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A field study on cost-effectiveness of five erosion control measures

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Abstract

Purpose – The purpose of this study is to quantitatively evaluate five erosion control measures at a residential development area in Louisiana, USA in order to provide Best Management Practices (BMPs) that have been tested in the field with demonstrated cost-effectiveness.

Design/methodology/approach – A total of six testing sites at a nine-degree slope were used in parallel to study five erosion control measures with one being the control site (no protection). Soil erosion rate was quantified using the erosion bridge method. Soil underlying the study area was analyzed for surface runoff potential. Precipitation was monitored using a Sigma rain gauge. Analysis of variance (ANOVA) and Student Newman-Keuls Post-Hoc ANOVA analysis were conducted to evaluate statistical significance of erosion control effectiveness. Ratio of soil erosion rate reduction to cost of each control measure is also analyzed.

Findings – All erosion control measures studied were very effective in reducing soil erosion for soils with high runoff potential, ranging from 75 percent to about 100 percent reduction in soil erosion rate. The most effective soil erosion protection was observed by Geojute fabric and Curlex blanket with greater than 90 percent reduction in soil erosion rate. However, after factoring-in cost, straw bedding was observed to be five times as cost-effective as Geojute fabric and Curlex blanket. The most cost-effective measure is temporary seeding using perennial rye grass. For each dollar spent, about 12 tons of soil per acre per year will be prevented from eroding.

Originality/value – The study evaluated erosion control measures in the field with quantitative cost-effectiveness analyzed. Besides enforcement, providing practical and cost-effectiveness control measures that have been tested in the field is critical for actual implementation of erosion control measures.

Keywords Soil erosion, Water pollution, Water treatment, Environmental management, United States of America

Paper type Research paper

Introduction

The overall goal of restoring the nations waters to "fisherable and swimmable" quality in the USA has yet to be reached. The National Water Quality Inventory: 2002 Report to Congress, the latest on the quality of the nation's waters, indicates that approximately 40 percent of the nation's lakes, rivers and estuaries do not meet designated use criteria – little change since 1992 (USEPA, 2007).

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The United States Environmental Protection Agency (USEPA) and Natural Resource Defense Council (NRDC) consider pollution from diffuse sources, including unban storm water pollution, to be the most important source of contamination in the nation's water (USEPA, 2007; NRDC, 2007). Spreading urban and uncontrolled shoreline developments can result in an unacceptable deterioration of water quality. This is due in part to the lack of implementation of Best Management Practices (BMPs) for mitigation of urban runoff 9NRDC, 2007). Of particular concern, is the erosion and associated contaminants resulting from construction activities which may account for as high as 2,500 tons ha^{-1}yr^{-1} soil loss if not checked by appropriate BMPs (Harbor *et al.*, 1995; Herzog, 1997; Novotny and Chesters, 1999).

Erosion is a natural process in which soil and rock material is loosened and removed. Soil erosion by water is usually caused by the force of water falling as raindrops and flowing in rills and streams. Any site where soils are exposed to water, wind, or ice can experience soil erosion problems. Human activities such as farming and construction can accelerate erosion by removing vegetation, compacting or disturbing the soil, changing natural drainage patterns and by covering the ground with impermeable surfaces (pavement, concrete, buildings). This results in large amounts of water moving more quickly across a site which can carry more sediment and other pollutants to streams and rivers (USEPA, 2007; NRDC, 2007; Olivera and DeFee, 2007; Novotny and Chesters, 1999).

