Proposal to Calculate Soil Loss in Claremont Canyon, East Bay Hills, Berkeley

Wing Tai (Kyle) Tse

Abstract Soil erosion and its effects negatively impact millions of lives and is responsible for widespread property damage in regions around the entire world. It will become an increasingly critical problem if steps are not taken to regulate its effects. On a smaller scale, it is important to pinpoint estimated locations where soil erosion occurs in order to prevent substantial soil loss. This project estimates the soil loss of Claremont Canyon, part of the greater East Bay Hills. There are three major landowners in Claremont Canyon; they consist of the University of California, Berkeley, the East Bay Regional Park District, and the City of Oakland. In the past, there have been fourteen major wildfires in the East Bay areas and assessment plans have been taken to reduce the fire risk. These studies on the negative effects of soil loss from wildfire have not yet been extended to the Claremont Canyon regions. This study will be conducted utilizing the Revised Universal Soil Loss Erosion Equation (RUSLE) to calculate the amount of annual soil loss. The strength of this model permits an all-inclusive analysis by breaking down soil erosion into elements based on vegetation, soil types, rainfall, topography, and urban land practice data. Results predicted long-term deterioration and provide a more accurate assessment for future developmental decision making on land use.

Introduction

On average, over 140,000 wildfires occur in the United States of America each year (IBHS 2003). Such consistent and frequent occurrences of this natural disaster have negative impacts upon the environment. Wildfires cause extensive soil erosion as the fire burns destroy the plant materials responsible for stabilizing the soil. (Fred Deneke 2002). In the past twentieth century, fourteen major wildfires have swept through the East Bay Hills (AEGIS 1995). Two out of the fourteen wildfires have also traversed through Claremont Canyon: the 1923 Berkeley fire and the 1991 Oakland Hills fire. In particular, the latter has played a significant role in history as the fire ranks first amongst the most expensive fire disaster in California history. The fire took 25 lives, over 2700 structures, and caused 1.68 billion dollars worth of damages (AEGIS 1995). Such damages impacted the landowners of the regions. Historically, the Claremont Canyon is a wild-interface land belonging to three major owners (Figure 1): the University of California (150 acres), Berkeley, the East Bay Regional Park District (208 acres), and the city of Oakland (13 acres) (The Claremont Canyon Conservancy 2003).
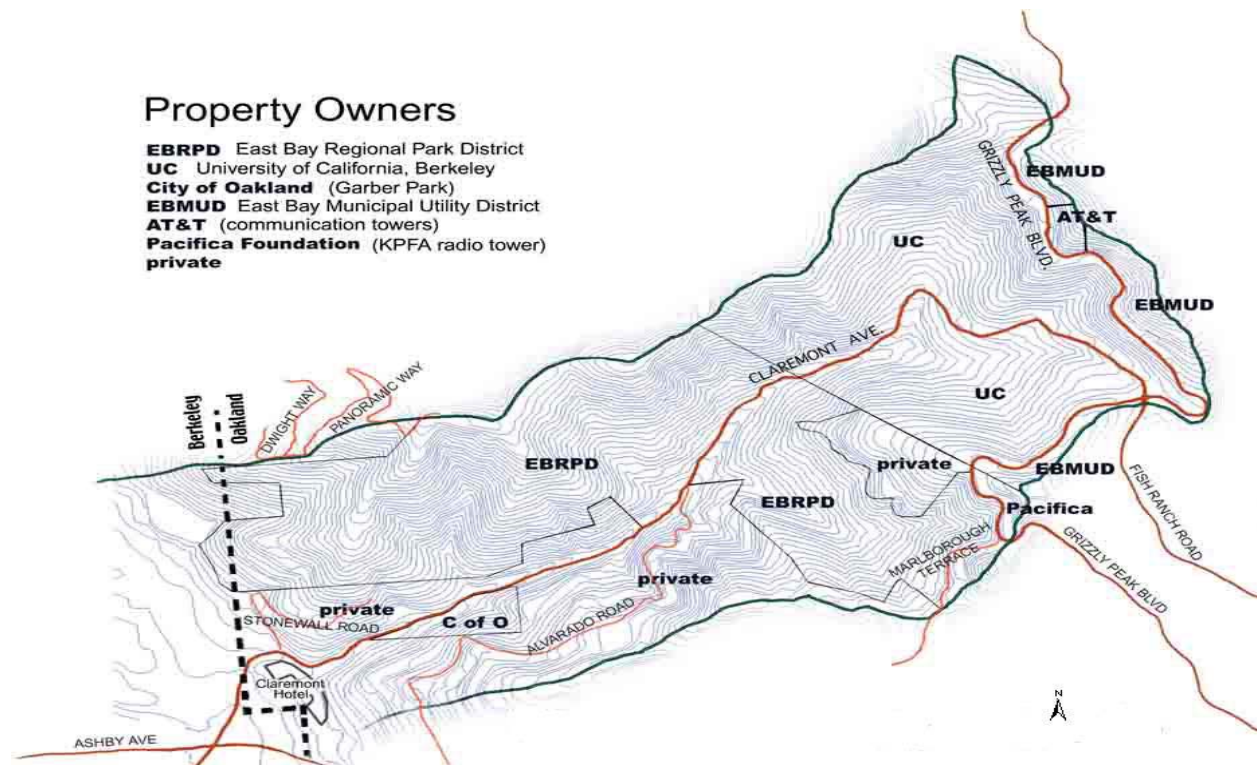

