Soil Erosion Control Methods for Steep Slope Vineyards 2010

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ABSTRACT

As viticulture expands in North Carolina due to growth in the state's wine industry, grape cultivation on steep slopes is becoming more prevalent. Little research has been done to establish options for controlling soil erosion in vineyards in this region. The purpose of this study was to compare the influence of two soil preparations on vineyard erosion to bare soil under vine (control). Randomized and repeated treatments (n=3) of coconut fiber cloth, white clover cover crop, and bare soil maintained by herbicide were applied to vineyard rows planted vertically across a 30° slope. Water runoff was collected after 14 rain events and analyzed for total volume and sediment content. Results averaged by categories of total rain quantity and maximum rain erosivity per collection date appeared to show trends of consistent reduction of rain runoff and sediment loss in the two comparative treatments over the bare soil control. Overall averages suggest clover may reduce sediment weights by roughly 120 percent compared to bare soil and reduce runoff by 30 percent. Erosion control cloth showed a roughly 350 percent reduction of sediment loss and 16 percent reduction of runoff compared to bare soil in these averages. However, the statistical analysis of differences between treatments (ANOVA) proved inconclusive due to high standard deviations and variation in results among treatment values. Bare soil rows also consistently showed the highest standard deviation.

INTRODUCTION

The grape and wine industry in North Carolina experienced a period of rapid growth between 2005 and 2010. In that time, the number of wineries in the state doubled and vineyard space expanded to over 1800 acres. The North Carolina Wine and Grape Council reported 4800 tons of grapes harvested in 2009 (NCWGC 2010). As land is converted to vineyards, moderate and steep sloped aspects are considered for cultivation especially in Western NC. Vineyards are particularly vulnerable to erosion due to the practice of maintaining bare soil below vines as a method of weed suppression. Data collected for Appalachian State University Enology and Viticulture's (ASUEV) 2010 vineyard survey confirmed that the majority of NC vineyards maintain bare soil below vines through the use of chemical herbicides in accordance with common industry practices (Smith, 2010). The objective of this study was to compare the efficacy of below-vine erosion control treatments on a steep slope to a bare soil control. The study was funded by the North Carolina Wine and Grape Council (NCWGC) with the participation of the North Carolina Department of Agriculture (NCDA) Upper Mountain Research Station (UMRS) in Lansing, NC.

Cover crops, including clover, are a common management tool to reduce soil erosion recommended by the Natural Resources Conservation Service (NRCS, 2007). In vineyards, cover cropping is often considered to introduce biodiversity into the vineyard, contribute organic matter to soil, improve soil structure, and to reduce soil erosion (Ingels *et al*, 1998). In reference to the use of grasses in vineyards, Ingles *et al* (1998) identify the mechanisms by which cover crops affect soil erosion such as reducing the rate of surface flow and increasing the soil penetration of water. In addition to plantings between vine-rows, cover crops can serve to stabilize soil under vines. Below vine cover cropping is used by some vineyard managers, especially those who practice organic or sustainable techniques (Rombough 2002). Erosion control cloth, however, is more common in construction sites than vineyards. This study was conducted to determine the viability of such vineyard treatments as methods to control water and soil erosion on a steep slope.

MATERIALS AND METHODS

The methodology for this study was developed following the recommendations of hydrology specialist Dr. Roy Sidle, former Program Director for the Environmental Sciences Program at Appalachian State University. Input from Dr. Richard McLaughlin, NCSU Department of Soil Science (July of 2009), was also considered in the experimental design.

