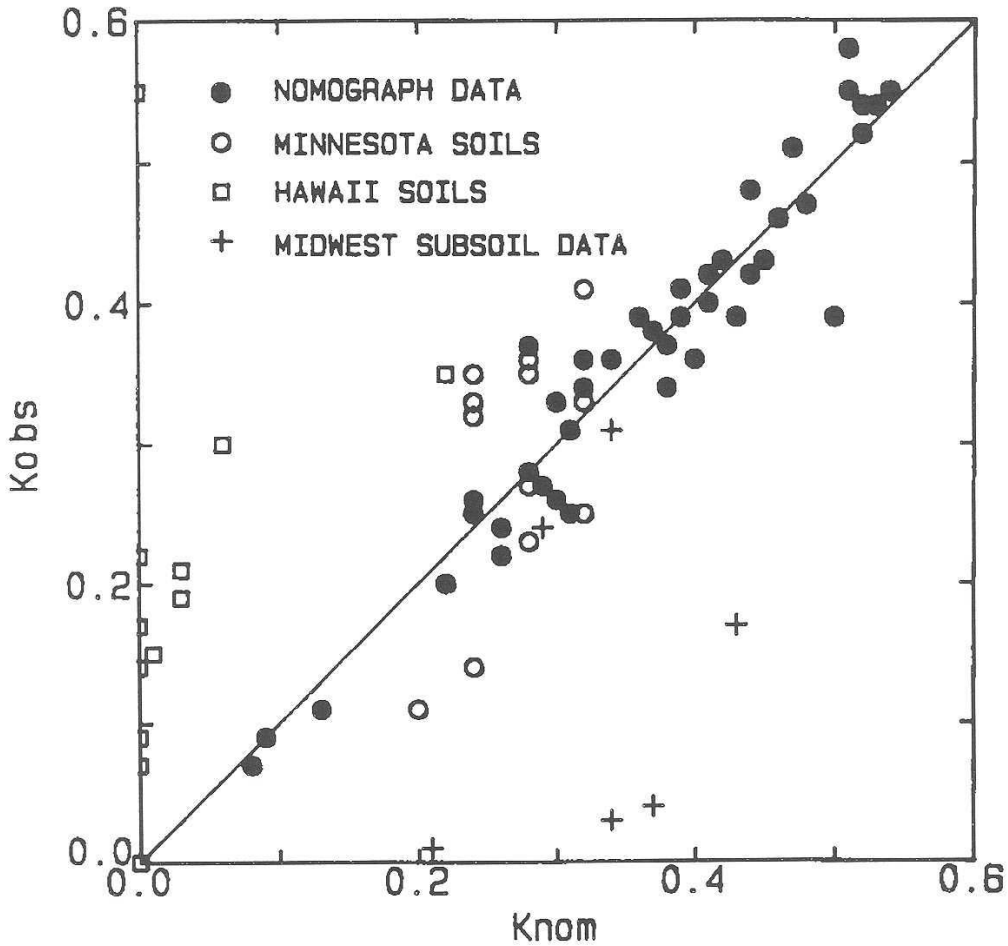


Units of tonCacreCh(hundreds of acre-ftCtonfCin)$^{-1}$

Wischmeier et al. 1971

Young and Mutchler 1977

9 El-Swaify and Dangler 1976

+ Romkens et al. 1975

Fig. 3-2 Relationship between observed and nomograph-predicted soil-erodibility factor values of several U.s. date sets.

Soil Erodibility (K)

- Temporal Variability in K
  - Soil Erodibility varies during the year
  - Freeze and Thaw is responsible for increased erodibility in spring
  - Low K seen in autumn months due to dryness
  - High K seen in summer months due to increased biological activity
- Adjusted K Values for temporal variability applicable to areas of eastern U.S. (East of 105^0 W. longitude)

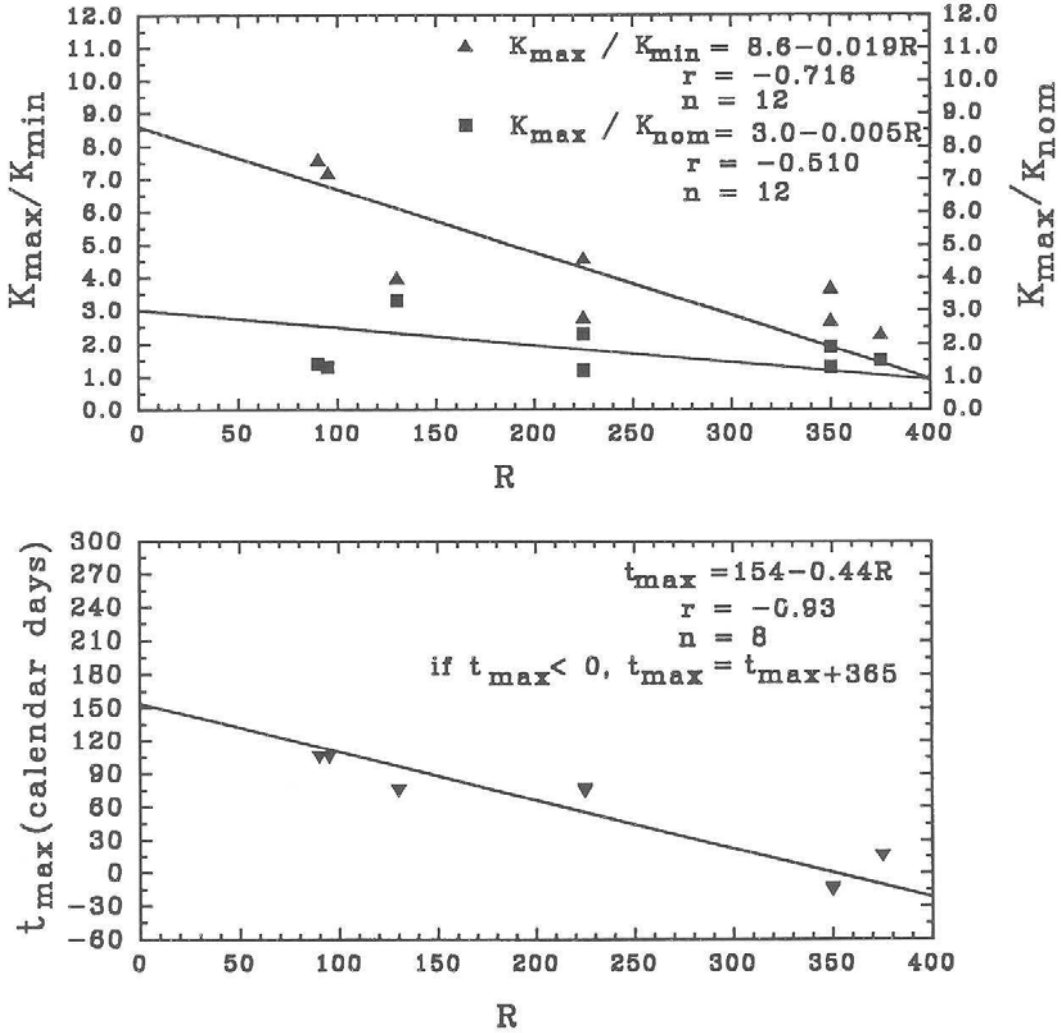


Fig. 3-4. K_{max}/K_{min}, K_{max}/K_{min}, and t_{max} relationships as a function of R for computing seasonal K-values. R is given in U.S. customary units.

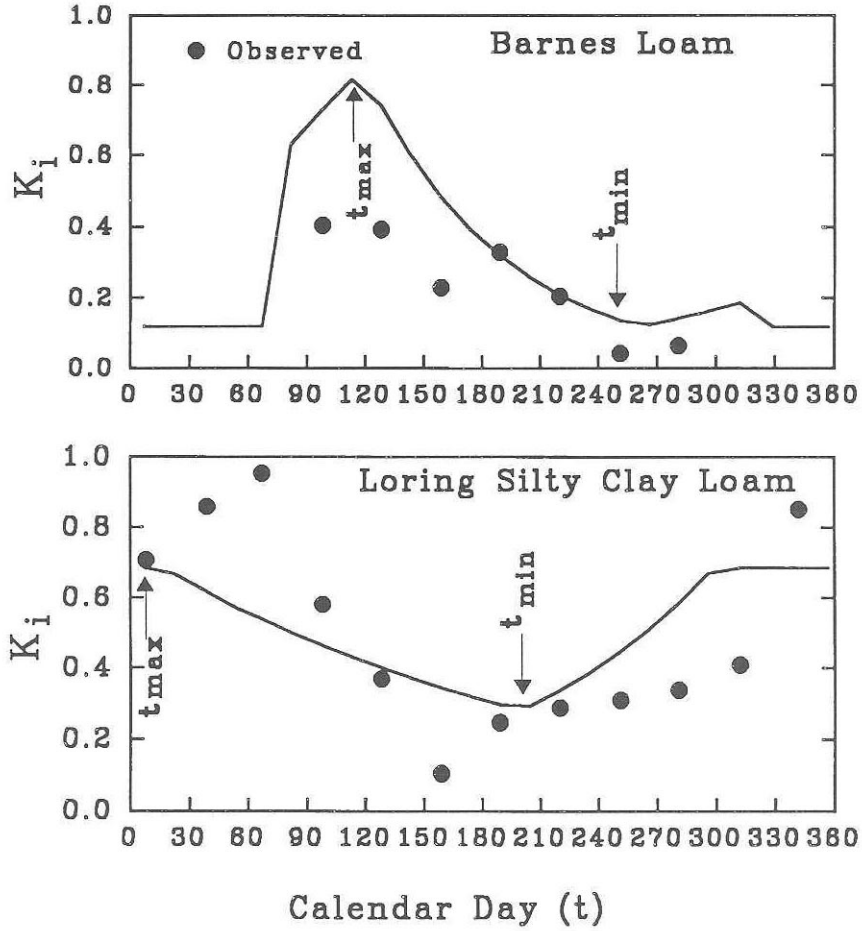


Fig. 3-6. Relationship of K_i to calendar days for a Barnes loam soil near Morris, Minnesota, and a Loring silty clay loam soil near Holly Springs, Mississippi. K is given in U.S. customary units.