Runoff from construction sites is by far the largest source of sediment in urban areas under development (Novotny and Chesters, 1999; Fennessey and Jarrett, 1994; Novotny and Olem, 1994). Construction site runoff carries the highest strength total suspended solids (mg/l) than all other point and non-point source wastewaters (Novotny and Chesters, 1999). Erosion rates from natural areas such as undisturbed forested lands are typically less than one ton acre^{-1}yr^{-1}, while erosion from construction sites range from 7.2 to over 1,000 tons acre^{-1}yr^{-1} (Fennessey and Jarrett, 1994). Each year an estimated 80 millions tons of sediment is washed from construction sites into the lakes, rivers and waterways of the USA (Fennessey and Jarrett, 1994; Novotny and Olem, 1994). Although this sediment is only a fraction of the total sediment load, it is the major source pollution of many lakes and streams that drain small watershed in which development is occurring. The nutrients contained in eroded soil can reduce water clarity, deplete oxygen, lead to fish kills, and create odors (Novotny and Chesters, 1999). Erosion of stream banks and adjacent areas destroys streamside vegetation that provides aquatic and wildlife habitats. Excessive deposition of sediments in streams blankets the bottom fauna, "paves" stream bottoms, and destroys fish spawning areas. Turbidity from sediment reduces in-stream photosynthesis, which leads to reduced food supply and habitat. Suspended sediment abrades and coats aquatic organisms (USEPA, 2007; Novotny and Chesters, 1999; Crawford and Lenat, 1989).

Erosion also reduces land fertility (Van de Nguyen *et al.*, 2008; Olivera and DeFee, 2007; Colacicco *et al.*, 1989). Erosion removes the smaller and less dense constituents of topsoil. These constituents, along with clay and fine silt particles and organic materials, hold nutrients that plants require. The remaining subsoil is often hard, rocky, infertile, and droughty. Thus, reestablishment of vegetation is difficult and the eroded soil produces less growth.

A number of BMPs for construction sites erosion control are documented in literature (Holt *et al.*, 2004; USEPA, 2002; TDEC, 2002; Lemly, 2002; IDNR, 1996; Goldman *et al.*, 1996). However, only a few provided quantitative evaluation of BMPs' effectiveness. Of those who did a quantitative analysis, some was solely based on computer simulations (TDEC, 2002), while others only reported the reduction of soil loss but no analysis on cost of BMPs (Holt *et al.*, 2004).

Purpose of this study

To significantly increase implementation of BMPs at construction sites, we should not only commit to effective enforcement, but also provide construction industries with BMPs that have been tested in the field with demonstrated cost-effectiveness.

The overall goal of this study is to test and quantitatively evaluate cost-effectiveness of five erosion control measures at a residential development area. This residential development area is representative of many new development areas located contiguous to the North Shore of Lake Pontchartrain in Mandeville, Louisiana, USA. Sediment is washed from those construction sites into the lake and cause land loss and deterioration of lake water quality. The Lake Pontchartrain is home to over 1.5 million people. The Pontchartrain Basin is one of the largest and most productive estuaries in the continental United States. Rapid development throughout the north shore is a major contributor of pollution to Lake Pontchartrain (Jin *et al.*, 2003). Recreational activities including swimming have been banned in areas of the lake. Oyster harvesting areas have been closed and threats to the fishing industry are of concern (Jin *et al.*, 2003). Implementations of cost-effective BMPs at constructions sites are essential for revitalization of the lake. In this paper, we report cost effectiveness of five BMPs using ratio of reduction of soil loss rate to cost of each BMP. These BMPs include: wood chips; straw bedding; temporary seeding; Geojute netting and Curlex blanket. This assessment would offer potentially valuable inputs for other similar projects in areas of similar climatic and geologic conditions.

Material and methods

Preparation of testing sites

Selection of the test sites are based on the following criteria: representative of the development area; homogeneity in soil texture and topographical slope; and proximity to a weather station. A diagram of the erosion testing sites is presented in Figure 1.

Six sites in close proximity were used in parallel to study erosion control BMPs. Study plots were duplicated by identical BMP applied to adjacent plots. This allowed for a measure of variability and precision of erosion measurements. Two plots served as experimental controls to determine background levels of erosion, i.e. no BMPs applied. All six sites are located at a 9° slope. Each site was 16 feet wide with each treatment plot eight feet wide. The erosion control sites were four feet in length. Each site and its duplicate were cleared of vegetation and then the appropriate BMP technique implemented.