Figure 1. Claremont Canyon Ownership Study Site

Due to the experiences of seasonal fires, the fire issue remains a concern to the three major owners, as well as some small private owners in the Claremont Canyon. Many studies aim to reduce the wildfire hazard by removing the coyote brush, poison oak, and eucalyptus trees in varies locations (Wallace and McClung 2002). The majority of the studies are allocated to vegetation management whose approaches have been published in a manual by the East Bay Hills in order to inform the public planners to become more aware of the effects of wildfire on vegetation (Danielsen *et al.* 2002). However, to my knowledge, there exist no studies that have specifically focused on soil erosion in the Claremont Canyon. Such a study would be beneficial to public planners in making future decisions. A study focusing on the soil erosion occurring in Claremont Canyon will provide more details on wildfire feedback resulting in soil loss. This information will be valuable to different owners who are trying to reduce the natural hazard occurrence on their properties within these areas. Studies are needed to give a concrete informational basis to make rational decisions for landowners. Therefore, my objective is to identify the region of highest soil erosion in the Claremont Canyon, East Bay Hills, and Berkeley.

Methods

In order to calculate the soil loss in Claremont Canyon, the RUSLE is utilized in this project. The RUSLE builds upon the Universal Soil Loss Equation (USLE) and this tool is designed and is currently implemented by soil conservationists (Wischmeier and Smith 1978). The RUSLE is widely applied on studying urban land use and recreation sites (Rennard *et al.* 1991). In one previous study conducted on the United States' Virgin Islands, Radke (1995) used the RUSLE to estimate regions of high soil risk for soil loss on the hilly coastal areas. My project structures itself along a similar model to calculate soil loss for Claremont Canyon.

A RUSLE model is composed of five variables and calculated from a formula that is written as $A = LS \times R \times C \times K \times P$, where

- A is the predicted average annual soil loss per unit area in (ton ac^{-1} yr^{-1});
- LS are the slope length factor and slope steepness factor in (dimensionless);
- R is the rainfall-runoff erosivity factor in ([hundreds of ft-tons] inch ac^{-1} hr^{-1} yr^{-1});
- C is the cover-management factor in (dimensionless);
- K is the soil erodibility factor in (tons hr [hundreds of f-tons]$^{-1}$ in^{-1});

- P is the support practice factor in (dimensionless).

LS Factor   The rate of soil erosion is greatly affected by the local topography of an area. The LS factor provides a quantitative representation of both slope length and steepness (ATTACC 1999). The slope steepness and length values for the LS factor were determined from a digital elevation model (DEM), an Arc Micro Language (lsfactor.aml), and a C language program (rusleinfo.exe). The LS factor is the first variable to be calculated in the RUSLE model. To calculate the LS factor, the following two-step process was applied.