Seasonal Variability for K

File Exit Help Screen

< Seasonally Variable K Factor 1.06 >

city code: 14001 EVANSVILLE IN estimated K: 0.28_

% rock cover: 0 # yrs to consolidate: 17 hyd. group: 2

soil series: surface texture: silt loam

1/1-1/15	1.0	0.359	7/1-7/15	7.0	0.193
1/16-1/31	2.0	0.411	7/16-7/31	7.0	0.17
2/1-2/15	3.0	0.475	8/1-8/15	7.0	0.148
2/16-2/28	3.0	0.544	8/16-8/31	6.0	0.13
3/1-3/15	3.0	0.55	9/1-9/15	4.0	0.12
3/16-3/31	4.0	0.484	9/16-9/30	4.0	0.137
4/1-4/15	5.0	0.422	10/1-10/15	3.0	0.157
4/16-4/30	5.0	0.371	10/16-10/31	3.0	0.18
5/1-5/15	5.0	0.326	11/1-11/15	2.0	0.208
5/16-5/31	6.0	0.287	11/16-11/30	2.0	0.238
6/1-6/15	6.0	0.25	12/1-12/15	2.0	0.272
6/16-6/30	7.0	0.22	12/16-12/31	3.0	0.311

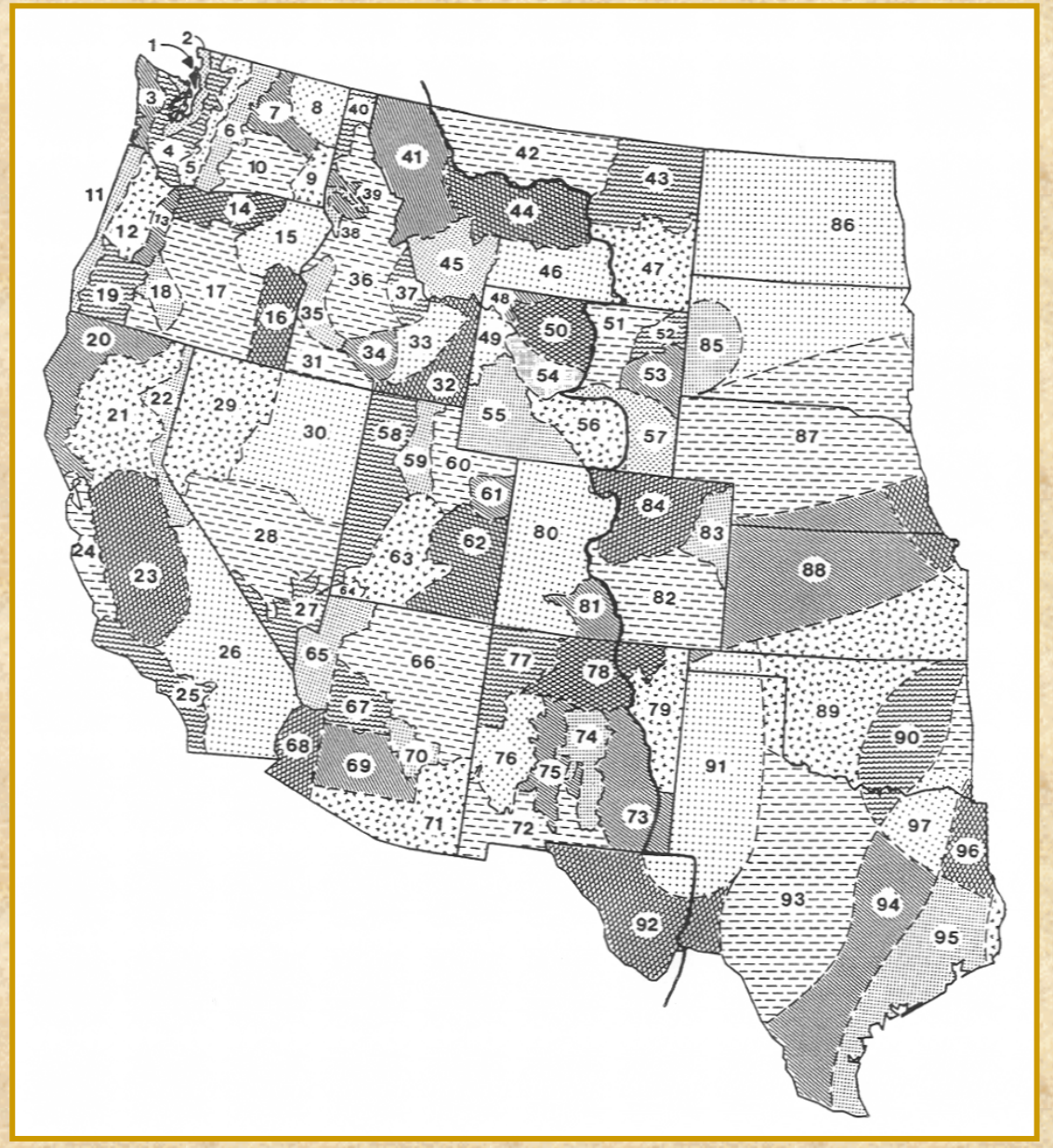
EI DIST.: 105 FREEZE-FREE DAYS: 216 AVERAGE ANNUAL K: 0.27

R VALUE: 200 Kmin = 0.117 on 9/5 Kmax = 0.56 on 3/6

< Esc exits >

Tab Esc F1 F2 F3 F4 F9

FUNC esc help clr cont call info



Map showing areas for which time-varying K should not be applied. Do not use time-varying K west of dark line.

Soil Erodibility (K)

Measured K Values from Reclamation Sites

- Black Mesa Mine Complex, Arizona.
  - 38 reclamation sites studied
  - Clay loam spoils range 0.04-0.21 with mean of 0.12
  - Very fine sandy loam, and clay loam soils averaged 0.33
- Appalachian coal mine spoil, Ohio.
  - Subsoil and resoil material averaged 0.12
- Kentucky studies
  - recently placed spoils averaged 0.18
  - spoil after six months of weathering was 0.19

Cover-Management (C)

- C represents the effects of vegetation, management, and erosion control practices
- RUSLE provides two C Factor options
  - time-invariant
  - time-variant
- RUSLE C Sub-factors
  - prior land use (PLU)
  - canopy cover (CC)
  - surface cover (SC)
  - surface roughness (SR)
  - antecedent soil moisture (SM)

Cover-Management (C)

RUSLE C Factor Options

- ***time-invariant:*** used for constant conditions that do not change sufficiently over time
  - rangeland
  - pastureland
  - conditions prior to disturbance

Cover-Management (C)

RUSLE C Factor Options

- ***time-variant:*** used where changes in vegetation and soil conditions significantly affect soil-loss rates
  - reclaimed prime agricultural lands
  - crop rotation sequences used on annual or longer cycles
  - pasture or rangeland where vegetation varies significantly during the year
  - first few years after revegetation of a reclaimed site

Cover-Management (C)

RUSLE C Sub-Factors

prior land use (PLU): reflects effects of soil loosening by tillage or other deep disturbance, and soil biomass on soil-loss rates

- *ex.* a plowed meadow or pasture is about 25% as erodible as land under continuous cropping due to effects of vegetation incorporated by tillage and stable soil aggregates formed under sod
- PLU is high during mining from less biomass due to stripped and stockpiled topsoil

prior land use (PLU) continued:

- tillage increases soil erodibility by effectively reducing soil consolidation and size of stable aggregates
- biomass and organic matter losses are minimized when topsoil and upper subsoil material is handled separately and directly spread on final-graded reclamation surface
- soil begins to consolidate once soil-disturbing activities cease
- soil is assumed to reach full consolidation 7 years after disturbance in eastern U.S. 20 years for western states
- consolidation time is a function of rainfall amount and characteristics

Cover-Management (C)

RUSLE C Sub-Factors

surface cover (SC): material in contact with soil that both intercepts raindrops and slows surface runoff

- mulches, rock fragments, live vegetation, and plant litter
- effectiveness of SC depends on type of soil erosion, slope gradient, extent of contact, and type of SC material
- SC is more efficient at reducing rill erosion rates than reducing interrill erosion rates
- SC is most effective on steep slopes (>10%)

Surface cover (SC) continued:

- based on land use, RUSLE computes a “b value”, which reflects effectiveness of SC in reducing soil-loss rates
- b increases as effectiveness of SC increases
- b increases for land uses where hillslope gradient increases
- *exception:* disturbed lands where SC is not in full contact with soil surface. Therefore, b increases with slope to a critical point, then decreases with increasing slope
- effectiveness of SC depends on good contact between soil and cover material, and cover remaining in place otherwise expect rill erosion
- mulch on subsoil = less contact and bonding, low “b value”
- mulch on topsoil = more contact and bonding, higher “b”

Surface cover (SC) continued:

b = 0.025	bare-soil rill erosion is low relative to interrill erosion, highly cohesive soils
b = 0.035	medium-textured soils disturbed for typical construction, coarse-textured soils for permanent pasture
b = 0.045	coarse rangeland soils with low rainfall
b = 0.050	bare-soil rill erosion > interrill erosion (steep slopes, long slopes, and soils easily eroded by overland flow) eg. thawing soils, soils high in silt, highly disturbed soils, coarse-textured soils

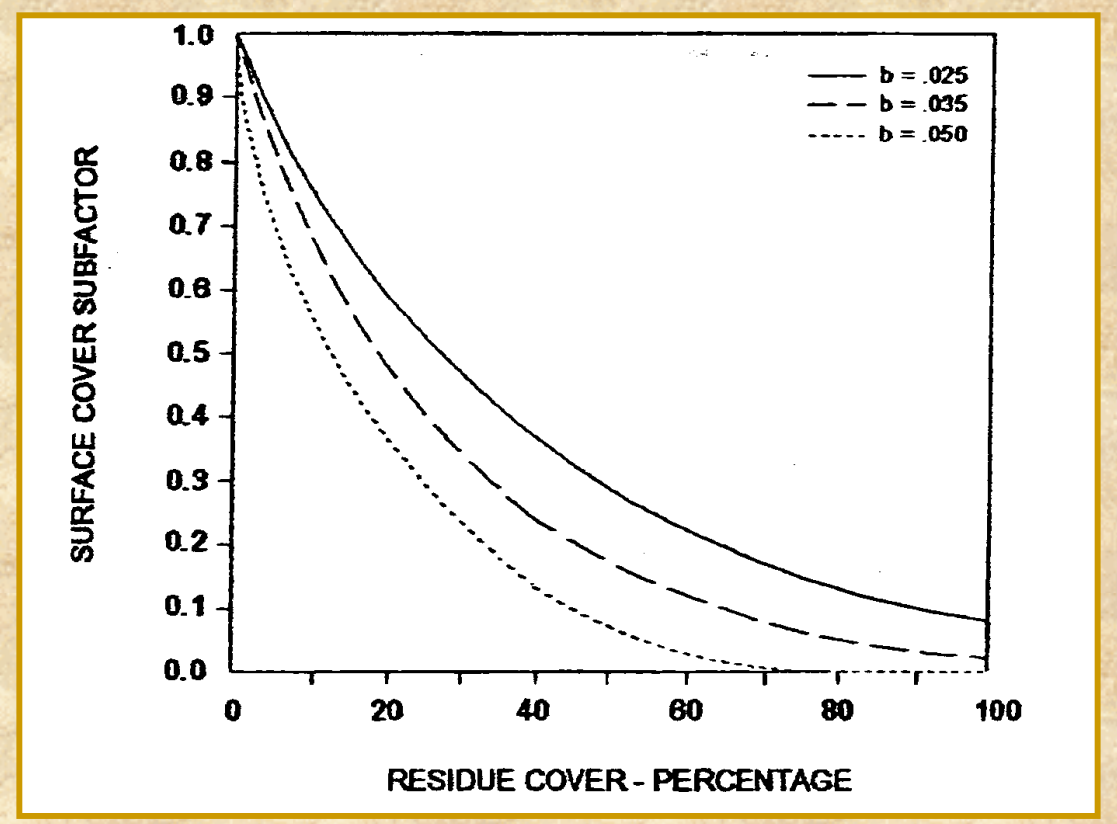
Surface cover (SC) continued:

- RUSLE inputs must reflect the mulch that remains in place
- crimping, netting, or tackifiers help secure mulch in place
- C values are based on combinations of mulch type, percent slope, and soil conditions
- RUSLE assumes that “placed topsoil” and “subsoil” are direct-hauled or stockpiled and well prepared to ensure optimum contact between soil and mulch material
- RULSE assumes that mulch is uniformly distributed and effectively anchored
- C values depends on when mulch is applied to the surface

Type of Mulch	Gradient (%)	Placed Topsoil	Subsoil	Stripped Topsoil
Straw, 2 tons/acre, 91% cover at placement, 84% cover at 3 months	1	0.10	0.10	0.09
	6	0.07	0.08	0.06
	15	0.06	0.08	0.04
	30	0.07	0.10	0.04
	50	0.08	0.11	0.03
Straw, 1 ton/acre. 69% cover at placement, 50% cover at 3 months	1	0.24	0.24	0.23
	6	0.18	0.20	0.16
	15	0.18	0.20	0.14
	30	0.18	0.24	0.12
	50	0.20	0.26	0.12
Straw, ½ ton/acre, 36% cover	1	0.35	0.35	0.34
	6	0.29	0.31	0.26
	15	0.28	0.32	0.23
	30	0.29	0.35	0.22
	50	0.30	0.38	0.21
Straw, 2 tons/acre, 20% rock fragment on soil before placement of mulch	1	0.09	0.09	0.09
	6	0.06	0.07	0.05
	15	0.06	0.08	0.04
	30	0.06	0.09	0.03
	50	0.07	0.10	0.03

