THE SPATIAL DISTRIBUTION OF K-FACTOR VALUES ACROSS A TOPOSEQUENCE AND A SOIL SURVEY MAP UNIT

A Thesis
presented to
the Faculty of California Polytechnic State University,
San Luis Obispo

In Partial Fulfillment
of the Requirements for the Degree
Master of Science in Agriculture
with Specialization in Soil Science
by
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July 2012
COMMITTEE MEMBERSHIP

TITLE: The spatial distribution of K-factor values across a toposequence and a soil survey map unit

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ABSTRACT

The spatial distribution of K-factor values across a toposequence and a soil survey map unit

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Rivers and streams are adversely affected by an increase in sedimentation in their waters from eroding land. High sediment loads in streams can bury fish eggs and prevent hatching, increasing nutrients in the water causing algae blooms, or even contaminating the water with heavy metals carried in or on the aggregates. The erodibility of soil is valuable knowledge to all land users so that we may predict soil loss and its potential to pollute streams. This is done by using the Revised Universal Soil Loss Equation (RUSLE). By predicting soil loss from a given landscape, land managers can take mitigation measures. The precision of the current scale available for soil erodibility (K-factor) by the US Department of Agriculture is not useful to small landowners or on a site-by-site basis. In California’s Central Coast, a grassland hillslope toposequence was investigated in a Los Osos-Diablo soil series complex. Geographic information systems software was used for spatial analysis of variation in the K-factor as well as interpolating areas that were not sampled. Analysis of soils’ particle size, infiltration rate, organic matter content, and structure across the toposequence allowed calculation of the soils’ K-factor values. K-factor values for the footslope, backslope, and shoulder were found to be statistically different from one another. All slope position’s average K-factor values were statistically different than the published Los Osos and Diablo series’ K-factor with the exception of the backslope which was not significantly different than Diablo’s K-factor value. The average of all K-factors was found not to be statistically different than the Los
Osos’ K-factor but it was statistically different from the Diablo’s soil series K-factor. The USDA K-factors overestimated the predicted soil loss for the study site.
ACKNOWLEDGMENTS

Thank you to Dr. Lynn Moody for being so understanding, patient, and constantly available for clarification and support. Thank you to Craig Stubler for all your help in the lab. Thank you to Dr. Bill Preston for helping me see the big picture in every scenario. Thank you to Dr. Greg Bohr for introducing me to the wonderful world of maps.

Thank you to my mom for having faith in my cone head. Thank you to my dad-who always puts things into perspective. “It’s all good.” And thank you both for raising me to cherish the natural world.

And lastly, thank you to my wonderful hubby, Justin, and his best friend, Mr. Cory Young, for grinding all my samples. Twice.
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>List of Figures</td>
<td>ix</td>
</tr>
<tr>
<td>List of Tables</td>
<td>xi</td>
</tr>
<tr>
<td>Introduction</td>
<td>1</td>
</tr>
<tr>
<td>Soil Mapping</td>
<td>2</td>
</tr>
<tr>
<td>RUSLE</td>
<td>2</td>
</tr>
<tr>
<td>The K-Factor</td>
<td>4</td>
</tr>
<tr>
<td>Utilizing GIS for RUSLE Predictions</td>
<td>6</td>
</tr>
<tr>
<td>Conclusion</td>
<td>8</td>
</tr>
<tr>
<td>Materials and Methods</td>
<td>10</td>
</tr>
<tr>
<td>Study Area</td>
<td>10</td>
</tr>
<tr>
<td>Background</td>
<td>10</td>
</tr>
<tr>
<td>Climate</td>
<td>10</td>
</tr>
<tr>
<td>Other Site Characteristics</td>
<td>10</td>
</tr>
<tr>
<td>Soils and Sample Collection</td>
<td>12</td>
</tr>
<tr>
<td>Data Collection</td>
<td>15</td>
</tr>
<tr>
<td>Permeability</td>
<td>15</td>
</tr>
<tr>
<td>Organic Matter</td>
<td>16</td>
</tr>
<tr>
<td>Particle Size Analysis</td>
<td>17</td>
</tr>
</tbody>
</table>
LIST OF FIGURES

Figure 1. Annual grasses and forbs at the shoulder of the hillslope looking down at riparian vegetation and oak trees along Stenner Creek. ................................................................. 12

Figure 2. Map of the study area in relation to Cal Poly, San Luis Obispo main campus (a), locations of plots along the hillslope (b), and the layout of each plot with samples taken at the four corners and example infiltration measurement locations within the square meter (c). (USGS Topographic Map; Bing Aerial Imagery, 2010) ............................................................... 13

Figure 3. Plot locations and the USDA soil map units containing the research plots (SLO Data Finder, 2007). .............................................................................................................. 14

Figure 4. Permeability class across the toposequence. A permeability class of 1 is rapid infiltration and 6 is very slow infiltration. Numbers in parenthesis represent the number of measurements in that slope position with the permeability class specified. ................................. 20

Figure 5. A comparison of the percent organic matter in the 48 soil samples and the slope position............................................................................................................................. 22

Figure 6. The particle size distribution for the shoulder (red), backslope (blue), and footslope (green) (NRCS, 2012b). ........................................................................................................... 23

Figure 7. Percent of aggregates retained on each sieve after wet-sieving apparatus. ............. 26

Figure 8. A comparison of mean weight diameter after wet aggregate size distribution test and K-factors ................................................................................................................. 27

Figure 9. A box and whisker comparison of the K-factor for the shoulder, backslope, and footslope. K-factor is calculated using organic matter, soil structure, permeability, and modified silt content. ........................................................................................................... 28
Figure 10. A kriging interpolation of the K-Factor values at each of the sample locations yields a gradient across the study area with the shoulder having the highest values. ........................................ 31

Figure 11. A kriging interpolation of the calculated total soil loss variation (tons/acre/year) at each of the sample locations using the field measured K-Factor values yields a gradient across the study area with the shoulder having the highest values. ........................................................................... 34
LIST OF TABLES

Table 1. A comparison between the different slope positions’ average organic matter content. Different letters in the statistical analysis section indicate the averages are statistically different. ............................... 21

Table 2. The particle size distribution for all samples along the toposequence grouped by 1-meter plot. ................................................................................................................................. 24

Table 3. A summary of K-factor variables analyzed and observed in the surface soil for each slope position. ................................................................................................................................. 25

Table 4. A comparison between the different slope positions’ average mean weight diameter. Different letters in the statistical analysis section indicate the averages are statistically different. ................................................................................................................................. 26

Table 5. A comparison of averages of the environmental variables with the K-factor values. .... 29

Table 6. A comparison between the USDA estimated K-factor values and averages of the field measured K-factor values. Different letters in the statistical analysis section indicates the averages are statistically different. A higher K-factor indicates a higher erodibility. .................. 30

Table 7. Average RUSLE predicted soil loss (tons/acre-year) values along a hillslope using the USDA K-factor values and the in-field measured K-factor values. ................................. 33
INTRODUCTION

Soil is one of the most underappreciated resources despite the fact that successful societies depend upon its properties. According to the NRCS, soil has five basic functions: support biological life, purify water, provide a substrate for buildings and structures, cycle nutrients, and to store water and regulate drainage (NRCS, 2012a). In the simplest terms, the understanding and mapping of soil is crucial. It can tell us what land is suitable for cropping, how a building foundation should be constructed, or even how much land is washed out to sea every year. This study aimed to analyze soil samples from a small area of land to determine the soil’s erodibility, variation of erodibility across a toposequence, compare erodibility to aggregate stability, and relate the findings to the published soil survey.