Installation of erosion control measures/BMPs

Five erosion control measures/BMPs are compared to control plots to evaluate mitigation of soil liberation. These include: wood chips; straw bedding; temporary

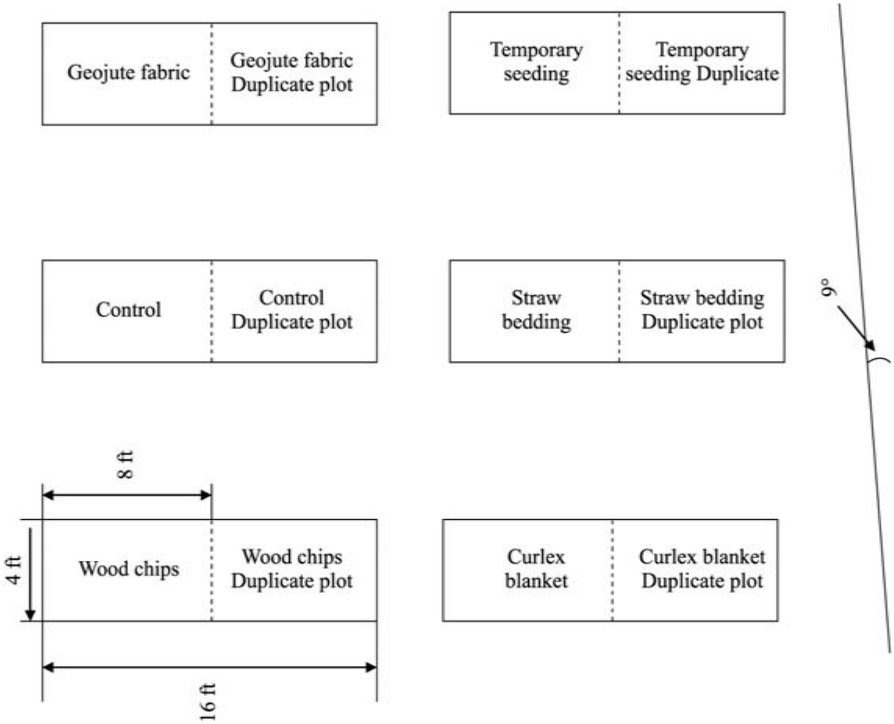


Figure 1.
Testing sites for comparing erosion control measures/BMPs

seeding; Geojute netting and Curlex blanket. All materials tested in this study are biodegradation materials. Biodegradable materials are the main focus of this study since natural materials are environmentally compatible and further problem are minimized. The installation and application of these five different erosion control measures were in accordance with the Tennessee and Indiana Erosion Control Handbook (TDEC, 2002; IDNR, 1996). The application rate and cost of each erosion control technology are listed in Table I.

Measurement of soil loss and soil erosion rate

Soil loss or erosion quantities were measured using an erosion bridge. An erosion bridge is an effective method used by many researchers to measure soil loss (Clarke and Walsh, 2006; Shakesby, 2006; Nash *et al.*, 2003; Whicker *et al.*, 2002; Blaney and Warrington, 1993) and was deemed to be the most appropriate method due to its

Erosion control measures	Application rate	Estimated cost (per 1,000 ft^2)
Wood chips	185-275 lbs/1,000 ft^2	\$15.00
Straw bedding	70-90 lbs/1,000 ft^2	\$5.00
Temporary seeding (perennial rye grass)	0.11 lbs/1,000 ft^2	\$0.20
Geojute netting	1,000 ft^2/1,000 ft^2	\$55.00
Curlex fiber blanket	1,000 ft^2/1,000 ft^2	\$47.80