Lexington Kentucky

- 150 ft hillslope
- "placed topsoil" and "placed subsoil" were dumped and bladed on March 15
- no initial vegetation
- no vegetation established for entire year
- C values 0.08 for first 3 months becomes 0.14 for the year



Relationship between percent residue cover and the RUSLE surface cover sub-factor

b = 0.025 rill to interrill erosion ratio low for bare soils

b = 0.05 rill to interrill erosion ratio is high for bare soils

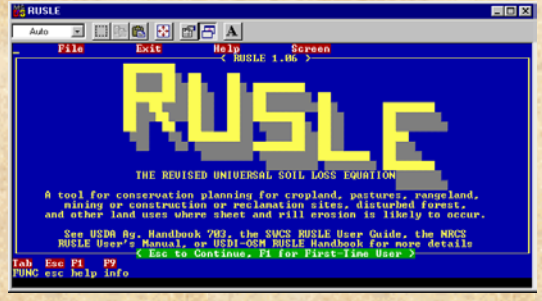
Surface cover (SC) continued:

- Manufactured erosion-control products affect rill and interrill erosion processes similarly as covers of natural materials

- important properties are:
  - percent of soil surface covered
  - mass of the applied material
  - rate at which the material decomposes
  - contact between mulch material and soil surface

Surface cover (SC) continued:

- Mined Lands
  - highly erodible conditions exist during site preparation when soil is bare and highly disturbed
  - high C values used to represent these conditions
  - C values are lower for “cut” materials because the soil is still consolidated and more resistant to erosion
  - C values are higher for “fill” materials because the soil has been loosened and soil-aggregation size has been reduced making soil much more susceptible to erosion processes
  - treat highly-compacted surfaces as “cut” condition



RUSLE Exercises

Ex1: Fill Embankment Stabilization During Highway Construction

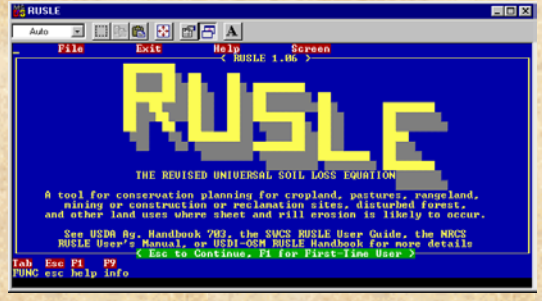
- **Scenario 2: Two Tons Per Acre Straw Mulch**
  - recall and modify previously saved files
  - time-varying option and long-term random roughness
  - time of soil consolidation
  - field operations display
  - ending a sequence of operations
  - half-month sub-factors and temporal residue decay
  - changes in previous land use and seasonal R factor distributions

Cover-Management (C)

RUSLE C Sub-Factors

canopy cover (CC): the vegetative cover above the soil surface that intercepts raindrops but does not contact the soil surface

- RUSLE utilizes percent of surface covered by canopy
- RUSLE also incorporates height within the canopy
- for plant communities with more than one type of vegetation, use the dominate cover type that dictates the effective raindrop ‘fall height’



RUSLE Exercises

Ex1: Fill Embankment Stabilization During Highway Construction

- **Scenario 3: Broadcast Seeding with Tall Fescue**
  - vegetation display and additional field-operation capabilities
  - result interpretation by half-month sub-factors to include canopy cover due to establishment and growth of grass cover
  - interplay between mulch decomposition and grass growth
  - relationships among mulch, grass growth, and temporal erosion potential

RUSLE Exercises

Ex1: Fill Embankment Stabilization During Highway Construction

- **Scenario 4: Rock Mulch**
  - substitution of rock cover to stabilize a fill outslope
  - field-operations data base
  - complete rock cover precludes post-reclamation land uses

Cover-Management (C)

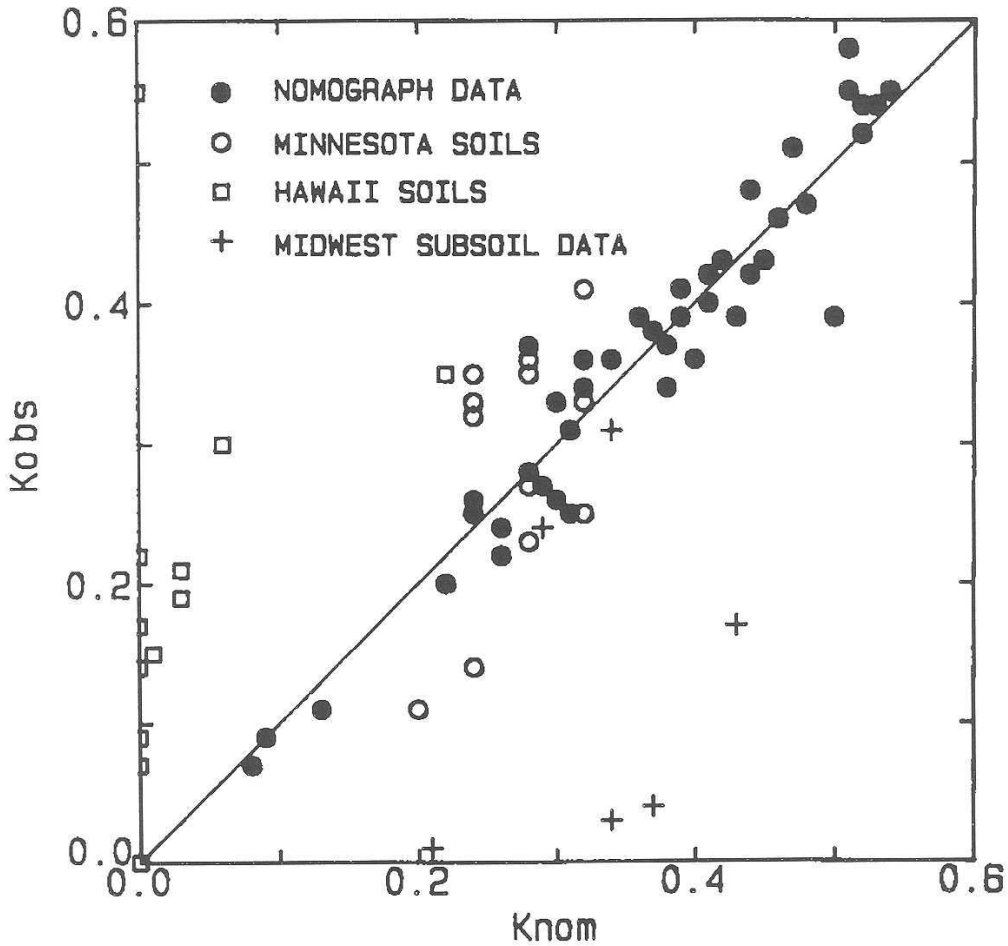
RUSLE C Sub-Factors

surface roughness (SR): two kinds

- ***oriented:*** has a recognizable pattern, the ridges and furrows left behind “cat-tracking” or a chisel plow. Oriented roughness is considered in the P Factor
- ***random:*** the standard deviation of the elevation from a plane across a tilled area after oriented roughness in taken into account. No recognizable pattern. Considered in the C Factor

Cover-Management (C)

- **Random Surface Roughness**
  - results from clods and aggregates produced by various soil-disturbing activities
  - depressions between the clods cause water to pond, slows runoff, increases infiltration, and stores sediment
  - to obtain Random Roughness: estimate or measure average distance between highest and lowest points on soil surface along furrow or ridge
  - *Ex:* Suppose average distance equals 9 inches, the RUSLE random roughness would equal 1.75 inches
  - Random Roughness tables exist for different types of rangeland communities and various tillage implements



Units of tonCacreCh(hundreds of acre-ftCtonfCin)$^{-1}$

Wischmeier et al. 1971

Young and Mutchler 1977

9 El-Swaify and Dangler 1976

+ Romkens et al. 1975

Fig. 3-2 Relationship between observed and nomograph-predicted soil-erodibility factor values of several U.s. date sets.