Experimental Design

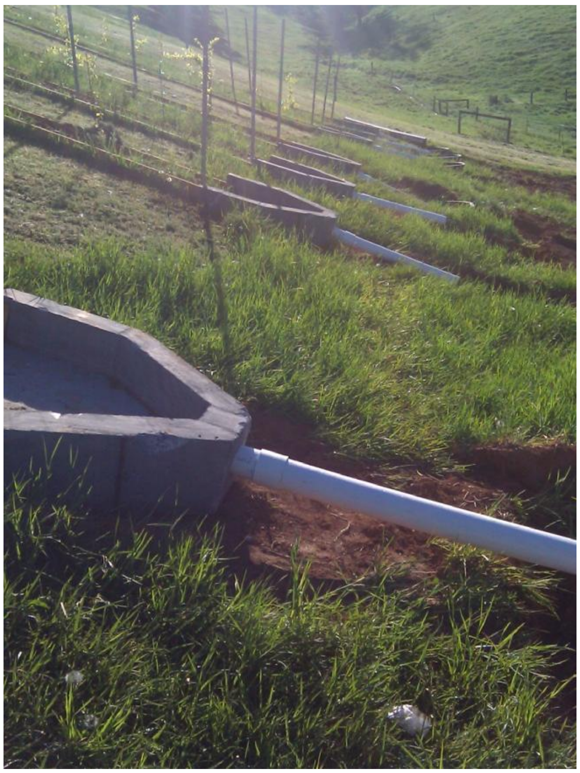
The study was conducted on 7,500ft^2 (2,286 M^2) at the NCDA UMRS in Lansing, North Carolina. Samples were collected during the 2010 growing season following fourteen rain events between June 28th and October 28th.

Vine rows were oriented N-S following a 30° slope. Vines were two years old at the time of study. Wooden borders of rough sawn locust boards (approximately 8" X 1.5" X 12') were installed around each row to create discrete 3' X 35'(0.9 X 10.7 M) plots. Concrete catchments were installed below each row and funneled runoff through a PVC pipe fitted to the base of each catchment. Pipes emptied into 110 gallon (417 L) plastic bins imbedded at row ends. Bins were covered by plywood to prevent direct collection of rainfall.

All rows were hand cultivated to remove existing growth under vines prior to the commencement of the experiment. Treatments were replicated at random across nine rows (n=3). Bare soil rows were maintained by use of Rely herbicide applied at a rate of 3 quarts per acre with backpack sprayer. Erosion control cloth studied was "American Excelsior Company Premier Coconut Material" purchased from Hanes Geo Components of Charlotte, NC. The material consists of 100% coconut fiber woven together with polypropylene netting and thread. Each roll, 8' X 112.5', was cut in half at the width and folded inward from the outer edges to cover the 3’ wide row interiors. Cloth was fixed to soil with ground cloth/erosion staples. A total of 52.5’ of length was used, with a total area of 210ft² (64 M²).

White Dutch Clover seed was broadcast by hand on April 30, 2010 at a rate of ~0.05 lb/row foot. [Note: this seeding rate is higher than seeding rate of 5-14 lbs per acre suggested by Sustainable Agriculture Research and Education (2007).] The White Dutch Clover variety was chosen due to the hardiness of the legume, relatively low required germination temperature (40°F), potential as a perennial crop, and accessibility of seed (SARE 2007). These factors make it a practical choice adaptable to commercial vineyard use.

Following each rain event, UMRS staff sprayed 1 gallon of water through each pipe to collect dried sediment within the basin channel, determined the total quantity of water in each bin, thoroughly agitated contents of the bins to suspend solids, and took 1 L samples of runoff from each row. Tubs were emptied and cleaned after each sampling.



The quantity and intensity of each rain event was recorded at UMRS throughout the period of study. Rainfall data recorded at UMRS was also retrieved from the State Climate Office of North Carolina’s Climate Retrieval and Observations Network Of the Southeast (CRONOS) weather database and compared to totals reported at sampling. The average rainfall per sample collection was 32.6 mm. (CRONOS database available at http://www.nc-climate.ncsu.edu/cronos/)

The Upper Mountain Research Station is supported by the NC Agricultural Research Service, station type: ECONET; Climate division: NC02 - Northern Mountains River basin. Ashe County Latitude: 36.40232° Longitude: -81.29711° Elevation: 3009 feet above sea level.

Laboratory Analysis

Water samples were transferred to the Enology Services Lab at Appalachian State University for dry weight analysis of sediment. Sediment samples were collected by vacuum filtration onto 0.45 micron quantitative filters, dried at 38°C for 24 hours in a Fisher Isotemp Oven, and weighed with an Ohaus Adventurer Balance.