The erodibility of soil is crucial knowledge to all land users. It depends on physical properties of the surface soil such as organic matter content, silt content, water infiltration rate, and structural class. Whether the land is being used for grazing, farmland, or urban development, soils on a slope will have a tendency to erode and discharge into streams. Soil loss can threaten landowners’ livelihoods as well as the overall health of an ecosystem. Eroded soil often results in polluted waterways. High turbidity in waterways can have harmful effects on local aquatic wildlife through algae growth from an excess of nutrients or heavy metal toxicity carried on soil aggregates (Lenzi and DiLuzio, 1997). High sediment loads will deposit on the stream bed burying fish eggs and preventing hatching. It can also decrease water clarity which inhibits photosynthesis in aquatic plants, therefore negatively affecting the whole ecosystem.
The common solution to ascertaining soil erosion potential is to use predetermined broad-scale information available to the general public. While this strategy is convenient and economical, the data are often generalized and the erodibility does not vary within an acre, which is unhelpful to small-landowners or site-specific land uses. A more detailed classification can help individuals identify specific locations on their land that have the potential to generate large amounts of soil erosion.

**Soil Mapping**

Traditional soil surveys are created using a three-step method centered around observations of landscape feature variation and inferences from sampled soils (Cook et al., 1996; Zhu et al., 2001). They are commonly used in decision making by the landowner to predict the amount of soil lost per year and to determine best management practices. Within the past decade, researchers have been interested in inputting soil data into predictive environmental models, which cannot be done reliably using the overly-generalized maps currently available (Band and Moore, 1995; Zhu et al., 2001). Recent advances in mapping technology such as remote sensing, geographic information systems, and terrain modeling offer opportunities for creating more detailed and accurate soil surveys (Scull et al., 2003, Zhu et al., 2001).

**RUSLE**

The Revised Universal Soil Loss Equation (RUSLE) is a widely used model to predict the quantity of soil lost from a specific site, given knowledge of several environmental factors.

\[ A = R \cdot K \cdot L \cdot S \cdot C \cdot P \]
RUSLE is dependent on six environmental influences: rainfall erosivity (R), slope steepness (S), cover management (C), erosion control practice (P), slope length (L), and the soil erodibility factor (K) (Wischmeier and Smith, 1978). The R-factor takes into account the rainfall amount and intensity in a region. The C-factor describes the ground cover such as grass, concrete, or chaparral that protects the soil from erosion. The P-factor represents the support practices in place to prevent erosion like contour farming or vegetation buffers. The K-factor will be discussed later in more detail.

RUSLE is used frequently in watershed management studies to assess whether the total watershed may be losing more soil than is acceptable. It is, however, a predictive model and the only definitive way to know how much soil is actually being lost, is to measure it directly. Typically, watersheds are monitored with gauges on one or several tributaries of streams to measure turbidity. These data are used to alert land users if the soil loss is above the tolerable amount. However, this strategy has been observed to be less effective than RUSLE. A study at the Chippewa River Watershed set up gauges along several drainages and showed that 90 percent of the sediment in the lower basin came from the areas of the watershed that were below the tolerable amount of soil loss (Nangia et al., 2010). When predicting K-factor it is crucial to look at erosion in specific locations as well as for the whole study area.

Another factor related to soil erosion potential is the T-factor, or the tolerable amount of soil loss. This value is reported by the USDA in their soil survey and is defined as the maximum erosion rate for an indefinitely sustainable soil. The value, ranging from 1 to 5 tons/acre/year, is determined based on the depth and “fragility” of the soil (Soil Survey Division Staff, 1993).
The predicted soil loss (by RUSLE value), can be reduced with better management practices. For instance, the C-factor in the RUSLE equation can be changed easily by increasing the vegetation or adding a more stable type of vegetation. The P-factor takes into account the erosion control practices put into use on the area such as jute netting. Even the K-factor can be improved with additions of organic matter which improves structure and aggregate stability. In addition, site-specific predictions of soil loss can alert land managers to install sediment control measures uphill from surface water bodies. Such mitigation measures include sediment basins and silt fences.

*The K-Factor*

The K-factor is a crucial influence on soil loss. Normally, when determining soil loss, this factor is taken from the USDA-NRCS database, represented as a shapefile in ArcGIS. The K-factor values in the USDA databases are generated based on soil surveys and official soil series descriptions that map the land as map units, sizes varying from 1 acre to 100 acres and larger. Since soil properties fluctuate with vegetation, slope, aspect, bedrock, sediment geology, and other factors, it seems it is nearly impossible to accurately pigeonhole large swaths of land into the same erosion class.

With varying landscape and geological properties, there is a corresponding variation of the soil properties that affect the K-factor value: organic matter content, permeability, texture including modified silt content, and structure. Typically organic matter binds aggregates together and with a loss of organic matter there is a decrease in aggregate stability and an increase of erodibility (Wu and Tiessen, 2002; Cantón et al., 2009; Vaezi et al., 2008). Soil permeability may be measured by determining infiltration rate. A higher infiltration rate of water is indicative of a more permeable soil. There is a
negative correlation between permeability and erosion (Yu et al., 2005), which means, for example, a highly compacted soil potentially will have a higher erosion rate; the compacted soil has lower permeability and therefore generates more runoff compared to a well structured soil. In particular, granular structure encourages infiltration and will experience a lower erosion rate than a massive soil. In terms of soil texture, a sandier soil will have higher infiltration, will be more permeable, and therefore exhibit potentially less runoff than a clay or silt soil if all other factors are equal (McBratney et al., 2003). Finer particles tend to erode more easily unless they are well aggregated (Berry et al., 2007). Modified silt content (0.002-0.1 mm), which includes silt and very fine sand, is used in the K-factor calculation because 0.1 mm was shown to be the threshold of cohesion and dispersion in a wet environment (Roose, 1996).

Beside structure, modified silt content, permeability, and structure class, broader land characteristics have an influence on erodibility as well. Andre and Anderson (1961) showed that there was a change in erodibility depending on the vegetation type, grassland being the plant community with the lowest erodibility when compared to soil under brush and next to trees. It has also been shown that there was a change in erodibility with a change in geology. For example, soil formed from acid igneous rock parent material is about 2.5 times more erodible than soil formed from basaltic parent material (Andre and Anderson, 1961; Perez-Rodriguez, et al., 2007).