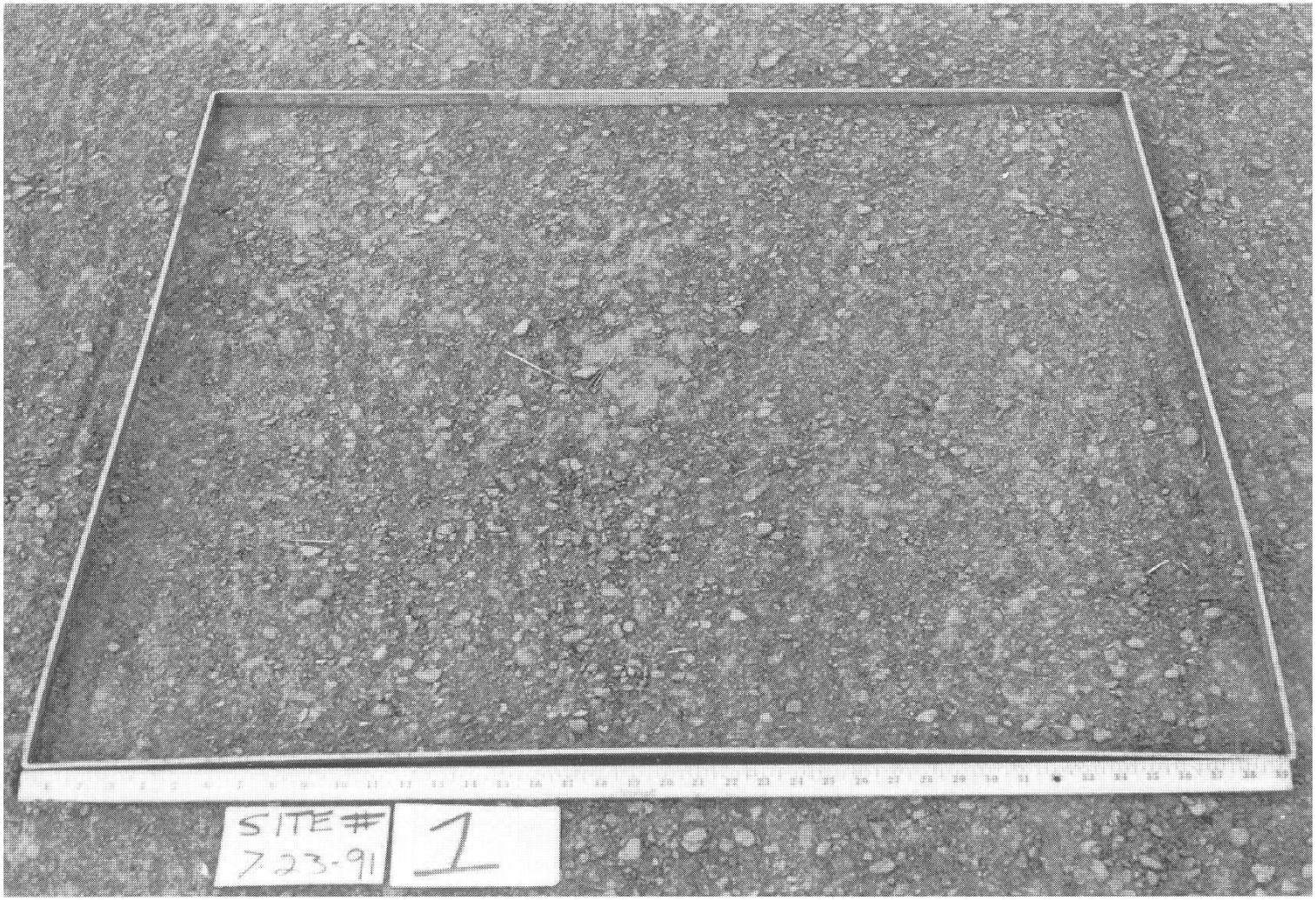


Figure C-1. Random roughness, R_t, of 0.25 in, site 1

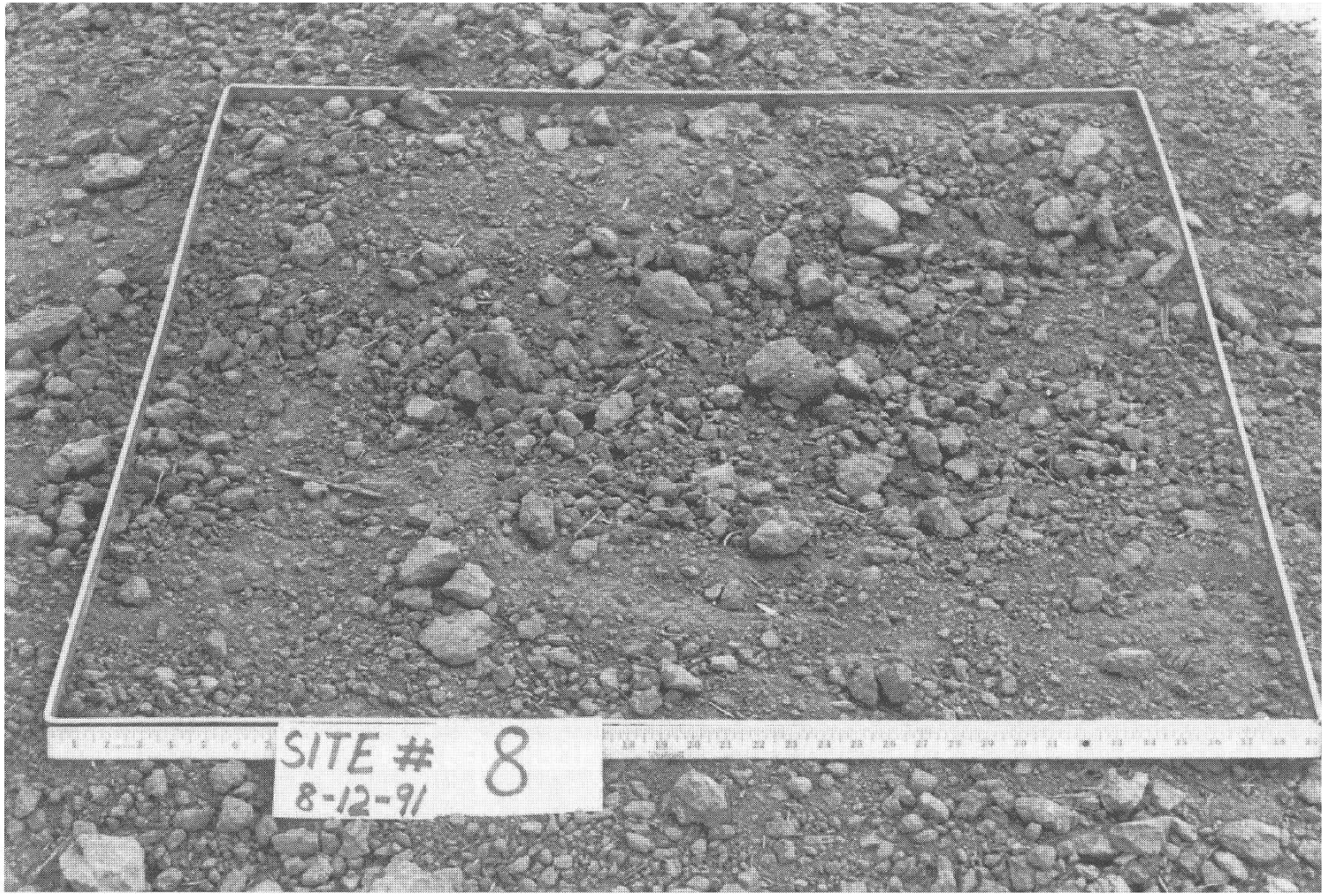


Fig. C-2. Random roughness, R_t, of 0.40-inches, Site 8

Fig. C-3. Random roughness, R_t, of 0.65-inches, Site 2

Fig. C-4. Random roughness, R_t, of 0.75-inches, Site 6

Fig. C-5. Random roughness, R_t, of 0.85-inches, Site 5

Fig. C-6. Random roughness, R_t, of 1.05-inches, Site 9

Fig. C-7. Random roughness, R_t, of 1.60-inches, Site 7

Fig. C-8. Random roughness, R_t, of 1.70-inches, Site 3

Fig. C-9. Random roughness, R_t, of 2.15-inches, Site 4

Attributes of typical tillage implements

Field operations	Random roughness (in)	Fraction of Residue left on surface (%)	Depth of incorporation (in)	Soil surface disturbed (%)
Chisel, sweeps	1.2	70	6	100
Chisel, straight point	1.5	60	6	100
Chisel, twisted shovels	1.9	45	6	100
Cultivator, field	0.7	75	3	100
Cultivator, row	0.7	80	2	85
Cultivator, ridge till	0.7	40	2	90
Disk, 1-way	1.2	30	4	100
Disk, heavy plowing	1.9	35	6	100
Disk, tandem	0.8	50	4	100
Drill, double disk	0.4	90	2	85
Drill, deep furrow	0.5	70	3	90
Drill, no-till	0.4	80	2	60
Drill, no-till into sod	0.3	90	2	20
Fertilizer applicator, anhydrous knife	0.6	80	2	15
Harrow, spike	0.4	80	2	100
Harrow, tine	0.4	85	2	100
Lister	0.8	20	4	100
Manure injector	1.5	50	6	40
Moldboard plow	1.9	5	8	100
Mulch treader	0.4	75	2	100
Planter, no-till	0.4	85	2	15
Planter, row	0.4	90	2	15
Rodweeder	0.4	90	2	100
Rotary hoe	0.4	85	2	100
Vee ripper	1.2	80	3	20

Table 5-6. Roughness values for rangeland field conditions

Condition	Random roughness (in)
California annual grassland	0.25
Tallgrass prairie	0.30
Clipped and bare	0.60
Pinyon/Juniper interspace	0.60
Cleared	0.70
Natural shrub	0.80
Seeded rangeland drill	0.80
Shortgrass, desert	0.80
Cleared and pitted	1.00
Mixed grass, prairie	1.00
Pitted	1.10
Sagebrush	1.10
Root-plowed	1.30

USDA Ag. Handbook No. 703

Random Surface Roughness (SR) continued:

- RUSLE automatically diminishes surface roughness through time as a function of accumulated rainfall volume and rainfall energy

Hillslope Length and Gradient (LS)

- LS accounts for the effect of topography on erosion
- Combines hillslope-length factor, (L) and hillslope-gradient factor, (S)
- RUSLE has been improved to use soil texture and general land use in the computation of LS

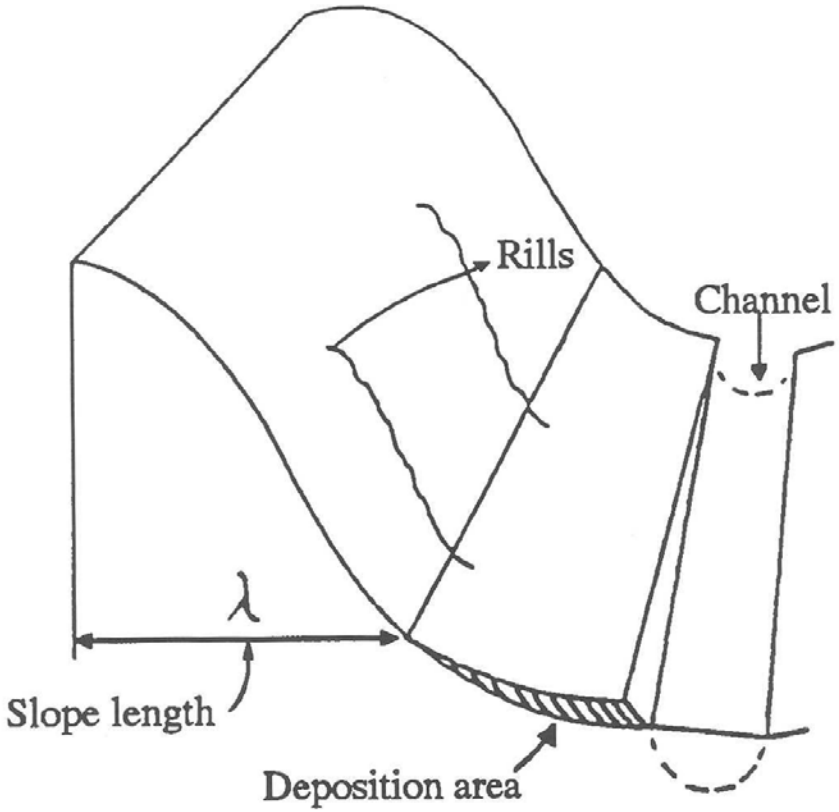


Fig. 1-1. Schematic slope profile for RUSLE applications for interrill and rill erosion. 8 is the RUSLE slope length (to the point where deposition occurs). Sediment yield is the sediment transported out of the channel section summed for time periods such as a storm event, month, crop stage, or year.

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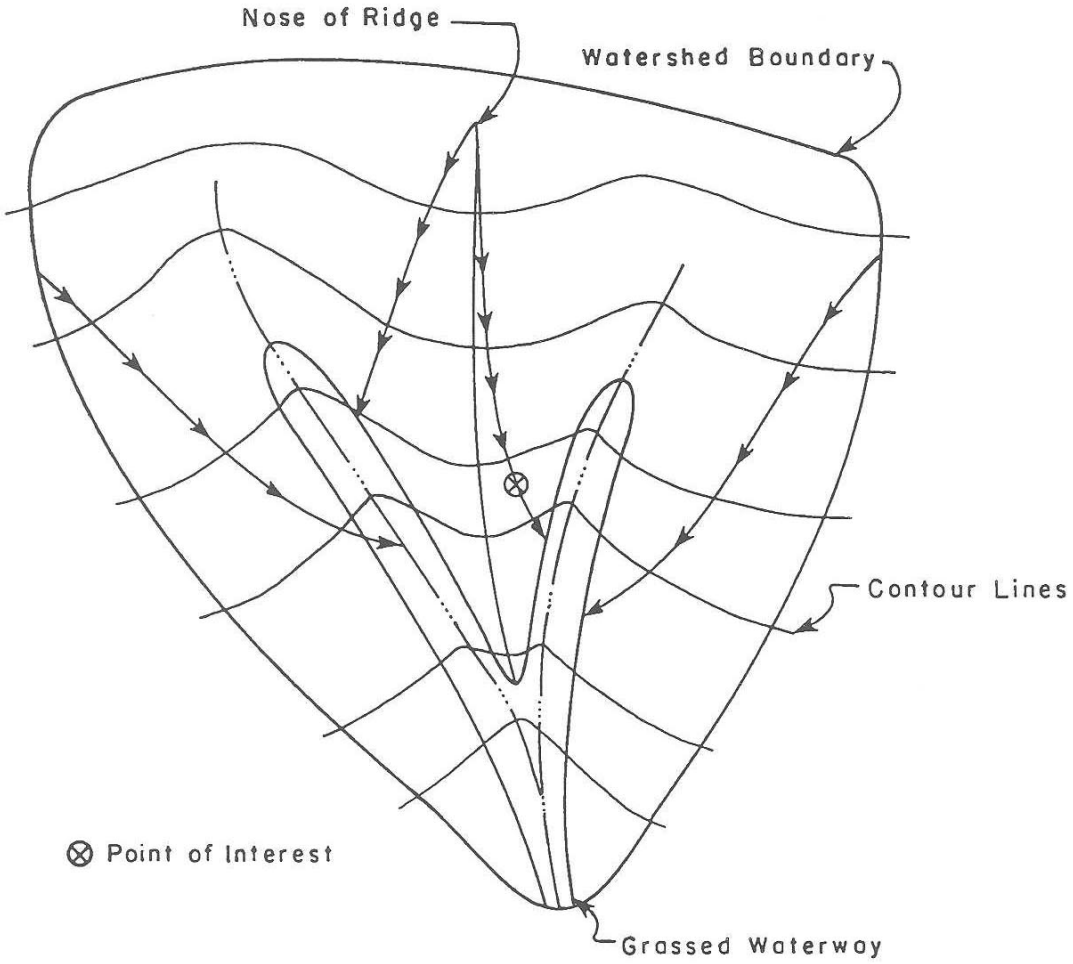