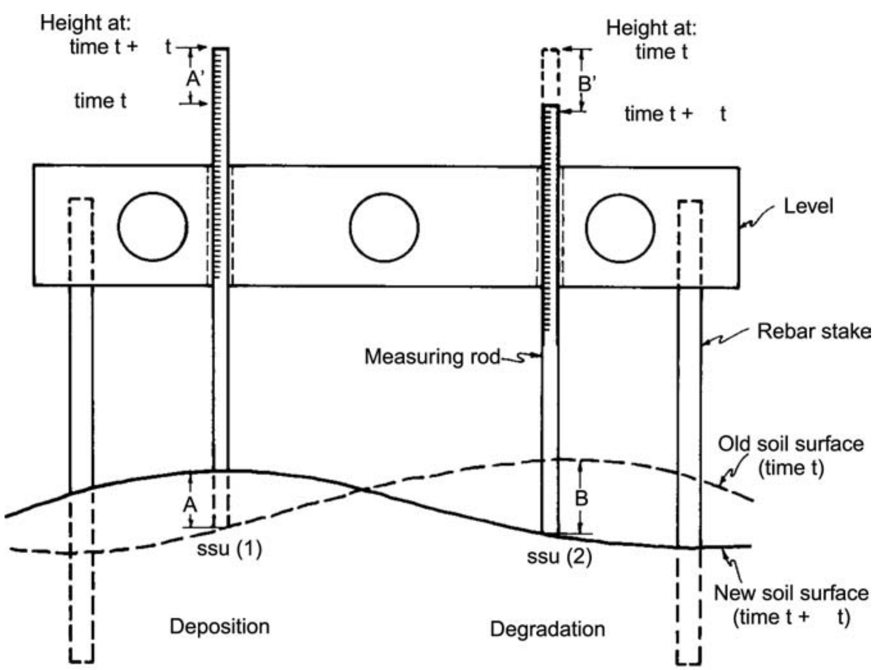
Table I.
Application rate and cost of erosion control measures/BMPs

adaptability and statistical soundness. The erosion bridge is a portable device consisting of a rigid level mounted on fixed stakes whose height does not change over time.

As shown in Figure 2, a measurement consisted of placing a rod through previously machined holes in the level and measuring from the top of the level to the top of the rod with a measuring ruler. The level has ten equally spaced holes drilled in the upper and lower flanges, thus there will be ten measurements per bridge. For each treatment plot in this study, we randomly selected six "primary sampling unit" (psu). PSU refers to a specific location within the treatment plot spanned by two erosion bridges placed end-to-end. At each psu, 20 measurements were taken. Each of these 20 measurements is referred to as a 'secondary sampling unit" (ssu). Thus, for each treatment plot, we measured soil level at a total of 120 sampling units/locations. Sampling was conducted every two to three weeks over an eight-month period.

The soil level change (Δd) for each plot was calculated to be the arithmetic mean of the difference of the readings at time one and time two for all sampling locations. The soil level change (Δd) was then converted to soil loss (r) by the following equation (Blaney and Warrington, 1993):

$$r = 113.31 \times \rho \times \Delta d$$



Source: Blaney and Warrington (1993)

Figure 2.
Measuring the differences in soil level over time using an erosion bridge

where:

r = soil loss (tons per acre)

ρ = bulk density of soil (g/cm^3)

Δd = soil level change (inches)

To evaluate soil erosion rate (tons acre^{-1}yr^{-1}) for each control measure, soil loss (r) divided by sampling period (Δd) was first calculated for each sampling period (two-to-three weeks) followed by calculating the arithmetic mean of soil erosion rates for all sampling periods.

Statistical analysis of erosion data

Analysis of variance (ANOVA) was conducted using soil level change (Δd) data from all sampling locations to evaluate the statistical significance of each erosion control measure/BMP as it compared to experimental control (i.e. no BMPs). Probability > F of 0.01 is considered of statistical significance. In addition, we also conducted Student Newman-Keuls Post-Hoc ANOVA analysis to compare all possible pairs of BMPs. This analysis allowed us to evaluate which BMP(s) is(are) statistically superior than other BMPs. Statistical Package for Social Science (SPSS) 14.0 was used as the statistical software.