Another study used dispersion along with aggregate stability to assess high erosion risk zones (Odeh and Onus, 2008). Aggregate stability and aggregate size distribution analysis tests how well the cohered particles withstand physical stresses such
as water and wind. If a soil has high aggregate stability or a large average aggregate size after exposing it to a wind or water test, the soil is less likely to erode.

**Utilizing GIS for RUSLE Predictions**

Geographic information systems (GIS) is a combination of maps, models, and shapes analyzed in a computer program such as ArcGIS (Ormsby et al., 2004). This program allows the user to display and compare spatial information represented layers. For example, a layer could be all roads in the county, voting districts, or the USDA soil survey. With the help of GIS, the user can map a single characteristic of the landscape and spatially relate it to other variables in the study area. The union of RUSLE and GIS is incredibly useful. By using GIS to determine RUSLE, layers can be created for every environmental and soil factor and then multiplied together to predict a net soil loss. Compared to calculating one soil loss value for an entire watershed, it is a more efficient strategy for in-depth analysis of large swaths of land.

When RUSLE and GIS are used in conjunction, a Digital Elevation Model (DEM), vegetation, rainfall intensity, and soil layers are used to determine the factors of RUSLE. Most analysts retrieve the K-factor from published soil surveys. Some of the soil data required for an in-depth RUSLE analysis may be from specific locations within the study area such as soil pit locations. There are issues with using singular location data when the intent is to assess the land as a whole. Landscape qualities vary over small areas so even though one square meter or a single pedon may be sampled, it by no means represents the entire landscape. For instance, given two sample locations 10 meters apart, it is necessary to systematically deduce the land characteristics between the two samples. This has been addressed using interpolation (Lee and Choi, 2010). Spatial interpolation is
commonly performed in a GIS program and is commonly used to estimate values between the sampled locations (Longley et al., 2011).

There are several types of interpolation tools including Inverse Distance Weighted, Kriging, Trend Surface Analysis, and Spline (ArcGIS, 2010). Each interpolation tool uses a different polynomial to smooth the surface between two values. Typically more values would create a more accurate surface representation. In a study done by Eldrandaly and Abu-Zaid (2011), a comparison of six interpolation methods showed that universal kriging and ordinary kriging were the most effective. Another study measured soil erodibility and used the kriging method because it decreases the variability when the values are correlated, which they are when calculating the K-factor (Perez-Rodriguez et al., 2007). For example, the modified silt content may have a direct effect on infiltration.

The raster imagery that is chosen for the RUSLE model will greatly affect the results. Raster imagery, for example aerial photos or Digital Elevation Models, is made up of square pixels in a grid pattern which completes the greater image. Image resolution, for example, one pixel being equivalent to 30 meters on the ground, is one of the major concerns. Slope length (L) and steepness (S) are determined from the Digital Elevation Model by looking at the elevation at the summit and toeslope of the hill and subtracting them to determine the hill height. Then simple algebra is applied to determine length and slope steepness. It is important to note that the resolution will vary the measurements and therefore the results of the RUSLE. However, the DEM resolution is typically determined by the availability of the imagery, not necessarily its effect on the data. Lee and Choi (2010) have developed a method of investigating the scaling effect on a GIS and RUSLE.
study. For their particular study area, a 67,500 acre basin, the most ideal resolution was 125 meters. Remote sensing data has also been used to determine land use, vegetation change (Normalized Difference Vegetation Index), salinity values (Normalized Difference Salinity Index), and moisture change between years (Normalized Difference Moisture Index) (Odeh and Onus, 2008). These data can all be determined using satellite imagery spanning visible and infrared wavelengths such as LANDSAT 7 15-meter resolution or SPOT 5 10-meter resolution (Lee and Choi, 2010).

Using GIS to perform RUSLE calculations will typically result in soil loss information at a much finer scale than currently available soil surveys. Depending on the DEM resolution available, the RUSLE calculation could display soil loss variation at a scale as fine as one meter. The accuracy of this data would be most directly related to the accuracy of the interpolation which is dependent on the total number of locations where the K-factor was measured.

Conclusion

Predicting soil loss is crucial to prevent adverse economic consequences on landowners and environmental degradation of local streams. While the current erodibility factor (K) is readily available to the public and helps estimate soil loss on a small scale, the inaccuracy and low variance contributes to its limited utility for landowners with small acreage or on a site-by-site basis. The technology is available to create a more accurate way of determining erosion potential.

The objectives of this study were (a) to calculate K-factor and soil loss predictions and compare them to those listed in the soil survey, (b) to utilize Geographic Information Systems to analyze the spatial variability of erodibility across a
toposequence with uniform vegetation and geology, (c) to identify correlations between aggregate size distribution and erodibility as assessed by the K-factor, and (d) to detect patterns of erodibility and potential soil loss at each slope position.
MATERIALS AND METHODS

Study Area

Background

California Polytechnic State University in San Luis Obispo (Cal Poly) is located on the central coast of California. Cal Poly possesses almost 10,000 acres, 6,000 of which are in San Luis Obispo County with the remainder located in Santa Cruz County comprising the Swanton Pacific Ranch (Marx, 2002). In addition to a traditional campus, Cal Poly serves as a working ranch, vineyard, dairy farm, and more. The university prides itself on using its land as an outdoor classroom, constantly challenging the students to apply their various fields of study with the Learn by Doing educational philosophy.

Climate

San Luis Obispo, California has a cool Mediterranean climate, that is characterized by mild to hot, dry summers with an average monthly high of 26°C (79°F) in August and an average monthly low of 11°C (53°F) and mild to cool, wet winters with an average monthly high of 17°C (63°F) and an average monthly low of 5°C (42°F) in January. Like most of the cities on California’s central coast, San Luis Obispo is warmer during the summer months but also often receives a marine layer of fog in the mornings. In terms of precipitation, Cal Poly receives an average of 60 cm (24 in) of rain annually with most of it falling in the winter (Western Regional Climate Center, 2011).

Other Site Characteristics

The Cal Poly land in San Luis Obispo County consists mostly of hilly or hummocky topography dominated by grassland and brush, and some trees in riparian areas. Cattle, sheep, and horse grazing are the main land uses with some farming and
urban development. Most of Cal Poly’s land is underlain by the Franciscan complex which includes sandstone, chert, shale, and limestone along with a mélange of serpentine and Miocene age marine sedimentary rocks (Jennings, 1977). The marine sedimentary rocks often contain carbonates due to ancient shells and marine skeletons deposited on an ocean floor. This study location is underlain by calcareous shale derived from marine sediments.

The study area is located on the Serrano Ranch, a 754 acre parcel of land purchased in 1950 that is now used for livestock grazing. The ranch is just south of the Los Padres National Forest and is transected by Southern Pacific Railroad tracks. The Serrano Ranch includes both Stenner Creek and Brizzolari Creek which eventually converge with San Luis Creek (Nieto, 1999). The study site is uphill from Stenner Creek and is therefore in the San Luis Obispo Creek watershed (Figure 1) (Trienan, 2008).