Fig. 4-2. Illustration of some RUSLE slope lengths

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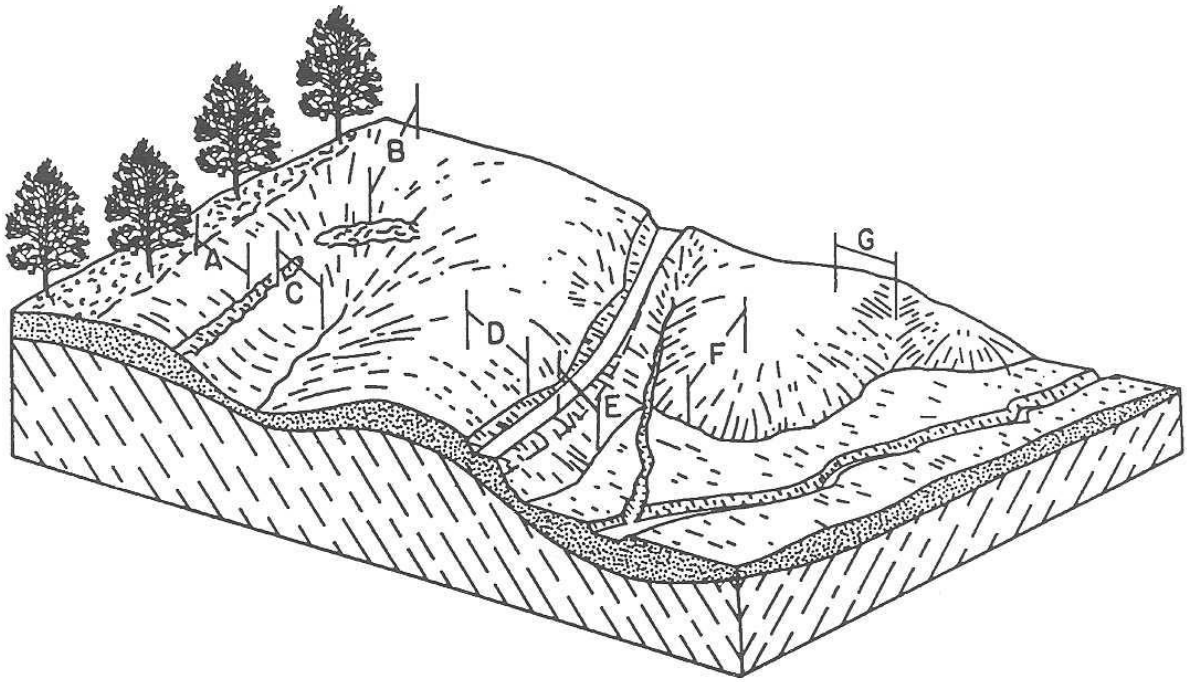

Fig. 4-1. Typical slope lengths (Dissmeyer and Foster 1980).

Slope A - If undisturbed forest soil above does not yield surface runoff, the top of slope starts with edge of undisturbed forest soil and extends down slope to windrow if runoff is concentrated by windrow.
Slope B - Point of origin of runoff to windrow if runoff is concentrated by windrow.
Slope C - From windrow to flow concentration point.
Slope D - Point of origin of runoff to road that concentrates runoff.
Slope E - From road to flood plain where deposition would occur.
Slope F - On nose of hill, from point to origin of runoff to flood plain where deposition would occur.
Slope G - Point of origin of runoff to slight depression where runoff would concentrate.

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Fig. 4-5B. One-foot contour interval map of the row crop field shown in figure 4-5A

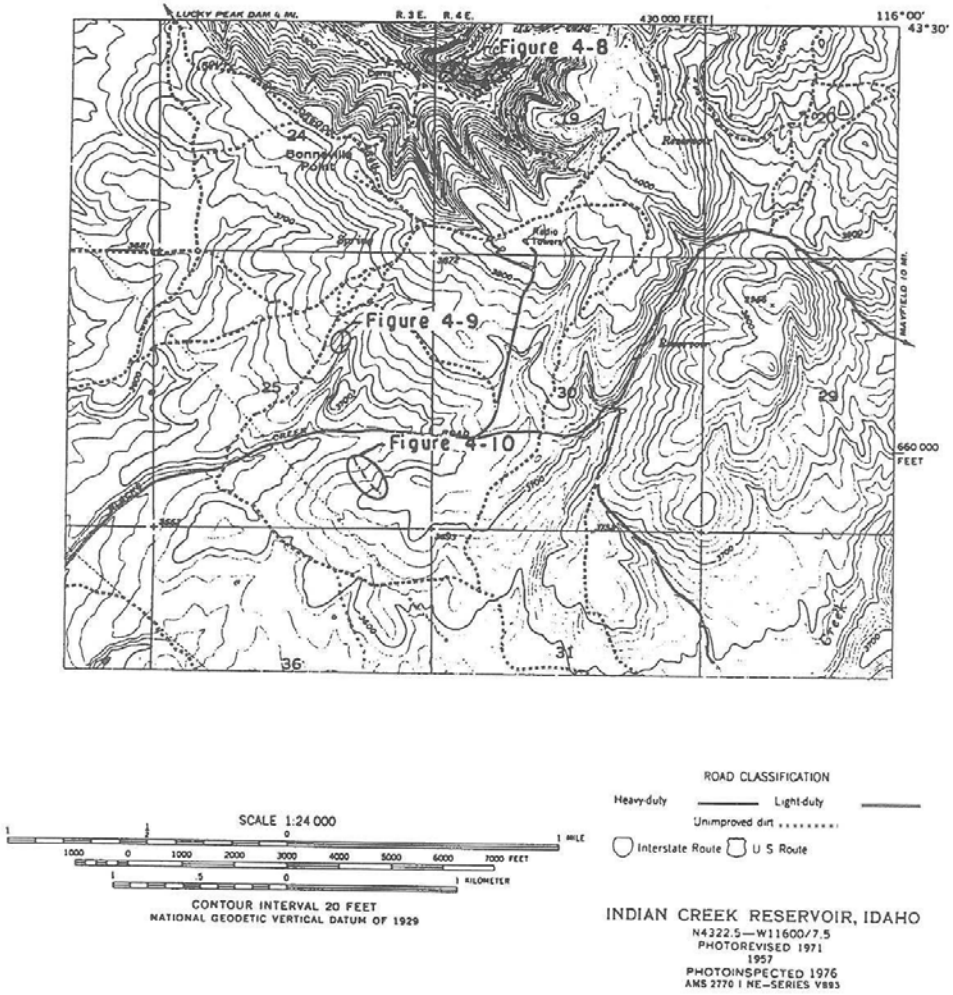
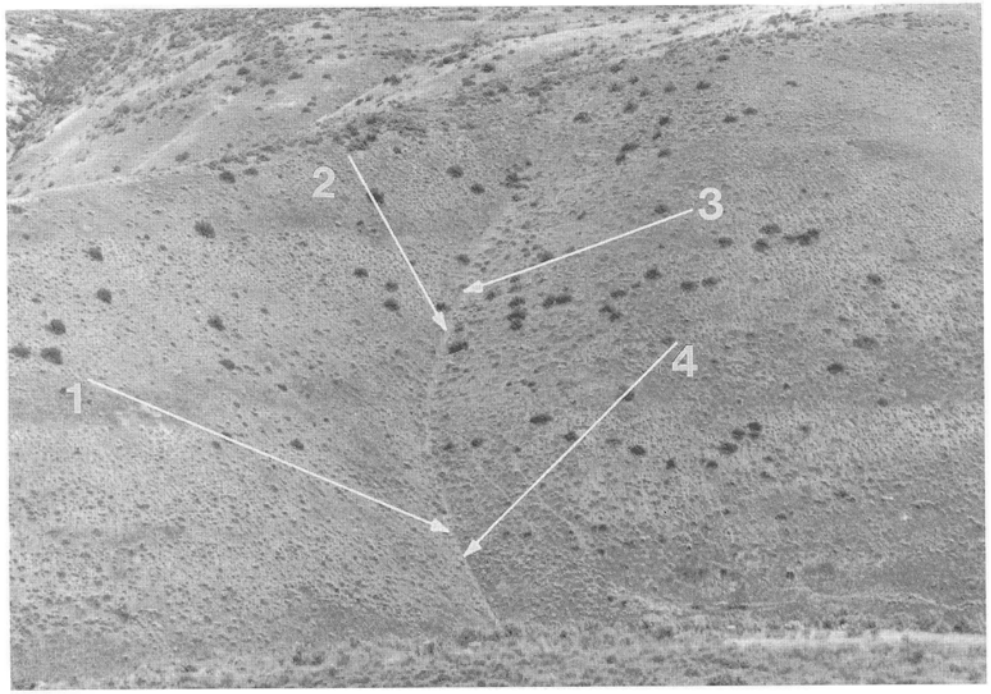
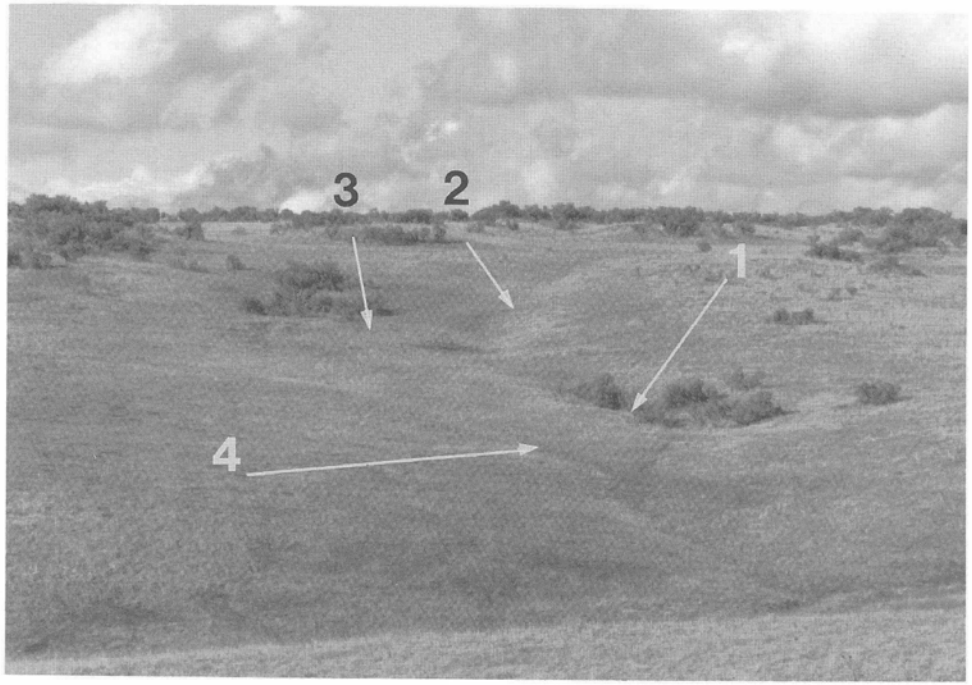