Measurement of precipitation

A Sigma tipping bucket rain gauge were programmed and mounted at the Tchefuncte Middle School, which is adjacent to the study area. The purpose is to record rainfall intensity and accumulation in order to correlate with soil loss from the testing sites. Built to National Weather Service standards, the gauge accurately measures rainfall in 0.01-inch increments. The eight inches diameter funnel directs rain water into a "tipping bucket", which is divided vertically into two halves. When 0.01 inch of rainfall fills one side of the bucket, the bucket tips, spilling the water through the bottom of the rain gauge. The other side of the bucket is then positioned under the funnel. The bucket alternates tips with each 0.01-inch of rainfall. With each tip, a magnet, mounted to the bucket, activates a sealed, magnetic reed (proximity) switch producing a momentary contact closure. When connected to the RAINLOGGER, the number of bucket tips, representing 0.01 inch of rainfall, is recorded in selectable time intervals. The rain gauge was installed at the "weather center" of the Tchefuncte Middle School, a clear area away from buildings and trees that could block the natural fall of the rain.

Soil survey and analysis

The soil conservation services "Soil Survey of St Tammany Parish, Louisiana" depicted the soils underlying the study area to include Abita (Aa), Guyton (Gt) and Ouachita (OB). The Abita series consist of somewhat poorly drained, slowly permeable soils formed in loamy sediments. The Guyton soils are very similar to Abita in that they are poorly drained and slowly permeable. The Ouachita series consist of well-drained, moderately slowly permeable soils that formed in recently deposited loamy alluvium. All of these soils fall within the hydrologic soil group "D". As to their permeability and surface runoff potential the soils in the United States have been classified by the Soil Conservation Service into four hydrologic groups: A, B, C, D. Group D soils have high surface runoff potential and very slow infiltration rates, and consist chiefly of clay soils with a high swelling potential, soils with a permanently high water table, soils with a clay pan or clay layer at or near the surface, and shallow soils over nearly impervious material. Bulk density of the soil was found to be 1.21 g/cm^3.

Results

Comparing each erosion control measure/BMP with the control

The erosion control data was collected over a period of eight months. A total of 45 inches of precipitation occurred during the period with rainfall intensity ranging from 0.005 inches/hour to 0.5 inches/hour as presented in Table II.

Erosion control effectiveness for various BMPs are presented in Figures 3-7 for wood chips, temporary seeding, straw bedding, Geojute bedding and Curlex blanket, respectively. Accumulative rainfall amounts are also included in these figures. All points represent the average of duplicate plot data for a given sampling event.

Table II.
Precipitation data (September 27, year one – June 4, year two)

Sampling period	Elapsed time (hours)	Accumulative rainfall (inches)	Average rainfall intensity (inch/hr)
09/27–10/25	673.2	3.58	0.0053
10/25–11/15	503.4	2.41	0.0048
11/17–12/03	375.8	2.47	0.0066
12/03–12/27	534.6	1.99	0.0037
12/27–01/27	736.0	10.53	0.0143
01/28–02/20	557.7	4.54	0.0081
02/21–03/06	318.9	3.58	0.0112
03/07–04/07	684.6	4.68	0.0068
04/08–05/07	671.8	5.94	0.0088
05/08–06/04	590.9	5.29	0.0090
Total	5,646.9	45.01	0.0080