Although most of Cal Poly sits on the Franciscan complex, the specific hillslope that was sampled is underlain by the Miocene Monterey formation (Dibblee, 2006; Jennings, 1977). The Monterey formation typically consists of siliceous or calcareous shale, siltstone, or dolomite (Dibblee, 2006). The predominant vegetation was annual forbs and grasses located on the shoulder and backslope with some riparian vegetation at the toeslope (Figure 1). As previously stated, changes in geology and vegetation across the landscape influence differences in the erodibility of the soil (Andre and Anderson, 1961; Perez-Rodriguez, et al., 2007); neither of these variations is of concern to this study since the geology was consistent and the samples were only taken in grasslands. However, gopher burrows and desiccation cracks were observed in most plots. Aspect can also affect the erodibility due to a difference in sun and rain exposure, however all
samples were taken on a northwestern facing slope. This technique of sampling on a consistent soil landscape was used to minimize the variables affecting the K-factors so that any differences in laboratory or field measurements can be attributed to hillslope position.

![Image](image_url)

Figure 1. Annual grasses and forbs at the shoulder of the hillslope looking down at riparian vegetation and oak trees along Stenner Creek.

Soils and Sample Collection

Soil samples were collected in transects along a hillslope with contours trending parallel to Stenner Creek on the Cal Poly campus in San Luis Obispo, California. A square meter plot was laid out at twelve separate locations: four on the shoulder of the hill, four on the backslope, and four on the footslope. Slope percent, elevation, vegetation, soil structure, and permeability measurements were measured or observed and recorded at each plot, and surface samples were collected at the four corners of each plot to a depth of about 10 centimeters (4 inches). A total of 48 soil samples were collected.
The permeability class was measured by taking three infiltration measurements within each plot using a Minidisk Infiltrometer (Decagon Devices, 2010) (Figure 2).

Figure 2. Map of the study area in relation to Cal Poly, San Luis Obispo main campus (a), locations of plots along the hillslope (b), and the layout of each plot with samples taken at the four corners and example infiltration measurement locations within the square meter (c). (USGS Topographic Map; Bing Aerial Imagery, 2010)

The samples were collected within two soil map units on the USDA soil survey (Figure 3). Both map units are mapped as Los Osos- Diablo Complex, with two different slope ranges (15 to 30 percent and 30 to 50 percent). The Los Osos series is a fine,
smectitic, thermic Typic Argixeroll and is described in the soil survey as having loam surface texture and weak fine subangular blocky structure in the A horizon. Slow permeability is typical of this series and it is mapped with moderate erodibility with a K-factor of 0.32 (Soil Survey Staff, 2012). The T-factor for the Los Osos series is 3 tons/acre/year. The Diablo series also has slow permeability but has a silty clay surface texture and strong medium granular structure in the first few centimeters above a moderate coarse blocky structure. It is taxonomically classified as a fine, smectitic, thermic Aridic Haploxerert and was mapped with a lower K value of 0.18 because clay is more resistant to detachment compared to silt and sand (Soil Survey Staff, 2012). The T-factor for the Diablo series is 4 tons/acre/year.

Figure 3. Plot locations and the USDA soil map units containing the research plots (SLO Data Finder, 2007).
Data Collection

To calculate the K-factor value, the following values needed to be determined: percent organic matter, modified silt percent, permeability, and soil structure class. K-factor depends on these values, as shown in the following equation (Wischmeier and Smith, 1978; Renard et al., 1997):

\[
K = \frac{[2.1 \times 10^{-4}(12 - OM) \times M^{1.14} + 3.25 \times (St - 2) + 2.5 \times (Pt - 3)]}{100}
\]

Where K is the K-factor,

- \( OM \) is the organic matter content expressed as percent,
- \( M \) is the modified silt percent (0.002-0.1 mm) multiplied by percent sand (0.1-2 mm) plus percent silt (0.002-0.05 mm),
- \( St \) is the soil structure code (1 = very fine granular, 2 = fine granular, 3 = coarse granular, and 4 = platy, massive, or blocky),
- \( Pt \) is the permeability class (rapid, 20.0 – 6.0 in/hr = 1; moderate to rapid, 6.0 – 2.0 in/hr = 2; moderate, 2.0 – 0.6 in/hr = 3; slow to moderate, 0.6 – 0.2 in/hr = 4; slow, 0.2 – 0.06 in/hr = 5; very slow, less than 0.06 in/hr = 6).

Structure class was determined in the field and given a ranking according to the K-factor structure code (Wischmeier and Smith, 1978; Renard et al, 1997). The remaining values of permeability class, modified silt percent, and organic matter percent were determined using laboratory equipment and procedures with the specifics below.

Permeability

Permeability measurements were taken using Decagon Devices’ Mini Disk Infiltrometer® at varying suctions depending on the rate of water intake and soil textural
class. Measurements were taken at varying time intervals (from 30 seconds to 2 minutes, depending on the soil) until a steady infiltration rate was reached. The hydraulic conductivity (or intrinsic permeability) was calculated using

\[ k = \frac{C_1}{A} \]

where \( k \) is hydraulic conductivity in cm/sec, \( C_1 \) is the slope of the curve resulting from a graph of the cumulative infiltration versus the square root of time, and \( A \) is a predetermined value based on soil type and suction of the infiltrometer (Decagon Devices, 2010). The data were converted to inches per hour and used in the K-factor equation.

From 1996 to 2003, the NRCS used intrinsic permeability rather than saturated hydraulic conductivity as the standard for measuring water movement through soil. Therefore, the permeability classes from the minidisk infiltrometer were determined using the National Soil Survey Handbook from 1996 (Soil Survey Staff, 2004). These classes are described above in the K-factor equation.

**Organic Matter**

Approximately one representative gram of each sample was ground to a fine powder and placed in a VarioMax graphite crucible. The samples were analyzed in a VarioMax CNS Combustion Analyzer for carbon and nitrogen percentages. To estimate percent organic matter, the nitrogen percentages were multiplied by 20 under the assumption that organic matter is on average 5 percent nitrogen (NRCS, 1977; Chaney and Swift, 1984; International Plant Nutrition Institute, 2011). Carbon content could not be used for organic matter estimation (Nelson and Sommers 1996), because some
samples contained free carbonate minerals, assessed by applying 10% HCl and observing effervescence.

**Particle Size Analysis**

All 48 samples were air-dried, gently ground, and sieved through a 2-mm sieve, chemically dispersed with sodium hexametaphosphate (Na-HMP), and mechanically dispersed to perform particle size analysis (PSA) (Gee and Orr, 2002). Each sample was quantitatively transferred to a sedimentation cylinder, the soil was mixed and suspended, and then hydrometer readings were taken at various times for 24 hours using the ASTM method.

The content of the sedimentation cylinders were then drained through a number 270 sieve and placed in evaporation dishes to oven dry. After the samples cooled, they were shaken through a nest of sieves: 1 mm, 0.5 mm, 0.25 mm, and 0.1 mm. The sediment retained on each sieve was measured to determine each sand fraction (Gee and Orr, 2002).