RESULTS AND DISCUSSION

Total rainwater runoff volumes and sediment were averaged per treatment per collection date. Water volumes and sediment were analyzed in reference to both total rain quantity and maximum rain intensity per collection date. Daily Rainfall Erosivity (DRE), a measure of rain intensity, is defined by the State Climate Office of North Carolina as a measure of the potential ability of rain to cause erosion in a day. It is the product of daily rainfall kinetic energy and the maximum daily 30-minute rainfall intensity. The maximum DRE as calculated by the State Climate Office per sample collection date was compared to runoff and sediment totals per date.

Samples noted by the lab as contaminated with grass (caused by mowing between vineyard plot sections too near sample row) were removed from data set. A total of 16 out of 237 available data points were removed due to grass contamination.

Treatment Comparisons

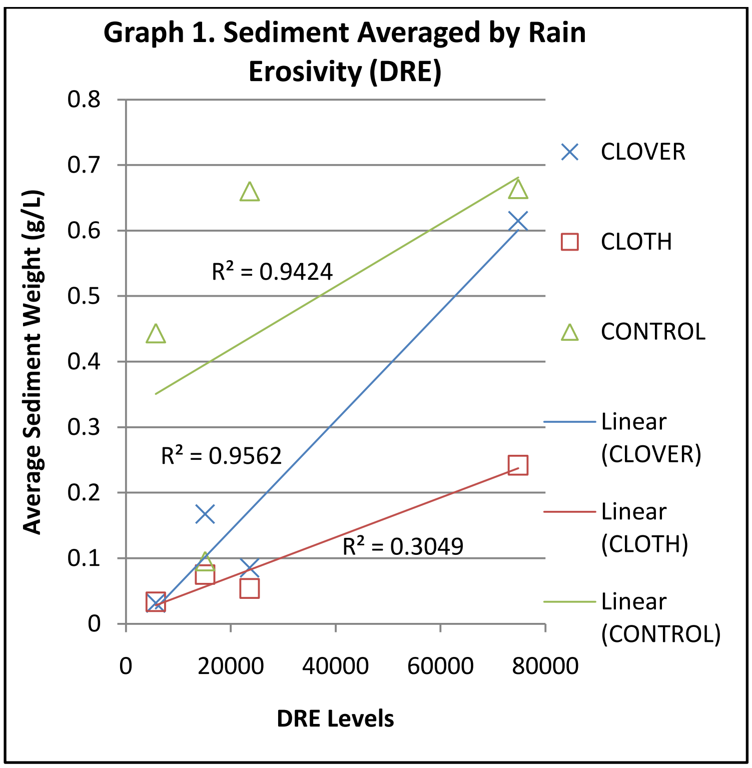
Values averaged by category, either of rain quantity or intensity, exhibit trends between the treatments. When comparing treatments by total rain quantity per collection date, clover and cloth treatments appeared to reduce both runoff and sediment levels versus the bare soil control. Averages of clover values showed the greatest reduction in runoff, while averaged cloth values showed the greatest reduction in sediment weights (Table 1).