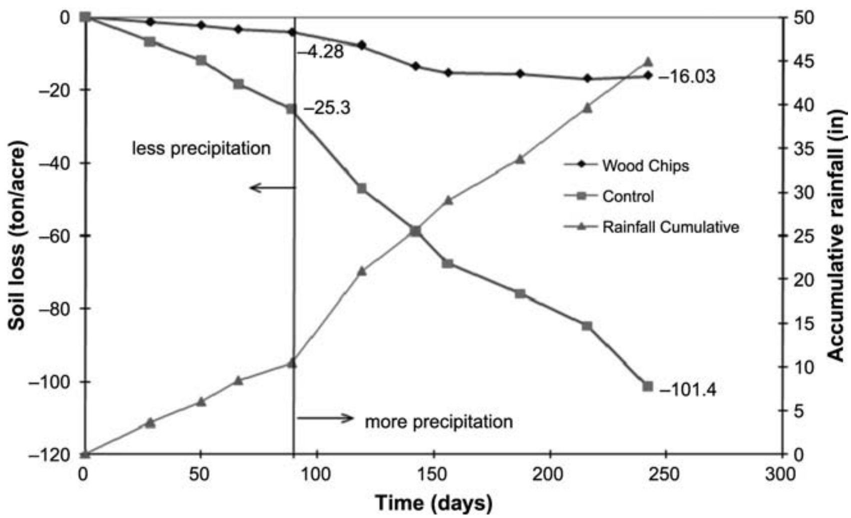


Figure 3.
Soil erosion control by wood chips

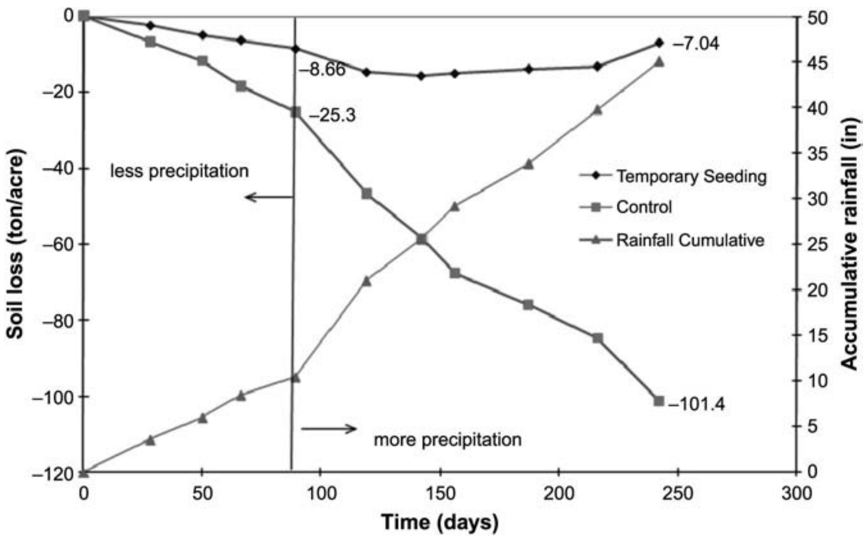


Figure 4.
Soil erosion control by temporary seeding

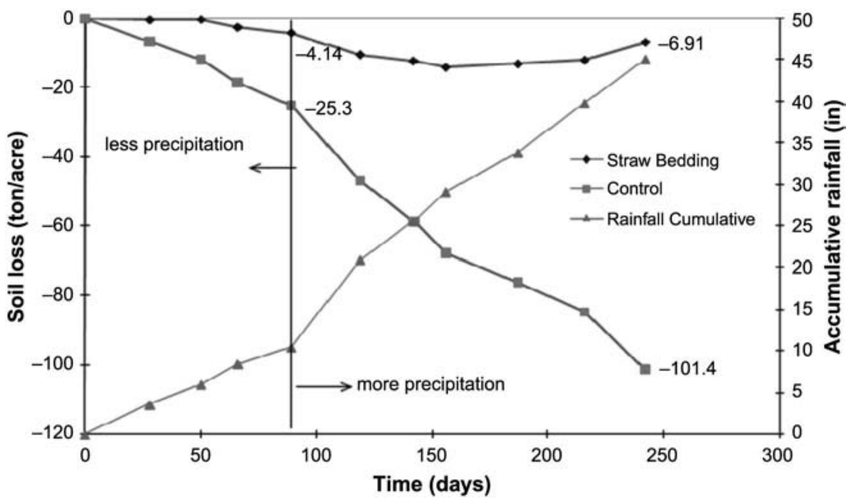


Figure 5.
Soil erosion control by straw bedding

As shown in Figure 3, there is more precipitation per month in the last 5 months of the study as compared to the first three months of the study. During the initial three months of the study (89 days), a total rainfall of ten inches was experienced. The control site lost 25 tons/acre during this period while only 4.3 tons/acre were eroded from the site containing wood chips as a stabilization material. Over the course of the eight-month study, about 100 tons/acre eroded from the control site as compared to only 16 tons/acre soil from the site using wood chips as BMP.