Step 1   A Triangulated Irregular Network (TIN) model was created for Claremont Canyon. First, the TIN model, based on the hypsography data, was obtained from the San Francisco Estuarine Institute (SFEI).   Next, the ArcGIS Three-Dimensional Analyst tool was applied to the hypsography data.   The product result was a TIN model creating many sample points; each having an x, y, and z coordinate (Figure 2). These points are connected by edges to form a set of non-overlapping triangles used to represent the topographical, three-dimensional surface (Peschier 1996).
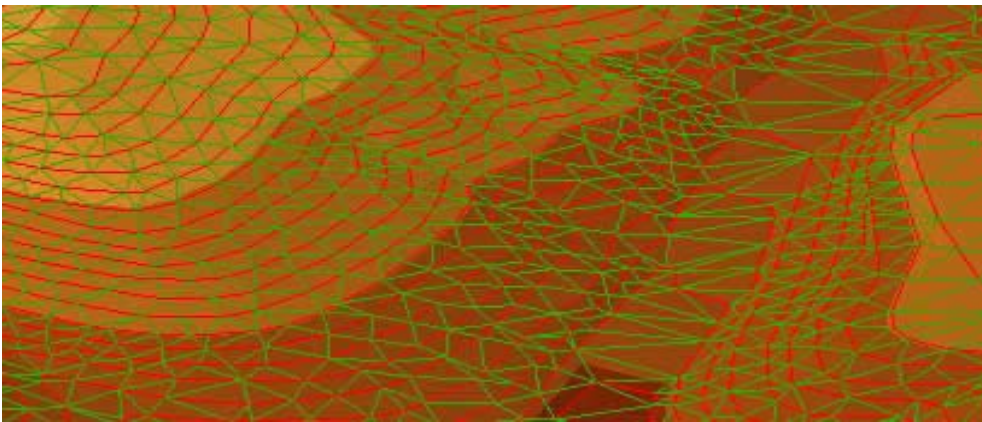

Figure 2. The TIN model for Claremont Canyon

Step 2   The U.C. Berkeley Applied Environmental Geographic Information System (AEGIS) laboratory provided an Arc Macro Language (lsfactor.aml) and a C language program (rusleinfo.exe). After running these programs on the TIN model, each line segment of a triangle contains a LS factor representing areas where soil deposition may occur (Figure 3).
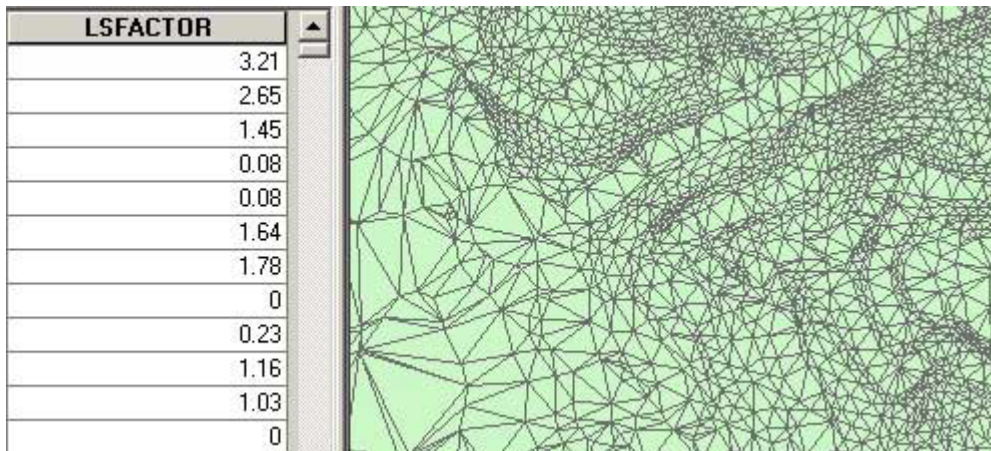
LSFACTOR
3.21
2.65
1.45
0.08
0.08
1.64
1.78
0
0.23
1.16
1.03
0