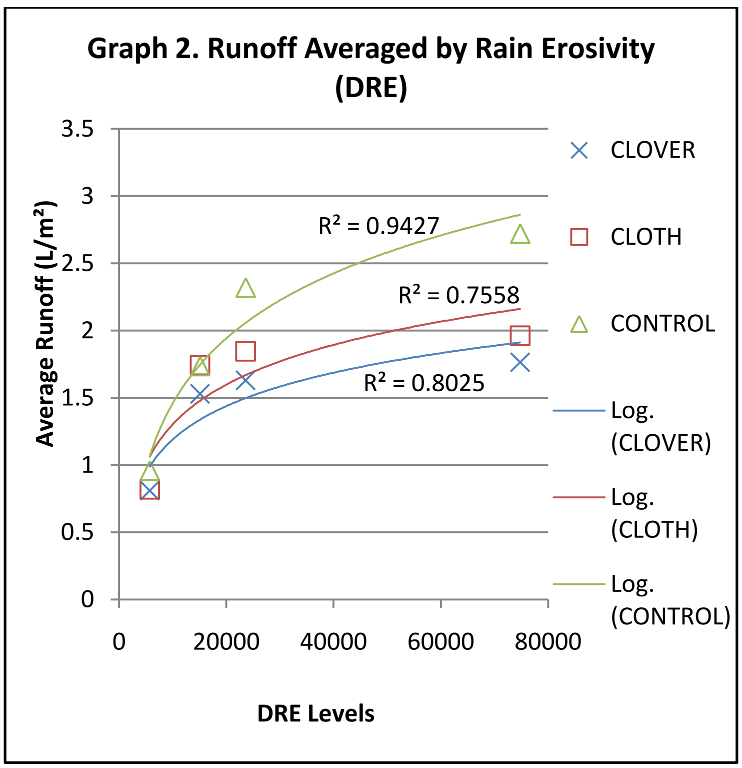
Runoff and sediment values averaged by level of rain intensity per collection date appeared to exhibit similar trends, with clover showing the greatest reduction of runoff compared to bare soil, and cloth showing the greatest reduction in sediment loss (Table 2, Graphs 1 and 2). The data arranged by rain erosivity showed a slightly higher level of standard deviation than data averaged by total rain quantity per collection date. (Runoff standard deviation averages were 0.61 and 0.73 L/m², and Sediment standard deviation values averaged at 0.35 and 0.36 g/L for Rainfall versus Erosivity data respectively).

Table 1. Runoff and Sediment Values per Treatment per Total Rain Quantity

Total Rain Reported per Collection (mm)			**Runoff (L/m²)**			**Sediment (g/L)**		
	10 to 20	**CLOVER**	0.868	+/-	0.35	0.053	+/-	0.09
Average	15.2 mm	**CLOTH**	0.894	+/-	0.33	0.049	+/-	0.07
		CONTROL	1.262	+/-	0.71	0.523	+/-	1.20
	20 to 30	**CLOVER**	1.301	+/-	0.53	0.173	+/-	0.30
Average	27.3 mm	**CLOTH**	1.518	+/-	0.57	0.073	+/-	0.11
		CONTROL	1.410	+/-	0.38	0.169	+/-	0.32
	30 to 40	**CLOVER**	1.729	+/-	0.65	0.393	+/-	0.60
Average	37.4 mm	**CLOTH**	1.834	+/-	0.65	0.166	+/-	0.32
		CONTROL	2.721	+/-	1.47	0.928	+/-	0.94
	50 to 60	**CLOVER**	2.346	+/-	0.56	0.070	+/-	0.07
Average	53.9 mm	**CLOTH**	2.780	+/-	0.79	0.059	+/-	0.04
		CONTROL	2.701	+/-	0.38	0.074	+/-	0.08

Table 2. Runoff and Sediment Values per Treatment per Daily Rain Erosivity (DRE)								
Maximum Daily Rainfall Erosivity Reported per Collection			**Runoff (L/m²)**			**Sediment (g/L)**		
DRE Range 0 to 10,000	Average 5694	**CLOVER**	0.808	+/-	0.33	0.032	+/-	0.03
		CLOTH	0.818	+/-	0.33	0.034	+/-	0.02
		CONTROL	0.956	+/-	0.27	0.444	+/-	1.14
DRE Range 10,000 to 20,000	Average 15096.4	**CLOVER**	1.530	+/-	0.74	0.167	+/-	0.30
		CLOTH	1.743	+/-	0.89	0.075	+/-	0.12
		CONTROL	1.735	+/-	0.72	0.096	+/-	0.13
DRE Range 20,000 to 30,000	Average 23593	**CLOVER**	1.630	+/-	0.68	0.085	+/-	0.08
		CLOTH	1.847	+/-	0.77	0.054	+/-	0.04
		CONTROL	2.320	+/-	0.90	0.660	+/-	1.00
DRE Range over 30,000	Average 74796.5	**CLOVER**	1.765	+/-	0.71	0.615	+/-	0.68
		CLOTH	1.962	+/-	0.74	0.242	+/-	0.37
		CONTROL	2.721	+/-	1.70	0.664	+/-	0.39





Sediment rates from bare soil rows showed the greatest variation in standard deviation (Tables 1and 2) and trend line (see Graph 1). Logarithmic trend lines for runoff data averaged by rain erosivity show that the highest rate of increase of runoff occurred in all treatments at the lower increasing increments of rain intensity (see Graph 2).