**Wet Aggregate Size Distribution**

The wet sieving method was used for measuring the wet aggregate size distribution of four samples from each of the three slope positions. Air-dried samples were sieved through a 6.3 mm sieve and then shaken through a nest of sieves: 4 mm, 2 mm, 1 mm, 0.5 mm, 0.25 mm, and 0.053 mm. This nest of sieves was placed in a wet-sieving apparatus for 20 minutes and raised and lowered at a rate of approximately 30 times per minute. The sieves were then air-dried and the aggregates retained on each
sieve were weighed to determine the percent retained on each sieve. Mean weight diameter (MWD) was calculated for each sample using

\[
MWD = \sum W_j X_j
\]

where \(W_j\) is the proportion of the total sample weight and \(X_j\) is the average of each set of sieve openings (Nimmo and Perkins, 2002). MWD was then statistically compared to K-factor using a general regression.

K-Factor

After K-factor variables were obtained at all slope locations, the sample data was analyzed using ANOVA and one sample t-tests in Minitab 16, and the kriging method in ArcGIS 10. An analysis of variance was performed on the footslope, backslope, and shoulder K-values to determine if their differences were statistically significant. T-tests were used to compare the calculated K-factors and predicted USDA values. Ordinary kriging was used as a spatial interpolation tool for the K-factors (Perez-Rodriguez et al., 2007).
RESULTS AND DISCUSSION

Field Results

Vegetation was found to be wild oats (*Avena fatua* and *Avena barbata*), fennel (*Foeniculum vulgare*), wild mustard (*Hirschfeldia incana*) and other native (*Nassella spp.*) and non-native annual grasses. The elevation was between 210 to 260 meters above sea level for all 12 sample sites. Slope steepness values on the shoulder, backslope, and footslope ranged between 25 and 35 percent, 20 and 35 percent, and 13 and 15 percent, respectively.

Soil structure was observed in the field for each sample that was collected and permeability was measured in three locations in each plot. Structure was found consistently to be strong fine subangular in amongst all samples, which is consistent with the Los Osos series. The Diablo series was mapped with granular structure in the uppermost few inches. Permeability was found to be successively higher downslope, with mostly slow infiltrometer readings at the shoulder to mostly rapid readings at the footslope (Figure 4).
Figure 4. Permeability class across the toposequence. A permeability class of 1 is rapid infiltration and 6 is very slow infiltration. Numbers in parenthesis represent the number of measurements in that slope position with the permeability class specified.

**Lab Results**

*Organic Matter*

Average organic matter content was found to increase from 5.6 percent on the footslope to 7.1 percent on the shoulder. Using analysis of variance and a pairwise comparison, the shoulder was found to be significantly different than the backslope and footslope whereas the backslope and footslope were not significantly different from each other (Table 1). The published organic matter percent according to the soil survey for Los Osos and Diablo soil series is between 2 and 3 percent, which is statistically different from (lower than) the analyzed soil at all slope positions (p-values were less than 0.000). Another Cal Poly study found a soil in the Los Osos series to have an organic matter percent of about 2 and a soil in the Diablo series to have about 6 percent organic matter (Perry, 2005). The footslope and backslope soils were not statistically different from
Perry’s (2005) Diablo series organic matter content but the soils on the shoulder were statistically different from Perry’s Los Osos and Diablo organic matter measurements (p-values were 0.273, 0.233, and less than 0.000 respectively).

Table 1. A comparison between the different slope positions’ average organic matter content. Different letters in the statistical analysis section indicate the averages are statistically different.

<table>
<thead>
<tr>
<th></th>
<th>Footslope</th>
<th>Backslope</th>
<th>Shoulder</th>
</tr>
</thead>
<tbody>
<tr>
<td>Organic Matter Average (%)</td>
<td>5.62</td>
<td>5.60</td>
<td>7.38</td>
</tr>
<tr>
<td>Statistical Analysis</td>
<td>A</td>
<td>A</td>
<td>B</td>
</tr>
</tbody>
</table>

Organic matter was also found to decrease downslope (Figure 5). This is not the typical trend as organic matter would be expected to deposit downslope with gravity and water movement (Birkeland, 1984). From Iowa to Iran, there was a slight increase in organic matter in studies done across toposequences (Cambardella et al., 2004; Mojiri et al., 2011). The decreasing trend may be explained by a difference in soil forming processes from the shoulder to the footslope. For instance, the toeslope may be washed out by Stenner Creek every few years, stripping the top soil of organic matter. Another possibility is that the vegetation was much drier on the shoulder than on the footslope so there may have been more seeds and pieces of dry grass in the shoulder’s surface sample in spite of efforts to remove these particles. Since nitrogen was used to estimate organic matter differences, the carbon nitrogen ratio may have introduced this variation. Typically the carbon and nitrogen ratio depends on the degree of decomposition and source of organic matter. Another factor to consider is that this land is often used for
grazing and urea has a high nitrogen content. Regardless, the most important value this study is interested in is a comparison of the K-values across the hillslope and for that, the estimated organic matter values were used as were the USDA values in the soil description and the same statistical result was yielded.

Figure 5. A comparison of the percent organic matter in the 48 soil samples and the slope position.

Particle Size Analysis

There is variation in clay and a decrease of silt downslope from primarily silt loam textures at the shoulder to clay textures at the footslope (Figure 6). The parent material along the hillslope is changing from residuum at the summit and shoulder to colluvium on the backslope and footslope. The changing silt and clay contents reflect the changes in parent material. The higher amount of silt in the summit reflects the silty shale parent material (Gomes et al., 2007). Lower silt and higher clay contents on the backslope reflect silty shale colluvium but more intense weathering has increased the clay content. On the footslope, the high level of clay illustrates yet more intense weathering.
accompanying colluvial transport. These textural classes were compared to the USDA soil series and then were used to calculate the modified silt percent and the K-value.

![Particle size distribution](image)

Figure 6. The particle size distribution for the shoulder (red), backslope (blue), and footslope (green) (NRCS, 2012b).

The Los Osos soil series, as mapped in the soil survey, contains loam in the A horizon whereas the Diablo soil series is a silty clay in the surface horizon. The particle size analysis revealed that most of the surface soils on the shoulder of the hillslope ranged from silt loam to sandy clay loam. On the footslope, all textures were determined to be clay and on the backslope all soils were either clay or clay loam (Table 2). All collected data was then used to calculate the K-factor (Table 3).
Table 2. The particle size distribution for all samples along the toposequence grouped by 1-meter plot.