Figure 3. The results of land slope length and steepness factor

R factor   I calculated the R-factor using data provided by the Western Region Climate Center (WRCC); whose data encompassed the dates listed in the years of 1971- 2001 Monthly Climate Summary for Berkeley, California (Table 1) inclusively. I used statistical data ranging from a thirty-year rainfall period to calculate the R factor. Such a specific range for precipitation data meets the necessary requirement of the RUSLE model, which states that the minimum record length of climate data to be used for R factor is 22 years (RUSLE 2002). I divided this data into two groups according to their seasons (summer and winter) and calculated their respective average precipitations.   The first season, summer, is measured by the average precipitation from May through October, and the second season, winter, measured average precipitation ranging from the months of November through April. As a result, the average for summer was equal to 0.496 inches per month and winter average was equal to 3.875 inches per month. Then these two numbers were implemented in the Dunne and Leopold (1978) equation to calculate the R factor in the RUSLE model.

	May	Jun	Jul	Aug	Sep	Oct	Average (May-Oct)	Climate (R-Factor)
Average Total Precipitation (in.)	0.69	0.2	0.1	0.1	0.4	1.5	2.98	2.98/6 =0.496
	Jan	Feb	Mar	Apr	Nov	Dec	Average (Nov.- April)	Climate (R-Factor)
Average Total Precipitation (in.)	5.24	5.1	3.7	1.8	3.6	3.8	23.14	23.14/6 = 3.857

Table 1. Historical Monthly Climate Survey Summary for Berkeley, California
Document obtained from Western Region Climate Center

C Factor In order to determine the C factor for each type of vegetation in Claremont Canyon, a four step process was applied. The first step was to overlay the vegetation polygon onto the Claremont Canyon air photo. Eight fuel types of vegetation classes were identified. They consisted of Dry North Coastal Scrub, Eucalyptus, French Broom, Grassland, Oak-Bay Woodland, Pines, and Wet North Coastal Scrub. Each of vegetation class was represented by a distinctive color (Figure 4). Ensuing after the overlay process where the vegetation types were identified, the second step entailed combining all the respective polygons into eight vegetation fuel types. This is necessary as demarcation of each type would be difficult to see if all fuel types were represented all at once. As viewed in figure 4 is difficult to delineate one fuel type from another because the scale cannot adequately represent differentiation. By individually separating one fuel type from the other, it allows the researcher to view one vegetation fuel type at a time while excluding others.
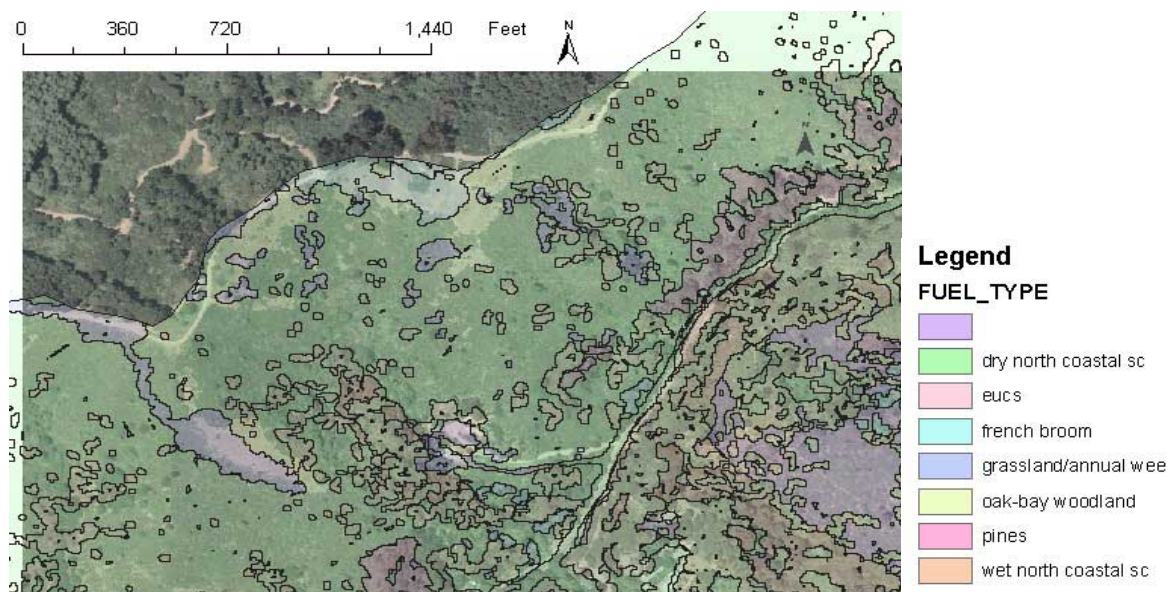

Figure 4. Vegetation polygon overlay on Claremont Canyon air photo.