As shown in Figure 4, when temporary seeding was employed as the surface stabilization method, about 8.6 tons/acre of soil lost were observed within the initial

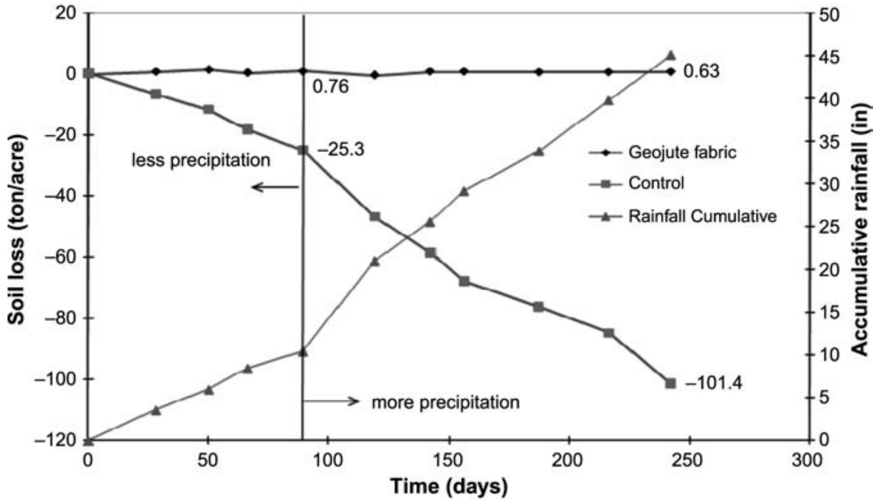


Figure 6.
Soil erosion control by Geojute fabric blanket

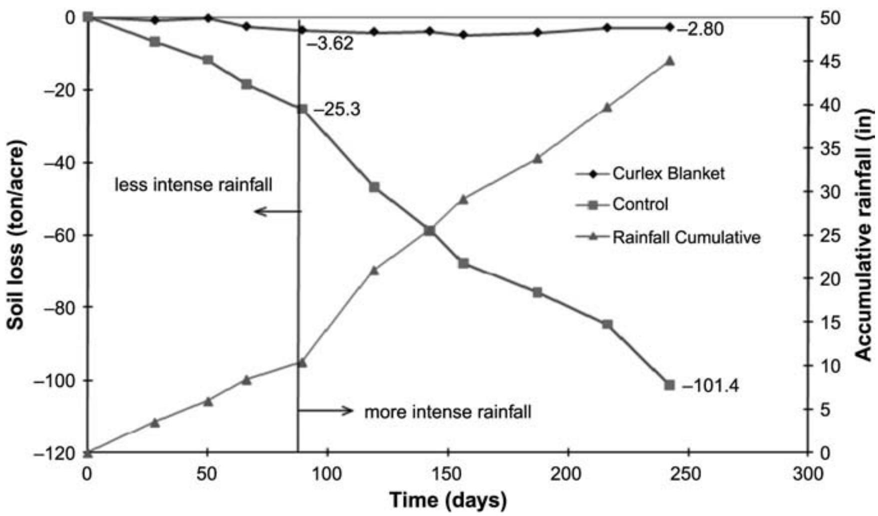


Figure 7.
Soil erosion control by Curlex blanket

three months. However, the rate of soil loss significantly decreased afterward with a total of approximately seven tons/acre soil loss was observed at end of the study.

Figure 5 indicates only 2.5 tons/acre soil were eroded over the initial three months, when straw bedding was employed as surface stabilization material and a total of seven tons/acre soil loss at the end of the study.

As shown in Figures 6 and 7, no significant soil loss was observed when the Geojute bedding and Curlex wood fiber blanket were employed as BMPs under both high and low precipitation periods.