Fig. 4-7. Portion of Indian Creek Reservoir USGS 7-1/2-min. Quad Sheet showing an area east of Boise, Idaho



Transect	Slope length (λ) (ft)	Slope steepness (s) (%)	LS
1	225	61	15.44
2	135	53	10.32
3	150	45	9.39
4	375	60	20.18

Fig. 4-8. Small rangeland watershed on Lydle Creek east of Boise, Idaho



Transect	Slope length (λ) (ft)	Slope steepness (s) (%)	LS
1	165	14	2.53
2	30	6	0.53
3	50	16	1.85
4	60	14	1.70

Fig. 4-9. Small rangeland watershed on Blacks Creek east of Boise, Idaho

Hillslope-Length Factor (L)

- **Hillslope Length:** the distance from the origin of the overland flow to a point along the hillslope profile where either the gradient decreases to the extent that soil deposition occurs, or where the overland flow becomes concentrated in a well defined channel

- Main areas of deposition that terminate hillslope length for RUSLE occur on concave hillslopes
- "Rule of Thumb" deposition begins where gradient is one-half of average gradient for the concave profile

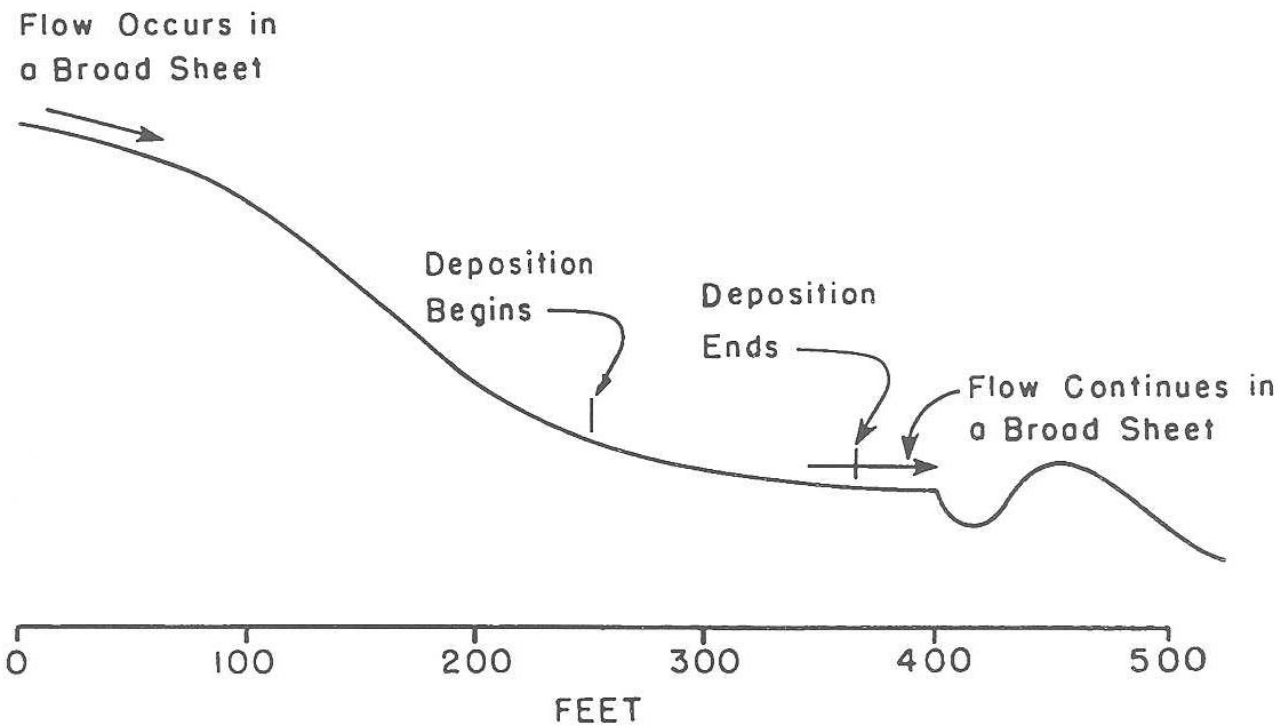


Fig. 4-3. Illustration of deposition beginning and ending on a slope

Hillslope Length and Gradient (LS)

- Effects of Hillslope Length on Soil Loss
  - depends on ratio of rill to interril erosion
  - ratio is a function of soil texture and general land use
  - high silt (>85%) have high rill to interrill (RtoI) erosion ratio
  - silt loam have high to moderate RtoI erosion ratio
  - high sand have moderate to low RtoI erosion ratio
  - high clay (>35%) have low RtoI erosion ratio
- Effects of Land Use on Soil Loss
  - disturbed mine or construction lands have high RtoI ratio
  - croplands and disturbed forests have moderate RtoI ratio
  - no-till cropland, pasture land, and range land have low RtoI erosion ratio

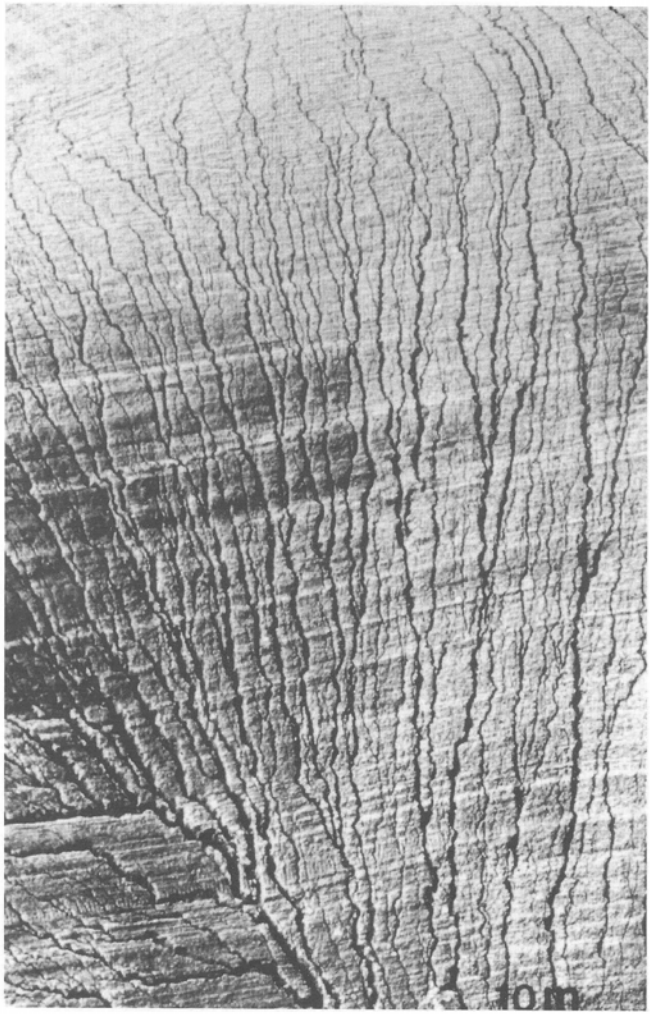


Fig. 4-4. Dendritic rill pattern on a concave, north-facing slope. Estimated soil loss was 82 ton/acre. From Frazier et al. (1983)

Fig. 4-6. Erosion from different crop managements on upper and lower halves of a slope. A large snow drift complicated the situation. From Frazier et al. (1983)

Hillslope-Length Factor (L)

- Soil Loss entirely generated by Interrill Erosion (nearly always uniform along a hillslope) produces an L value of 1
- Soil Loss entirely generated by Rill Erosion, L value increases linearly with length
- Soil Loss is usually a combination of Rill and Interrill
  - where interrill predominates, L value remains nearly constant as hillslope lengths increase
  - where rill erosion predominates, L values increase as hillslope lengths increase

Hillslope-Length Factor (L)

- *Example:* Assume concave hillslope decreases from 18% (at upper end) to 2% gradient (at lower end)
  - average gradient = 10%
  - 1/2 of average gradient = 5%
  - deposition assumed to begin at location where hillslope flattens to 5% gradient thus equaling the segment's endpoint
- *Example 2:* Assume concave hillslope decreases from 4% (at upper end) to 2% (at lower end)
  - average gradient = 3%
  - 1/2 of average gradient = 1.5%
  - no deposition because slope does not drop below 2%

Hillslope-Length Factor (L)

- When RUSLE soil-loss values are used to estimate off-site sediment delivery
- Hillslope Length is measured from origin of overland flow through the depositional area
- Accuracy of L Estimates:
  - most accurate for hillslope lengths of 35 to 300ft
  - moderately accurate for hillslope lengths of 20 to 35 and 300 to 600ft
  - least accurate for hillslope lengths from 600 to 1000ft and should not be used for lengths longer than 1,000 feet

Hillslope-Gradient Factor (S)

- Soil Loss increases more rapidly as gradient increases than as length increases.
  (S is more sensitive than L)
- Rill erosion is affected more by hillslope gradient than is interrill erosion
- Accuracy of S Estimates:
  - most accurate for hillslope gradients from 3 to 20%
  - moderately accurate for gradients 1 to 3% and 20 to 35%
  - least accurate for gradients exceeding 35%

Hillslope Length and Gradient (LS)

- Entering LS data for disturbed land
  - assumes rill erosion > interill erosion
  - L is influenced by the “cut” or “fill” nature of the material
  - topsoil surface is assumed to be less susceptible to rill erosion than subsoil
- Research shows some graded spoil materials are highly erodible due to high bulk densities, crusting, and low porosities resulting in low permeabilities and infiltration capacities
- Influence of land use on LS is greater for long hillslopes than for short hillslopes because of greater downslope accumulation of runoff

Hillslope Length and Gradient (LS)

Hillslope Length = 100 ft, silt loam soil	Land Use		
Slope Gradient (%)	Disturbed Land, Subsoil Fill	Regularly Tilled Cropland	Pasture Land
0.5	0.088	0.086	0.085
1	0.15	0.14	0.14
3	0.41	0.39	0.37
6	0.82	0.77	0.73
10	1.46	1.38	1.29
15	2.52	2.38	2.22
20	3.57	3.39	3.16
30	5.59	5.32	4.96
50	9.15	8.74	8.16

LS values for 100-ft hillslopes

Hillslope Length and Gradient (LS)

Hillslope Length = 600 ft, silt loam soil	Land Use		
Slope Gradient (%)	Disturbed Land, Subsoil Fill	Regularly Tilled Cropland	Pasture Land
0.5	0.12	0.099	0.090
1	0.24	0.19	0.16
3	0.98	0.66	0.48
6	2.47	1.64	1.09
10	5.04	3.38	2.17
15	9.49	6.53	4.12
20	14.1	9.91	6.23
30	23.4	16.9	10.6
50	40.4	29.9	19.1

LS values for 600-ft hillslopes

Hillslope Length and Gradient (LS)

Hillslope Profile Forms:

- Uniform
  - moderately erosive
- Concave
  - least erosive
  - steepest where flow is least, therefore less erosion; most deposition occurs at toe of slope where slope lessens
- Convex
  - most erosive
  - steepest at toe of slope where runoff is greatest
- Complex (convex-concave)
  - *optimal:* convex at top of slope and concave at toe

RUSLE Exercises

Ex2: Reclaimed Outslope Reconstruction

- **Scenario 1: Uniform Hillslope**
  - input and evaluate a *uniform* hillslope profile
  - calculate K values based on inputs of soil-particle size percentages
  - account for the effect of percent rock fragments
  - account for the effect of specifying a roughened soil-surface
  - a method to estimate surface roughness

RUSLE Exercises

Ex2: Reclaimed Outslope Reconstruction

- **Scenario 2: Concave Hillslope**
  - input and evaluate a *concave* hillslope profile
  - calculate K values based on inputs of soil-particle size percentages
  - account for the effect of percent rock fragments
  - account for the effect of specifying a roughened soil-surface
  - a method to estimate surface roughness