<table>
<thead>
<tr>
<th>Slope Position</th>
<th>Silt Separate (%)</th>
<th>Clay Separate (%)</th>
<th>Sand Separate (%)</th>
<th>Texture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shoulder</td>
<td>65</td>
<td>8</td>
<td>27</td>
<td>Silt Loam</td>
</tr>
<tr>
<td>Shoulder</td>
<td>48</td>
<td>23</td>
<td>29</td>
<td>Loam</td>
</tr>
<tr>
<td>Shoulder</td>
<td>43</td>
<td>32</td>
<td>25</td>
<td>Clay Loam</td>
</tr>
<tr>
<td>Shoulder</td>
<td>55</td>
<td>20</td>
<td>25</td>
<td>Silt Loam</td>
</tr>
<tr>
<td>Shoulder</td>
<td>52</td>
<td>20</td>
<td>28</td>
<td>Silt Loam</td>
</tr>
<tr>
<td>Shoulder</td>
<td>52</td>
<td>20</td>
<td>28</td>
<td>Silt Loam</td>
</tr>
<tr>
<td>Shoulder</td>
<td>50</td>
<td>22</td>
<td>28</td>
<td>Silt Loam</td>
</tr>
<tr>
<td>Shoulder</td>
<td>59</td>
<td>18</td>
<td>23</td>
<td>Silt Loam</td>
</tr>
<tr>
<td>Shoulder</td>
<td>28</td>
<td>40</td>
<td>32</td>
<td>Clay</td>
</tr>
<tr>
<td>Shoulder</td>
<td>55</td>
<td>33</td>
<td>12</td>
<td>Silty Clay Loam</td>
</tr>
<tr>
<td>Shoulder</td>
<td>23</td>
<td>47</td>
<td>30</td>
<td>Clay</td>
</tr>
<tr>
<td>Shoulder</td>
<td>39</td>
<td>35</td>
<td>26</td>
<td>Clay Loam</td>
</tr>
<tr>
<td>Shoulder</td>
<td>50</td>
<td>20</td>
<td>30</td>
<td>Silt Loam</td>
</tr>
<tr>
<td>Shoulder</td>
<td>48</td>
<td>22</td>
<td>30</td>
<td>Loam</td>
</tr>
<tr>
<td>Shoulder</td>
<td>19</td>
<td>30</td>
<td>51</td>
<td>Sandy Clay Loam</td>
</tr>
<tr>
<td>Shoulder</td>
<td>42</td>
<td>29</td>
<td>29</td>
<td>Clay Loam</td>
</tr>
<tr>
<td>Backslope</td>
<td>35</td>
<td>40</td>
<td>25</td>
<td>Clay</td>
</tr>
<tr>
<td>Backslope</td>
<td>34</td>
<td>33</td>
<td>33</td>
<td>Clay Loam</td>
</tr>
<tr>
<td>Backslope</td>
<td>32</td>
<td>40</td>
<td>28</td>
<td>Clay</td>
</tr>
<tr>
<td>Backslope</td>
<td>40</td>
<td>30</td>
<td>30</td>
<td>Clay Loam</td>
</tr>
<tr>
<td>Backslope</td>
<td>24</td>
<td>46</td>
<td>30</td>
<td>Clay</td>
</tr>
<tr>
<td>Backslope</td>
<td>25</td>
<td>47</td>
<td>28</td>
<td>Clay</td>
</tr>
<tr>
<td>Backslope</td>
<td>43</td>
<td>26</td>
<td>31</td>
<td>Loam</td>
</tr>
<tr>
<td>Backslope</td>
<td>28</td>
<td>45</td>
<td>27</td>
<td>Clay</td>
</tr>
<tr>
<td>Backslope</td>
<td>41</td>
<td>34</td>
<td>25</td>
<td>Clay Loam</td>
</tr>
<tr>
<td>Backslope</td>
<td>27</td>
<td>43</td>
<td>30</td>
<td>Clay</td>
</tr>
<tr>
<td>Backslope</td>
<td>30</td>
<td>42</td>
<td>28</td>
<td>Clay</td>
</tr>
<tr>
<td>Backslope</td>
<td>35</td>
<td>40</td>
<td>25</td>
<td>Clay</td>
</tr>
<tr>
<td>Backslope</td>
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<td>60</td>
<td>21</td>
<td>Clay</td>
</tr>
<tr>
<td>Backslope</td>
<td>17</td>
<td>61</td>
<td>22</td>
<td>Clay</td>
</tr>
<tr>
<td>Backslope</td>
<td>16</td>
<td>62</td>
<td>22</td>
<td>Clay</td>
</tr>
<tr>
<td>Backslope</td>
<td>21</td>
<td>73</td>
<td>6</td>
<td>Clay</td>
</tr>
<tr>
<td>Footslope</td>
<td>25</td>
<td>46</td>
<td>29</td>
<td>Clay</td>
</tr>
<tr>
<td>Footslope</td>
<td>13</td>
<td>62</td>
<td>25</td>
<td>Clay</td>
</tr>
<tr>
<td>Footslope</td>
<td>25</td>
<td>46</td>
<td>29</td>
<td>Clay</td>
</tr>
<tr>
<td>Footslope</td>
<td>18</td>
<td>55</td>
<td>27</td>
<td>Clay</td>
</tr>
<tr>
<td>Footslope</td>
<td>15</td>
<td>56</td>
<td>29</td>
<td>Clay</td>
</tr>
<tr>
<td>Footslope</td>
<td>12</td>
<td>61</td>
<td>27</td>
<td>Clay</td>
</tr>
<tr>
<td>Footslope</td>
<td>12</td>
<td>62</td>
<td>26</td>
<td>Clay</td>
</tr>
<tr>
<td>Footslope</td>
<td>9</td>
<td>67</td>
<td>24</td>
<td>Clay</td>
</tr>
<tr>
<td>Footslope</td>
<td>2</td>
<td>70</td>
<td>28</td>
<td>Clay</td>
</tr>
<tr>
<td>Footslope</td>
<td>4</td>
<td>70</td>
<td>26</td>
<td>Clay</td>
</tr>
<tr>
<td>Footslope</td>
<td>4</td>
<td>68</td>
<td>28</td>
<td>Clay</td>
</tr>
<tr>
<td>Footslope</td>
<td>2</td>
<td>70</td>
<td>28</td>
<td>Clay</td>
</tr>
<tr>
<td>Footslope</td>
<td>2</td>
<td>68</td>
<td>30</td>
<td>Clay</td>
</tr>
<tr>
<td>Footslope</td>
<td>5</td>
<td>66</td>
<td>29</td>
<td>Clay</td>
</tr>
<tr>
<td>Footslope</td>
<td>6</td>
<td>65</td>
<td>29</td>
<td>Clay</td>
</tr>
<tr>
<td>Footslope</td>
<td>8</td>
<td>63</td>
<td>29</td>
<td>Clay</td>
</tr>
</tbody>
</table>
Table 3. A summary of K-factor variables analyzed and observed in the surface soil for each slope position.