Statistical Difference

The statistical analysis of differences between treatments (ANOVA) proved inconclusive due to high standard deviations and variation in results among treatment values. (Compare averages to standard deviations in Tables 1 and 2). Plotting of all data points confirmed that trends were not strong. This discrepancy implies a high margin of error in the data. When all bare soil sediment weights were plotted against rain erosivity, the control had the lowest r^2 value for the relationship (Appendix).

Although this study did not show a statistical difference due to the variability of results per treatment, trends can be identified from the averaged and totaled results and merit additional consideration with some modification of the field-design and sample collection methods. There are implications that in practice, the most soil erosion and water runoff occurred under bare soil rows (Table 3), although this was not absolute in year-one of this study. Overall averages suggest clover may reduce sediment weights by roughly 120 percent compared to bare soil and reduce runoff by 30 percent. Erosion control cloth showed a roughly 350 percent reduction of sediment loss and 16 percent reduction of runoff compared to bare soil in these averages. Minor adjustments in the sample collection methods and timing may help improve the statistical variance encountered in this study. As such, the relationship between absolute rainfall and water runoff, on average, was very poor. This suggests error associated with sampling at the time of rain event and a need for increased precision of volume measurements in the field. Additional years of data will help increase our understanding of the efficacy of the three treatments over time.

Table 3. Total, Average, and Rates of Difference by Treatment

		Clover	Cloth	Control
Sediment	Total[1]	6.64	3.33	14.59
	Average[2]	0.17	0.09	0.39
	Standard Deviation	0.35	0.17	0.77
	Reduction Compared to Control (Total)	120%	338%	
	Reduction Compared to Control (Average)	126%	350%	
Runoff	Average (L/m²)	1.47	1.65	1.92
	Reduction Compared to Control (Average)	30%	16%	

[1]Total dry weight (g) collected from samples by treatment

[2]Average of all sediment weights per treatment (g/L)

CONCLUSIONS

The purpose of this study was to compare the performance of two soil treatments in reducing vineyard erosion. However, variability among treatments between collection dates was higher than expected and resulted in a lack of statistical difference between treatments. Bare soil rows showed the greatest discrepancies in results between collection dates. Overall (total and average) levels of runoff and sediment from rows suggest that some practical difference exist between treatments, albeit these values were not statistically distinct. Additional research will be necessary to shed light on the potential causes of the variation seen in results.

A revision of the study methodology utilizing the permanent research infrastructure installed at the Upper Mountain site would provide further insight and data, and potentially reduce the margin of error seen in this preliminary study considerably. Additions to study methodology include accounting for variables such as the cumulative effect of multiple minor rain events on samples. Supplementary monitoring of human variables such as mowing and consistent data collection technique will also contribute to more consistent results.

In practical application, the cost of materials and labor must also be taken into consideration. Even at a very heavy seeding rate, the clover used cost ~$15 to cover same row distance as $59.50 in erosion control cloth (Clover @ $2.95/lb, Cloth @ $85 per roll). Herbicide was applied to bare soil control rows at a material cost of $39/acre. Labor costs will vary on management style of cover cropping or herbicide use. Along with continued evaluation of treatment performance, these practical variables will require further study to determine the true cost-effectiveness of these treatments. Viticulture concerns such as the interaction of these treatments with crop vigor or pest and disease issues, however, also affect the practicality of using cover crop, cloth, or another treatment such as straw, and should be studied further.

Additional variables to be explored in relation to soil erosion include the possible accumulative benefits of using a soil erosion control method over multiple years, a comparison of types of cover crops (legume versus grass for example), a comparison of seeding rates, and the overall cost effectiveness of cover crop or cloth management techniques.

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Appendix: Example Treatment Comparisons