RUSLE Exercises

Ex2: Reclaimed Outslope Reconstruction

- **Scenario 3: Convex Hillslope**
  - input and evaluate a *convex* hillslope profile
  - calculate K values based on inputs of soil-particle size percentages
  - account for the effect of percent rock fragments
  - account for the effect of specifying a roughened soil-surface
  - a method to estimate surface roughness

RUSLE Exercises

Ex2: Reclaimed Outslope Reconstruction

- **Scenario 4: Complex Hillslope**
  - input and evaluate a *complex* hillslope profile
  - calculate K values based on inputs of soil-particle size percentages
  - account for the effect of percent rock fragments
  - account for the effect of specifying a roughened soil-surface
  - a method to estimate surface roughness

Support-Practice (P)

- P Value is the ratio of soil loss with a specific support practice to the corresponding soil loss with straight-row upslope and downslope tillage

- P factor accounts for control practices that reduce erosion potential of runoff by influencing drainage patterns, runoff concentration, runoff velocity, and hydraulic forces exerted by runoff on soil

Support-Practice (P)

- Support Practices that Influence P
  - tillage (furrowing, soil replacement, seeding, etc.)
  - strips of close growing vegetation
  - deep ripping
  - terraces
  - diversions
  - concave slopes
  - silt fences
  - *in general:* soil-management practices orientated on or near the contour that result in the collection and storage of moisture and reduction of runoff

Support-Practice (P)

- Sediment Yield from Concave Hillslopes
  - the depositional area at base of hillslope should be described with at least four segments
  - gradient of last segment requires careful delineation due to its greatest effect on sediment yield
  - gradient at lower end of hillslope controls sediment amount that leaves the hillslope
  - degree of concavity = the ratio of gradient at upper end of hillslope to the average gradient for entire slope
  - sediment-delivery ratios are affected by cover-management conditions along the hillslope

Support-Practice (P)

- Example Calculations of Concavity
  - Upper slope gradient 19%
  - Lower slope gradient 1%
  - Average slope gradient 10%
  - Degree of Concavity 19 / 10 = 1.9

RUSLE Exercises

Ex3: Sediment Yield and Deposition Along a Hillslope

- **Scenario 1: No Erosion Controls, a Uniform Hillslope of 5%**
  - RUSLE can predict sediment yield at the end of a hillslope
  - off-site assessments can be made
  - predict quantity of sediment on average annual basis
  - estimate sediment-storage requirements for sediment-control structures

RUSLE Exercises

Ex3: Sediment Yield and Deposition Along a Hillslope

- **Scenario 2: No Erosion Controls, a Concave Hillslope from 10 to 1%**
  - predict sediment yield at the end of a hillslope
  - off-site assessments can be made
  - predict quantity of sediment on average annual basis
  - estimate sediment-storage requirements for sediment-control structures

RUSLE Exercises

Ex3: Sediment Yield and Deposition Along a Hillslope

- **Scenario 3: No Erosion Controls, a Convex Hillslope from 1 to 10%**
  - predict sediment yield at the end of a hillslope
  - off-site assessments can be made
  - predict quantity of sediment on average annual basis
  - estimate sediment-storage requirements for sediment-control structures

RUSLE Exercises

Ex4: Terraces, Deep Ripping, and Contour Furrows

- **Scenario 1: No Erosion Controls Measures**
  - time invariant C factor

Support-Practice (P)

- Terracing:
  - reduces interrill and rill erosion
  - breaks hillslope into shorter hillslope lengths
  - if terraces are level, low gradient, or have closed outlets, deposition along terraces trap much of the sediment eroded from inter-terrace surfaces above
- Terrace P Sub-Factors
  - conservation planning (terraces protecting soil resources)
  - sediment yield (estimate sediment quantity leaving a slope)
  - sediment-delivery ratio (deposition depends on extent that sediment load exceeds transport capacity)
  - transport capacity is a function of runoff and grade of the terrace channel. Deposition depends of sediment characteristics

- Terracing

	Soil Loss on Inter-Terrace Interval (tons/acre/year)		
Terrace Grade (%)	6 t/ac/yr	15 t/ac/yr	28 t/ac/yr
0.1	0.20	0.12	0.10
0.2	0.32	0.18	0.13
0.5	0.78	0.36	0.23
0.75	1.00	0.53	0.32
1.0	1.00	0.71	0.42
1.5	1.00	1.00	0.62
2.0	1.00	1.00	0.83
2.5	1.00	1.00	1.00
3.0	1.00	1.00	1.00

Sediment-delivery ratios for graded terraces on sandy loam soil with hillslope length of 300ft and 10% gradient

	Terrace Grade (%)	
Soil Texture	0.1	0.5
Sand	0.14	0.77
Sandy loam	0.20	0.78
Silt loam	0.32	0.82
Silt	0.43	0.85
Clay	0.25	0.80

Sediment-delivery ratios for graded terraces as a function of soil textures, for 300ft 10% hillslope. Soil loss on the inter-terrace interval is 6 tons/acre/year

Soil Texture	Lexington, KY (A=6 t/ac/yr)	Huron, SD (A=1.8 t/ac/yr)	Dallas, TX (A=10.1 t/ac/yr)
Sand	0.14	0.17	0.12
Sandy loam	0.20	0.20	0.20
Silt loam	0.32	0.27	0.36
Silt	0.43	0.32	0.49
Clay	0.25	0.27	0.24

Same conditions with terrace grade 0.1% at three locations with different climates

Table 6-8. Computed critical slope length as a function of $(EI)_{10}$ storm erosivity and cover-management conditions [1]

$(EI)_{10}$ Storm erosivity	For cover-management condition[2]						
	C1 (ft)	C2 (ft)	C3 (ft)	C4 (ft)	C5 (ft)	C6 (ft)	C7 (ft)
10	1,000	1,000	1,000	1,000	1,000	1,000	933
25	1,000	1,000	1,000	1,000	1,000	824	348
50	1,000	1,000	1,000	1,000	885	387	184
100	1,000	1,000	1,000	1,000	446	201	104
200	1,000	1,000	1,000	579	243	111	61

[1] 7% slope, hydrologic soil group C

[2] Cover-management conditions are defined in table 6-4.

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Table 6-7. Critical slope length values computed by equation [6-12] and critical slope length values from AH 537

Slope (%)	From Equation [6-1][1] (ft)	From AH 537 (ft)
1.5	1000	400
4.0	384	300
7.0	200	200
10.5	125	120
14.5	80	86
18.5	60	64
23.0	50	50

[1]Moderate ridge height, hydrologic soil group C, C6 cover-management condition (defined in table 6-4), 100 ft·tonf·in (acre h)$^{-1}$ $(EI)_{10}$ storm

Source: Wischmeier and Smith (1978).

RUSLE Exercises

Ex4: Terraces, Deep Ripping, and Contour Furrows

- **Scenario 2: Terraces**
  - terrace systems
  - P values for conservation planning
  - estimating sediment that leaves a terrace

Support-Practice (P)

- Effectiveness of tillage practices
  - decreases through time
  - depends on climate, soil, topography, and cover

Common Mechanical Practices Applied to Rangelands, Reclaimed Lands, and Construction Sites

Practice	Degree of Disturbance	Surface Configuration	Estimated Duration of Effectiveness (Years)	Runoff Reduction
Rangeland drill	Minimal tillage except in furrow	Low ridges (<2 inches) and slight roughness	1- 2	None to slight
Contour furrow/ Pitting	Major tillage 8-12 inches deep	High ridges, about 6 inches (up to 9 in)	5-10	Slight to major
Chaining	Severe surface but shallow	Slight to moderate random roughness	3- 5	Slight to moderate
Land imprinting	Moderate-sized shallow depressions	Short channels (40 inches) & small to moderate ridges	2- 3	Slight to moderate
Disk plows, offset disks	Major tillage, about 4-8 inches deep	Moderate ridges 2-4 inches	3- 4	Slight to moderate
Grader Ripping, grubbing, root plowing	Minimal but often deep, 8+ inches	Slight to very rough, especially when done both up & down the hillslope & along the contour	4- 7	Moderate to major
Dozer Ripping	Moderate surface disturbance, 2 to 3 feet deep	Very rough, especially when done both up & down the hillslope & along the contour	5-10	Moderate to major

Support-Practice (P)

- Frequently Disturbed
  - terracing
  - contouring
  - permanent barriers
  - strips of close-growing vegetation
  - concave profiles
- Infrequently Disturbed
  - terracing
  - contouring
  - mechanical disturbances

Support-Practice (P)

- P is computed from the product of P Sub-Factors typically used in combination
  - contouring and terracing
  - towner disk or chisel plow with a rangeland drill

- Tillage and planting operations performed “on contour” reduce erosion from low to moderate intensity storms
- Contouring, however, provides little protection against high-intensity, long-duration storms

Support-Practice (P)

- Contour Tillage
  - along contour will partially or completely redirect runoff
  - high ridges left by tillage keep runoff within furrows
  - ridges placed precisely on contour produce maximum runoff storage and infiltration (minimizing runoff and erosion)
  - most effective when high ridges between furrows are constructed

Ex: Columbia, Missouri. Bare soil, 9% hillslope gradient, 72.6ft hillslope length, and low ridge height (<2in) had P = 0.96 when ridge height was increased to (>6in), P = 0.12, and effectively reduced erosion by more than 80%

Lexington, Kentucky: P values for contour furrowing on 300ft slope with 10% gradient

Ridge Height (inches)	About 50% Cover	Nearly Bare Soil
Very low (0.5-2)	0.66	0.81
Moderate (3-4)	0.42	0.67
Very high (>6)	0.35	0.57

Hydrologic Soil Group **A**

Ridge Height (inches)	About 50% Cover	Nearly Bare Soil
Very low (0.5-2)	0.85	0.98
Moderate (3-4)	0.58	0.89
Very high (>6)	0.35	0.81

Hydrologic Soil Group **B**

P values for contour furrowing on 300ft slope with 10% gradient

Ridge Height (inches)	About 50% Cover	Nearly Bare Soil
Very low (0.5-2)	1.00	1.00
Moderate (3-4)	0.70	0.95
Very high (>6)	0.41	0.89

Hydrologic Soil Group **D** from Lexington, Kentucky

Ridge Height (inches)	About 50% Cover	Nearly Bare Soil
Very low (0.5-2)	0.66	0.66
Moderate (3-4)	0.42	0.42
Very high (>6)	0.35	0.35

Hydrologic Soil Group **B** from Denver, Colorado

Support-Practice (P)

- Tillage operations carefully placed on contour
  - use “zero” for furrow grade
- Buffer strips and strips of close-growing vegetation
  - use a ratio of furrow grade to land gradient of 0.5%
- Tillage operations without carefully laying out contour lines but still on contour
  - use a ratio of furrow grade to land gradient of 0.1%
  - use 1% furrow grade for 10% land gradients

Support-Practice (P)

- Contouring:
  - alone is often inadequate for effective erosion control
  - reclamation plans should include terraces and down-drains for off-slope conveyance of runoff water
  - loses its effectiveness on long hillslopes
  - critical hillslope length is a function of hillslope gradient, ridge height, residue cover, and runoff potential

Support-Practice (P)

Hydrologic Soil Group	About 50% Cover	Nearly Bare Soil
A (low runoff potential)	>1000	238
B (moderate runoff potential)	859	147
D (very high runoff potential)	589	113

Critical hillslope length (ft) for contour furrowing on a 300 ft long hillslope with 10% gradient (Lexington, KY)

Hillslope Gradient (%)	About 50% Cover	Nearly Bare Soil
5	>1000	330
10	859	147
15	539	92
20	389	67
25	303	52
30	249	43