<table>
<thead>
<tr>
<th></th>
<th>Shoulder</th>
<th>Backslope</th>
<th>Footslope</th>
</tr>
</thead>
<tbody>
<tr>
<td>Avg. Organic Matter (%)</td>
<td>7.1</td>
<td>5.6</td>
<td>5.6</td>
</tr>
<tr>
<td>Avg. Modified Silt Content (%)</td>
<td>65</td>
<td>46</td>
<td>32</td>
</tr>
<tr>
<td>Avg. Clay Content (%)</td>
<td>27</td>
<td>45</td>
<td>62</td>
</tr>
<tr>
<td>Most Common Permeability Class</td>
<td>4</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Structure (Class)</th>
<th>Shoulder Subangular Blocky (4)</th>
<th>Backslope Subangular Blocky (4)</th>
<th>Footslope Subangular Blocky (4)</th>
</tr>
</thead>
</table>

Wet Aggregate Size Distribution

Wet aggregate size distribution was performed on four samples from each slope position, one from each plot. After wet sieving, the majority of the aggregates were retained on the 2 mm sieve (Figure 7). Mean weight diameter (MWD) was calculated and the averages were not statistically different from one another (Table 4). Most of the MWDs were between 2 and 3 mm, which is considered to be “very stable” and is typical of high clay or high organic matter content (Le Bissonnais, 2005). These soil classes will not erode very easily nor will they be greatly affected by rainfall impact.
Figure 7. Percent of aggregates retained on each sieve after wet-sieving apparatus.

Table 4. A comparison between the different slope positions’ average mean weight diameter. Different letters in the statistical analysis section indicate the averages are statistically different.

<table>
<thead>
<tr>
<th></th>
<th>Footslope</th>
<th>Backslope</th>
<th>Shoulder</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean Weight Diameter (mm)</td>
<td>2.40</td>
<td>2.39</td>
<td>2.32</td>
</tr>
<tr>
<td>Statistical Analysis</td>
<td>A</td>
<td>A</td>
<td>A</td>
</tr>
</tbody>
</table>

The MWDs were then compared to the K-factor values calculated for each sample to determine whether there was a correlation (Figure 8). The correlation between the 16 MWDs and the K-factor values was not statistically significant, with a P value of 0.067. A possible aggregation factor that is not accounted for in the K-factor equation is the presence of free carbonates in these soil samples. Divalent calcium may be encouraging flocculation (Moody, 2012). There was, however, a general negative trend, meaning a
lower MWD would have a higher K-factor value. This is what would be expected since a higher mean weight diameter means the soil is more stable and a higher K-factor means it is more erodible.

Although the correlation was not statistically significant, aggregate size distribution remains a reliable test for soil erodibility. While the K-factor predicts the erodibility based on soil properties inputted into an equation, the aggregate size distribution experiment physically tests the aggregates in a trial similar to real life conditions. Aggregate stability or MWD of wet aggregate size distribution may be a more direct representation of erodibility and therefore prove a superior means for calculating soil loss.

![Figure 8. A comparison of mean weight diameter after wet aggregate size distribution test and K-factors.](image)
**K-Factor Calculation**

The K-factor was calculated for each data point where all data was available. Some soil samples did not have a corresponding permeability class and so K-factor could not be calculated. Using analysis of variance, at the 5 percent significance level, the average K-factor of the backslope is significantly different from the shoulder and the footslope, and the footslope is significantly different from the shoulder (Figure 9).

![Figure 9. A box and whisker comparison of the K-factor for the shoulder, backslope, and footslope. K-factor is calculated using organic matter, soil structure, permeability, and modified silt content.](image_url)

A multiple regression of organic matter, sand percent, silt percent, and infiltration with the K-values yields an explanation of how each soil property influences K-factor. The spectrum of K-factors, 0.03 to 0.35, or the most erodible sample being ten times more than the least erodible, implies that the soil property influences are noteworthy. A 10 percent increase in silt is associated with a K-factor increase of 0.04 times after
removing the effects of organic matter, infiltration, and sand content. A 10 percent increase in sand is associated with a K-factor increase of 0.03 times after removing the other influences and a 10 percent increase of organic matter is associated with a K-factor decrease of 0.12 times after removing the other influences. Finally, a 10 inch per hour increase in the infiltration rate is associated with a K-factor decrease of 0.05 time after removing the effects of the silt, clay, and organic matter percent content (Table 5). According to these data, the silt content has a higher effect on the K-factor than sand although both are strongly correlated to the K-factor. However, in a study done in Ghana, sand was found to be the best indicator of erodibility because of its negative effect on the strength of the aggregates under wet conditions (Veihle, 2000). Sand content remains fairly consistent (between 20 and 30 percent for the most part) along the hillslope in this study so sand content is not a useful K-factor determining value.

Table 5. A comparison of averages of the environmental variables with the K-factor values.

<table>
<thead>
<tr>
<th>K-Factor Response</th>
<th>+10% Silt Content</th>
<th>+10% Sand Content</th>
<th>+10% OM Content</th>
<th>+10 in/hr infiltration rate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>+0.04</td>
<td>+0.03</td>
<td>-0.12</td>
<td>-0.05</td>
</tr>
</tbody>
</table>

The K-factor across the slope positions was compared to the published USDA K-factors. As previously discussed, the shoulder’s soil samples were closer to the Los Osos soil in terms of particle size distribution and permeability whereas the footslope were more similar to the Diablo soil and the backslope falls in between the two series. The measured K-factor values from the shoulder (average 0.25) were compared to the Los Osos series published K-factor, 0.32 and the Diablo series’ published K-factor, 0.15. At
the 5 percent significance level, using a one-sample t-test, the shoulder’s average K-factor is significantly different from the K-factors of the Los Osos and Diablo series as mapped. Also using a one sample t-test, the footslope’s average K-factor (0.06) is significantly different from both the Los Osos and Diablo series’ recorded K-factor. The backslope’s K-factor values (0.13) were significantly different from the Los Osos series but failed to reject the null for the Diablo series’ K-factor. Nevertheless, the average of all sample’s K-factor values was not significantly different from the Diablo series K-factor published but it was significantly different from the published Los Osos K-factor (Table 6). This comparison was done to determine how representative the USDA K-factor values were of the area as a whole. Although the map unit is the Los Osos- Diablo soil series complex, it appears that the field measured K-factor values are more similar to the Diablo erodibility rather than the Los Osos erodibility.

Table 6. A comparison between the USDA estimated K-factor values and averages of the field measured K-factor values. Different letters in the statistical analysis section indicates the averages are statistically different. A higher K-factor indicates a higher erodibility.

<table>
<thead>
<tr>
<th></th>
<th>Footslope Average</th>
<th>Backslope Average</th>
<th>All Samples Average</th>
<th>USDA Diablo Series (Published)</th>
<th>Shoulder Average</th>
<th>USDA Los Osos Series (Published)</th>
</tr>
</thead>
<tbody>
<tr>
<td>K-Factor Value</td>
<td>0.06</td>
<td>0.13</td>
<td>0.13</td>
<td>0.15</td>
<td>0.25</td>
<td>0.32</td>
</tr>
<tr>
<td>Statistical Analysis</td>
<td>A</td>
<td>B</td>
<td>B</td>
<td>B</td>
<td>C</td>
<td>D</td>
</tr>
</tbody>
</table>

The kriging interpolation was performed to determine the K-factor for the areas between the sample locations (Figure 10). The K-factor values ranged from 0.03 to 0.28 and are spatially limited to the extent of the GPS locations of the sample points. In other
words, locations should not be analyzed further north, south, east, or west than was sampled. There is a clear distinction between the high K-factors of the shoulder and the eastern-most backslope point and the rest of the points. There are a few values in the middle range, with most either being categorized as high or low K-Factor values. Using this kriging methodology, we can assess the effectiveness of the USDA soil survey in representing the true K-value distribution.