Thereafter, the third step would be a careful examination of each vegetation fuel type. For example, I selected the Grasslands highlighted in green as my vegetation fuel type (Figure 5). Noticed the entire grassland polygons highlighted in green were shifted towards southwestern direction on the Clermont Canyon air photo. This discrepancy was due to the mistake of digitizing work on the vegetation polygons.
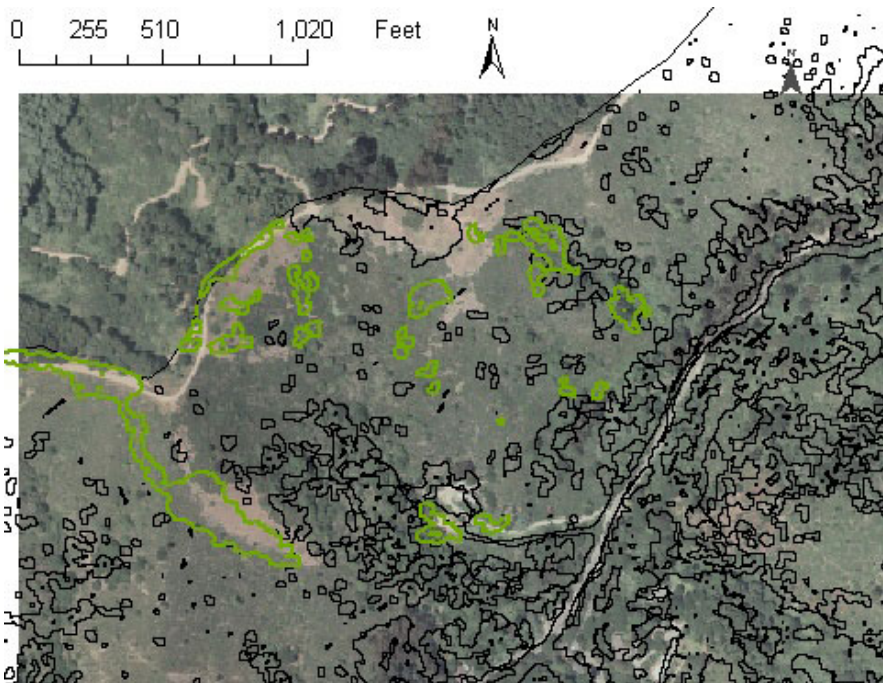

Figure 5 Vegetation fuel type (Grassland).

After a preliminary survey of the fuel types, the fourth step would be to determine the percent of canopy cover, which is the type of vegetation that causes shading effects over an area; thus preventing the capacity to analyze the vegetation that it hides. Then data should to be found on the ground cover, which determines, from the point of view of looking at particular study sites, the type of vegetation that is found there. Opposed to analyzing vegetation types and looking at general locations, an inverse perspective permits a more thorough analysis of particular segments and its compositions. Then, data should be collected on the percent of ground cover, which is the proportion of the vegetation type on each of the selected areas. It is possible that multiple vegetation types can grow in the same areas; this data would permit the researcher to see proportionality of dominant vegetation types in each selected region. To my estimation on figure 5 the overall Grassland canopy is unknown, the ground cover is mostly

grass plant materials, and there is about 80 percent Grassland covering the highlighted green areas. Taking these three pieces of information, I determined that the C factor was equal to 0.013 from tables (Dune and Leopold 1978). The four step process was repeated again of the remaining seven vegetation fuel types.