Critical hillslope length (ft) for contour furrowing on a hillslope with Hydrologic Soils Group **B**

Location	About 50% Cover	Nearly Bare Soil
Lexington, KY	859	147
Birmingham, AL	663	117
Grand Island, NE	>1000	181
Huron, SD	>1000	347
Dallas, TX	578	103
Denver, CO	>1000	457

Critical hillslope length (ft) for contour furrowing on a 300 ft long hillslope with 10% gradient and Hydrologic Soils Group **B**

RUSLE Exercises

Ex4: Terraces, Deep Ripping, and Contour Furrows

- **Scenario 3: Ripping, Contour Furrows, and Terraces**
  - effects of contour furrows on soil-loss rates
  - effects of deep ripping on soil-loss rates
  - effects terraces in conjunction with contour furrows and deep ripping on soil-loss rates

Cover-Management (C)

Cover Management Systems

- Computation of C values require:
  - complete list of plant types
  - surface covers
  - operations
  - dates of planting and implementation
- Consult NRCS Office
  - to obtain existing plant type, material, and operation information for the particular area of interest
  - for assistance in identifying the best possible analogies for use in the C-value computations

Table 5-3. Typical values for established forage stands[1]

Common name	Root mass in top 4 in (lbs·acre^{-1})	Canopy cover just prior to harvest (%)	Effective fall height (ft)	Average annual yield (tons·acre^{-1})
Grasses:				
Bahiagrass	1,900	95	0.1	4
Bermudagrass, coastal	3,900	100	0.2	8
Bermudagrass, common	2,400	100	0.1	3
Bluegrass, Kentucky	4,800	100	0.1	3
Brome grass, smooth	4,500	100	0.1	5
Dallisgrass	2,500	100	0.1	3
Fescue, tall	7,000	100	0.1	5
Orchardgrass	5,900	100	0.1	5
Timothy	2,900	95	0.1	5
Legumes:				
Alfalfa	3,500	100	0.2	6
Clover, ladino	1,400	100	0.2	3
Clover, red	2,100	100	0.1	4
Clover, sweet	1,200	90	2.0	2
Clover, white	1,900	100	0.1	2
Lespedeza, sericea	1,900	100	0.5	3
Trefoil, birdsfoot	2,400	100	0.3	4

[1]These values are for mature, full pure stands on well-drained nonirrigated soils with moderate-to-high available water-holding capacity. These values hold for species shown only within their range of adaptation. Except for biennials, most forages do not attain a fully-developed root system until end of second growing season. Root mass values listed can be reduced by as much as half on excessively drained or shallow soils and in areas where rainfall during growing season is less than 18 in. The values listed are from Bennett and Doss (1960), Denison and Perry (1990), Doss et al. (1960), Holt and Fisher (1960), Kramer and Weaver (1936), Lamba et al. (1949), MacDonald (1946), and Pavlychenko (1942).

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Table 5-1. Parameter values of typical crops[1]

Crop	Residue/yield ratio[2]	Surface p[3]	α[4] (acre · lb^{-1})	Residue at 30% cover[5] (lb · acre^{-1})	Yield	Row spacing[6] (in)	Plant population[6] (plants acre^{-1})
Alfalfa	0.15	0.020	0.00055	650	6 ton · acre^{-1}	(drilled)	180,000
Bromegrass	0.15	0.017	0.00055	650	5 ton · acre^{-1}	7 (drilled)	330,000
Corn	1.00	0.016	0.00038	950	130 bu · acre^{-1}	30	25,000
Cotton	1.00	0.015	0.00022	1,600	900 lb · acre^{-1}	38	35,000
Oats	2.00	[7]0.008	0.00059	600	65 bu · acre^{-1}	7 (drilled)	890,000
Peanuts	1.30	0.015	0.00030	1,200	2,600 lb · acre^{-1}	36	558,000
Rye	1.50	[7]0.008	0.00055	650	30 bu · acre^{-1}	(drilled)	890,000
Sorghum	1.00	0.016	0.00036	1,000	65 bu · acre^{-1}	30	41,000
Soybeans	1.50	0.025	0.00059	600	35 bu · acre^{-1}	30	110,000
Sunflowers	1.50	0.016	0.00024	1,500	1,100 lb · acre^{-1}	30	20,000
Tobacco	1.80	0.015	0.00036	1,000	2,200 lb · acre^{-1}	48	6,000
Wheat (spring)	1.30	[7]0.008	0.00059	600	30 bu · acre^{-1}	7 (drilled)	890,000
Wheat (winter)	1.70	[7]0.008	0:00059	600	45 bu · acre^{-1}	7 (drilled)	890,000

[1] Values in table are taken from Alberts et al. (1989), Ghidey et al. (1985), Gregory (1982), Gregory et al. (1985), Larson et al. (1978), National Research Council (1975), USDA (1990), and USDA-SCS (1991).

[2] Weight ratio of crop residue at harvest to crop yield,

[3] A constant that controls the exponential decomposition rate or surface residue from this crop. There are not enough data to justify different values for subsurface decay p values, so default values in program show identical decay rates for surface and buried residue. This can be changed by user.

[4] Ratio of area covered by a piece of residue to its mass.

[5] Mass of residue required to cover 30% of the surface area, corresponding to given value of α.

[6] Not currently used in program; is simply an aid in defining cropping patterns and likely residue levels

[7] Use 0.017 for the Northwestern Wheat and Range Region, or for small grain cover killed in the vegetative state.

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```
        File          Exit          Help          Screen
+-------------------< C Factor: results by operations 1.06 >--------------------+
| veg. # 1/1: grama-1st yr          prev. veg.: grama-1st yr                     |
|                        % res. cover    op.          date                      |
|---operation------------after op.----date---------next op.-----SLR-----%EI----|
| place (dump) fill          0         3/15/1        3/17/1       0.846    0.0  |
| blade fill matl            0         3/17/1        3/18/1       1.06     0.0  |
| heavy offset disk          0         3/18/1        3/20/1       0.793    0.1  |
| range drill                0         3/20/1        3/22/1       0.896    0.1  |
| add straw mulch            70        3/22/1        3/15/2       0.072   99.8  |
|---------- Rotation C Factor = 0.073 -------- Veg. C Factor = 0.073 ----------|
|                                                                                |
|                                                                                |
|                                                                                |
+------------------------< Esc Returns to C Result Menu >----------------------+
Tab  Esc F1   F3   F9   PgUp PgDn Home End
FUNC esc help cont info pgup pgdn 1st  last
```

Example C-Factor value for Flagstaff, AZ

Support-Practice (P)

- Sediment-Control Barriers and Structures
  - main objective of any reclamation plan is to control sediment in an efficient and economical manner
  - the selection of erosion and sediment-control techniques, in combination, provides the greatest opportunity for success

Support-Practice (P)

RUSLE ex for barriers: Stiff-grass hedge at toe of 200ft hillslope with 6% gradient. 8% effective width for P-Factor

```
        File        Exit        Help        Screen
+-----------------------< P Strips & Concave 1.06 >-----------------------+
| specified soil texture: silt loam                                        |
|        number of years: 1    strip width specification code: 1           |
|    year:  +--< 1 >---+                                                   |
|  strips:  |    2     |                                                   |
| strip 1   | 6 92  6  |                                                   |
| strip 2   | 1 100 6.0|                 code  COVER/ROUGHNESS PATTERN:        |
|           +----------+            +-----------------------------------+  |
|                                   |      1. C1) estab. sod-forming grass |  |
|                                   |      2. C2) 1st year grass or cut for hay|
|                                   |      3. C3) heavy cov. and/or very rough |
|                                   |      4. C4) moderate cov. and/or rough   |
|                                   |      5. C5) light cov. and/or mod. rough |
|                                   |      6. C6) no cover and/or min. rough.  |
|                                   |      7. C7) clean tilled, smooth, fallow |
|                                   +-----------------------------------+  |
|     NOTE:  computed soil loss and sediment yield for strips/barriers     |
|         assume that the grade along the upper edge is < 0.5%             |
+-------------------------< F3 when done, Esc exits >-----------------------+
Tab  Esc F1   F2  F3   F9
```

Support-Practice (P)

Effective width of barrier as a percent of hillslope length

Hillslope Gradient (%)	Close-growing grasses	Straw bales, Gravel, Filter barriers	Stiff-grass hedges	Silt fences and berms
<5	5	8	12	15
5-10	3	5	8	10
10-15	2	3	4	5

Width of pond used to compute P values for sediment-control barriers. The width used in RUSLE is the width of the barrier strip, plus width of the pond obtained from this table

Support-Practice (P)

Under actual field conditions, the effectiveness of these barriers varies widely, from highly effective to virtually ineffective, depending on their design, installation, and maintenance. The values computed by RUSLE assume that the barriers are properly designed, installed, and maintained.

Periodic maintenance is essential to the continued operation of barriers as sediment-control structures. The storage capacity behind these barriers can be filled with sediment during one or a few storm events. If the sediment is not removed or the barrier raised, the barrier will trap little sediment during subsequent events.

Support-Practice (P)

Gradient %	Shortgrass Strip	Gravel Bag	Stiff Grass Hedge	Silt Fence
<5	0.37	0.21	0.11	0.08
5-10	0.55	0.37	0.21	0.15
10-15	0.67	0.55	0.45	0.37

Typical P values for barriers constructed on a silt loam at Lexington, Kentucky

Support-Practice (P)

- RUSLE used to Compute Sediment Yield
  - if a diversion or terrace is placed on the downslope side of an erosion-control structure, such as a stiff-grass hedge, or downslope of a concave hillslope element, the terrace sub-factor should not be used because it will compute additional deposition when none would occur

RUSLE Exercises

Ex5: Pre- and Post-Mining Soil Loss Emphasizing Effects of Vegetation

- **Scenario 1: Estimating Pre-Mining Soil Loss**
  - C factor plant-community inputs for pre-mining conditions

RUSLE Exercises

Ex5: Pre- and Post-Mining Soil Loss Emphasizing Effects of Vegetation

- **Scenario 2: Estimating Soil Loss at Phase III Bond Release**
  - method to evaluate established plant community at 10 years after reclamation

Comparison of site characteristics

RUSLE Factor	Eastern United States	Western United States
Rainfall - Runoff Erosivity (R)	Charleston, WV Slope gradient = 8.65 Adjust ponding = yes (R = 140)	Flagstaff, AZ Slope gradient = 8.65 Adjust ponding = yes (R = 30)
Soil Erodibility (K)	Silt loam Si + vfs = 65% Clay = 15% Organic matter = 0.5% Structure = 2 Permeability = 4 % Rock cover = 0 Consolidation = 7 Hydrologic group = 3 (K = 0.471)	Silt loam Si + vfs = 65% Clay = 15% Organic matter = 0.5% Structure = 2 Permeability = 4 % Rock cover = 0 Consolidation = 15 Hydrologic group = 3 (K = 0.444)
Topographic Factor (LS)	Segments = 3 Measured downslope Segments vary in length Soil texture = Silt loam General land use = 8 Gradients = 10, 15, 5% Lengths = 100, 200, 300 ft (LS = 3.50)	Segments = 3 Measured downslope Segments vary in length Soil texture = Silt loam General land use = 8 Gradients = 10, 15, 5% Lengths = 100, 200, 300 ft (LS = 3.50)
Cover - Management (C)	No Adjust for soil moisture % Rock cover = 0 b-value code = 1 Years in rotation = 0 Long-term rough = 0.24 Consolidation = 7 Winter small grain Place (dump) fill Blade fill material Broadcast planter Add straw mulch (2000lbs) (C = 0.085)	No adjust for soil moisture % Rock cover = 0 b-value code = 1 Years in rotation = 0 Long-term rough = 0.24 Consolidation = 7 Grama - 1st year Place (dump) fill Blade fill material Heavy offset disk Range drill Add straw mulch (2000lbs) (C = 0.073)