Figure 10. A kriging interpolation of the K-Factor values at each of the sample locations yields a gradient across the study area with the shoulder having the highest values.

Although the USDA soil map reveals a general pattern of dividing the high K-values (shoulder) from the medium K-values (backslope) in the course of conventional soil mapping, there are some trends that are not accounted for in the USDA soil survey. First, since all average K-values for each slope position were significantly different from one another according to the analysis of variance, it appears more divisions in the soil map unit would be helpful as the kriging interpolation shows (Figure 10). Even within the
entire map unit categorized as a Los Osos-Diablo complex, 30-50 percent slopes, a wide range of measured K-values assigns four unique map units. Unit boundaries trend almost perpendicular to the soil survey map unit boundaries. The kriged map units do not follow elevation contour, nor the aspect. This pattern may be due to slight variations in elevation, slope shape, or even a geological inclusion that influences the direction in which the eroded sediment moves down the hillslope. For purposes of erosion and sediment control, this may represent a practical alternative to the conventional soil survey, or an important addition to the soil survey.

The statistically significant difference between this study’s K-factors and the USDA’s can be attributed to differences in particle size and organic matter content. Both the Los Osos and Diablo soil series are each described in the published soil survey as having about 3 percent organic matter. This value is significantly different than the organic matter percentage in the sampled soil, which had an average value of about 6 percent. Also, the official soil series description classifies the Los Osos surface soils as loams but most of the samples were determined to be silt loam with high variation, ranging from clay to sandy clay loam. The Diablo soils are silty clays according to the official description but the samples were all found to have a clay texture. On the other hand, the subangular blocky structure and slow permeability classes are consistent with the measured infiltration and observed structure. Therefore, the soil texture and organic matter content are responsible for the differences in K-factors, in this and in previous studies (Atawoo and Heerasing, 1998).
**K-Factor in Context**

In order to compare how a K-factor difference will impact the landowner, it should be used to predict the soil loss of an area. Using publicly available soil surveys, field measured slope, and GIS measured slope length, the soil loss was calculated using the USDA’s K-factor values and the field measured K-factor values. The predicted soil loss based on the USDA’s erodibility values for the Los Osos and Diablo soil series range from 0.36 tons/acre·year to 2.03 tons/acre·year, whereas the RUSLE based on this K-factor values measured in this study range from 0.13 tons/acre·year to 1.54 tons/acre·year (Table 7). The USDA values overestimate the soil loss which is consistent with a study done by Vaezi, et al. (2010), in which the estimate of soil loss based on previously established soil surveys was considerably higher than the RUSLE derived soil loss based on measured K-factor values.

Table 7. Average RUSLE predicted soil loss (tons/acre·year) values along a hillslope using the USDA K-factor values and the in-field measured K-factor values.

<table>
<thead>
<tr>
<th></th>
<th>Shoulder</th>
<th>Backslope</th>
<th>Footslope</th>
</tr>
</thead>
<tbody>
<tr>
<td>USDA Values</td>
<td>2.03</td>
<td>1.34</td>
<td>0.36</td>
</tr>
<tr>
<td>Measured Values</td>
<td>1.54</td>
<td>0.69</td>
<td>0.13</td>
</tr>
</tbody>
</table>

A kriging interpolation of the total soil loss shows a similar pattern as the K-factor interpolation, with the greatest values at the shoulder, the smallest at the footslope, and the backslope is transitional. The RUSLE interpolation was made using the soil loss values calculated from the field measured K-factor to show the variability of the soil loss in response to the variation of K-factor (Figure 11). The only varying RUSLE factors
across the sample points were length, slope, and erodibility; cover, rainfall, and erosion practices were consistent throughout. This demonstrates how important an accurate and precise K-factor is when mapping even a small parcel of land.

Figure 11. A kriging interpolation of the calculated total soil loss variation (tons/acre/year) at each of the sample locations using the field measured K-Factor values yields a gradient across the study area with the shoulder having the highest values.
SUMMARY & CONCLUSION

Soil erodibility, or the K-factor, affects every landowner. It is a crucial value when predicting the effects of land use and management on soil loss, and is typically taken from soil surveys completed on a small or general scale. The K-factor is based on permeability class, soil structure, modified silt content, and organic matter percent. These values were measured across a toposequence on the Central Coast of California to investigate a typical USDA map unit and its associated K-factor.

Three slope positions were chosen with 48 total samples. Modified silt content and organic matter were lowest at the footslope and highest at the shoulder. Permeability was highest at the footslope and lowest at the shoulder. Structure was subangular blocky across all samples. Higher modified silt content increases the K-factor and higher infiltration and organic matter content decreases the K-factor because it encourages aggregate stability and therefore more resistance to erosion (Wu and Tiessen, 2002; Cantón et al., 2009; Vaezi et al., 2008).

A kriging interpolation was used to display K-factor influences across the entire study area. The K-factor values ranged from 0.03 to 0.35 with a significant difference between the shoulder and the backslope, and less difference between the backslope and footslope. The backslope and footslope do not have as wide of a variance. Each slope position’s average K-factor values were statistically different from one another and also statistically different from the Los Osos USDA K-factor value but the backslope’s average K-factor value was not significantly different than the Diablo’s K-factor value based on one-sample t-tests and analysis of variance. Although sand content was found to
increase the K-factor value, presumably from an increase in infiltration rate, the silt content was found to have a greater influence on increasing the K-factor.

This study has shown a practical approach to estimating soil loss over a smaller area with a higher precision. It is recommended that in future studies and mapping, the soil should be sampled in a broader area and across several soil series types. Also, it would be interesting to compare several soil structure types and their affect on the K-factor. Aggregate stability has the potential to be a useful tool when predicting soil loss and future studies investigating their relationship are recommended. In terms of GIS utilization, a full RUSLE model would provide a more accurate calculation of total soil loss. This model would include layers such as Digital Elevation Models, rainfall erosivity, vegetation map, and a K-factor raster created through sampling and then interpolation. And lastly, further investigation is recommended to explain the decreasing trend of organic matter downslope.

Erodibility varies with all landscape characteristics including vegetation, slope position, aspect, and more. The USDA K-factor pigeonholes large swaths of land into one erodibility class. This study and others found that the USDA K-factor overestimated the soil loss using the RUSLE equation. This may be a tactic to conservatively estimate soil loss but does not seem to function as an accurate representation. If a landowner is seriously concerned about soil loss, samples should be taken and the K-factor should be measured in the laboratory rather than using the K-factor associated with the land’s soil type. Granted, some landowners may not have the resources or monetary means to conduct these experiments, and in that case, they have no choice but to rely on the available information. Either way, knowledge is power and a better understanding of the
soil provides the foundation for understanding the entire landscape and how it will react to anthropogenic influences.
REFERENCES