K Factor The AEGIS Department at the University of California, Berkeley provides the soil type data in digital format for the entire Claremont Canyon. There are thirteen soil types in my study area and they consist of Altamont clay, Gilroy clay loam, Lodo clay loam, Los Osos clay loam, Los Osos-Millsholm complex, Maymen loam, Maymen-Los Gatos complex, Millsholm loam, Rock outcrop-Xerorthents association, Urban Land, Urban land-Tierra complex, Xerorthents-Los Osos complex, and Xerorthents-Millsholm complex. Each unique soil type was assigned a numerical value for the K factor from the United States Department of Agriculture (USDA) 1977 Soil Survey of Contra Costa County, California. Lastly, the P factor, the support practice factor, should equal to a constant value of 60; where 60 is provided from the Isoerodent Map of California (USEPA 2001).

After I collected all five variables: LS, R, K, C and P factor. I superimposed the vegetation, soil, and LS layers on top of one another to create a topological structure. This is done so that each surface triangle representing the surface area was assigned to a vegetation and a soil factor. Then, the RUSLE formula (LS × R × C × K × P) was applied to calculate the annual soil loss; respectively for the summer and winter seasons (Table 2).

LSFACTOR	RSummer	RWinter	Cfactor	Kfactor	Pfactor	S_RUSLE	W_RUSLE
2.91000000000	0.4960	3.8570	0.0120	3.0	60.00	3.1177	24.2436
2.96000000000	0.4960	3.8570	0.0120	3.0	60.00	3.1712	24.6601
3.85000000000	0.4960	3.8570	0.0120	3.0	60.00	4.1247	32.0748
3.85000000000	0.4960	3.8570	0.0030	3.0	60.00	1.0312	8.0187
6.72000000000	0.4960	3.8570	0.0030	3.0	60.00	1.7999	13.9963
5.64000000000	0.4960	3.8570	0.0030	3.0	60.00	1.5106	11.7469

Table 2. The annual soil loss calculation results from RUSLE formula.

Results

I selected the top five regions most susceptible to soil erosion for both the summer and winter seasons and buffered these areas with a radius 0.02 kilometers to provide a better vantage point since the areas are pinpointed and difficult to see on such a large scale alone. Four buffer points

were chosen in the Claremont Canyon area as two of the regions merged due to its proximity to one another.   Then, I converted each of the polygons into a shapefile so that each polygon possesses further information from the attribute table. By selecting the regions, data on the region is pulled up for the viewer to investigate.   The results of the model over the expanse of the four buffer points yielded the average annual soil loss for summer to be 60.33 (tones/acres/year), and for winter to be 429.83 (tones/acres/year).   Both of the dominant vegetation types across all buffer areas were found to be Wet Coastal Scrub and North Coastal Scrub. In addition, the dominant soil type was Maymen Los Gatos; a shallow type of soil.

I displayed all eight buffered points on the Claremont Canyon air photo (Figure 6). Interestingly, I found all eight at risk areas clustered together in the areas belong to the three major owners of Claremont Canyon; University of California, Berkeley, East Bay Hills Park and Regional Districts, and City of Oakland. Three out of eight locations were completely covered with wild vegetation. The remaining five locations were the wild-interface land.
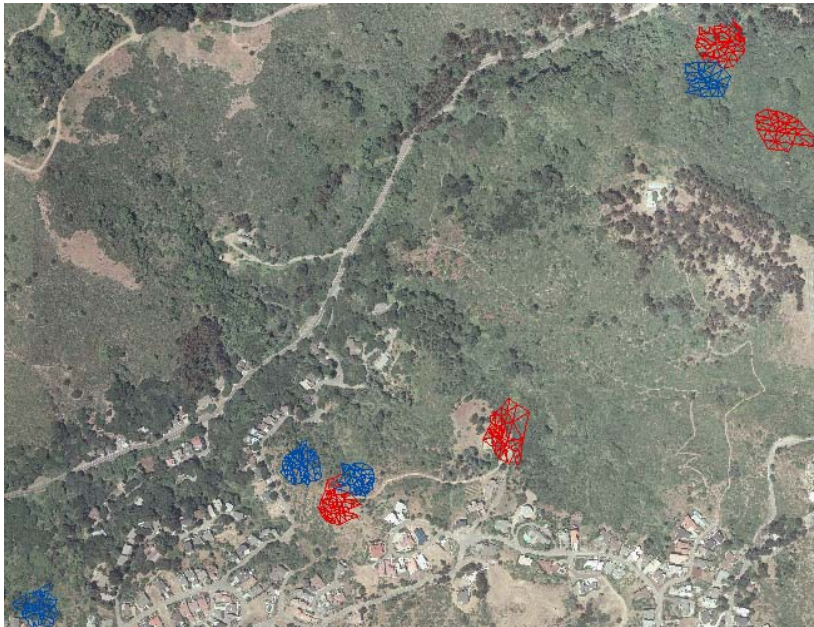

Figure 6. Eight most susceptible soil erosion areas on the Claremont Canyon air photo.

One at risk region was found to be underlying a constructed building (Figure 7). Therefore, the foundation of this building has the potential to erode away and collapse due to heavy rainfall. Further steps should be taken on renovation in order to maintain its structural safety; otherwise, greater property lost may result from the lack of action taken on this area.
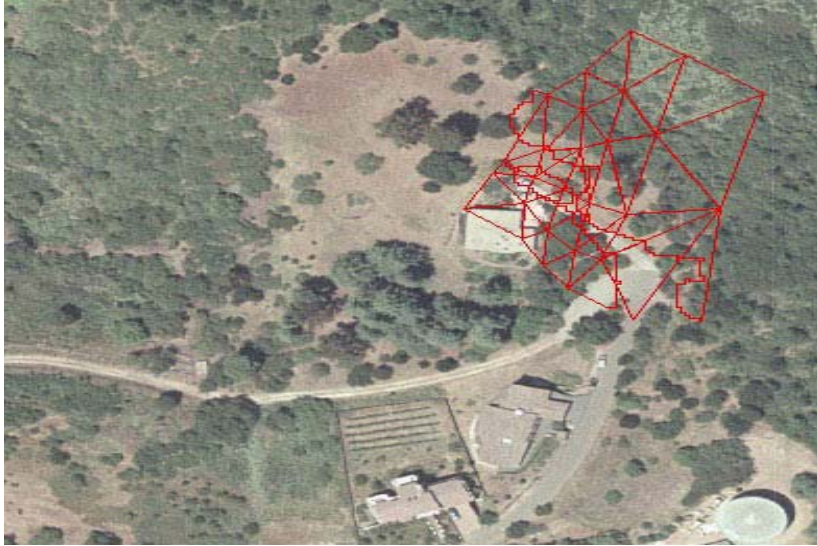
Figure 7. A buffered area found on a constructed building.

Another at risk location was found in between the wild lands and residential buildings (Figure 8). This area is vulnerable to great soil loss and is at danger to for landslides that could impact residential infrastructures, putting at risk property damage and human lives. Due to this threat, appropriate preventive measures should be taken into consideration.

Figure 8. A buffered area found in between the wild and residential buildings.

Discussion

The results of this model generated useful data found on the interactions between slope length and steepness, rainfall, vegetation, soil and land-use practice in the Claremont Canyon and its impact upon the environment. The results served as a basis for further decision-making concerning land use practices and any determining the necessity for modification and action. Such action could entail future planning regarding development. This information will better inform developers conditions for safety of residency. The ultimate goal of this model reveals what parts of the Claremont Canyon are most in jeopardy to soil erosion. In applying this model, and once modifications in land use are implemented, the Claremont Canyon should benefit from decreased dangers from soil erosive events, and preventing high costs and saved lives from sudden damage. This project can also be modified in order for use as a basis for modeling other management issues.

Appendix I. Digital Data Sets of the Claremont Canyon

	Hysography	Soil	Vegetation
Description:	Elevation lines	Soil types	Vegetation types
File name:	Hypso_sp.shp	soils_sp	Veg221.shp
Format:	ESRI shapefile	ESRI shapefile	ESRI shapefile
Metadata:	Yes	Yes	Yes
Extent:	Claremont Canyon	Claremont Canyon	Claremont Canyon
Projection:	California zone III NAD 1983 in feet	California zone III NAD 1983 in feet	California zone III NAD 1983 in feet
Feature Type:	Line	Polygon	Polygon
Number of features:	891	26	6217
Source:	U.C.Berkeley	U.C.Berkeley	U.C.Berkeley

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