ANOVA test was conducted to compare statistical difference between the control and applied BMPs. As indicated in Table III, differences between control and all BMPs implemented are statistically significant.

Comparison of erosion control effectiveness and cost-effectiveness among five BMPs

Accumulative soil eroded (tons/acre) for all BMPs over the period of study were summarized in Figure 8. Effectiveness of erosion control appears to be similar among wood chips, temporary seeding and straw bedding. Curlex blanket and Geo-jute fabric appear to be more effective as compared to other three BMPs. Results of Student Newman-Keuls Post-Hoc ANOVA analysis (Table IV) show that temporary seeding, wood chips and straw bedding are in one group while geojute and curlext blanket are in another group.

Soil erosion rate and ratio of soil erosion rate reduction to cost of BMPs (integrating data shown in Table I) for all five erosion control measures are summarized in Table V.

As indicated, all five erosion control measures/BMPs were very effective, ranging from 75 percent to about 100 percent reduction in soil erosion rate. The most effective soil erosion protection was observed by Geojute fabric and Curlex blanket BMPs. However, cost-effectiveness indicated by ratio of soil erosion rate reduction to cost for

	Wood chip	Temporary seeding	Straw bedding	Geojute	Curlex
Hypothesis	H = Ho	H = Ho	H = Ho	H = Ho	H = Ho
F-value	147.4	143.8	153.1	449.9	350.3
Prob. > *F*	0.0001	0.0001	0.0001	0.0001	0.0001
Conclusion	Significant	Significant	Significant	Significant	Significant

Note: Ho = control (no protection)

Table III. Statistical comparison between control and erosion control measures/BMPs

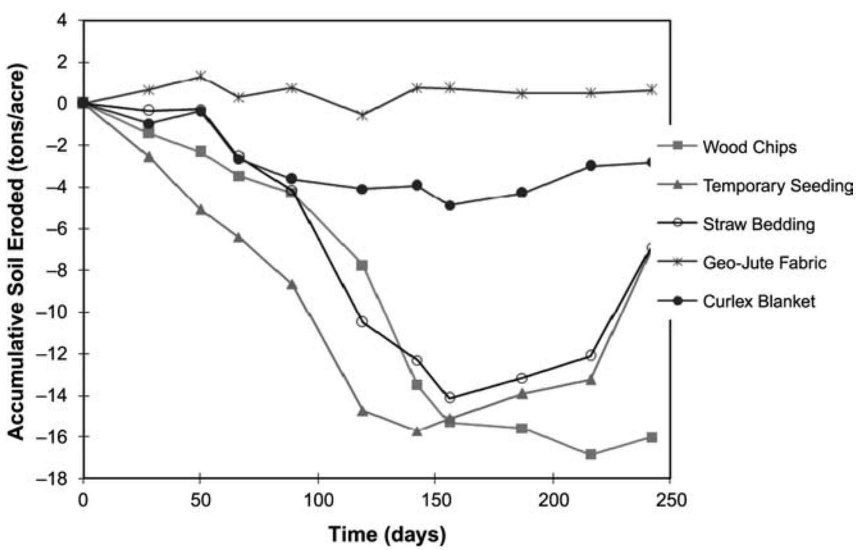


Figure 8. Comparison of erosion control effectiveness of five BMPs

these two BMPs were least attractive. Straw bedding was observed to be five times as cost-effective as Geojute fabric and Curlex. The most cost effective BMP is the temporary seeding using perennial rye grass. For each dollar spent, about 12 tons of soil will be prevented from erosion per acre per year.

Discussions

There is more precipitation per month in the last five months of the study as compared to the first three months of the study. Average intensities of the rainfalls were also higher during the last five months as compared to earlier. As expected, soil erosion at control site occurred at a higher rate during the last five months. Reduced soil loss from woodchips applied site was observed in both high and low precipitation periods, yet the greatest protection was observed during low precipitation period. The amount of soil loss from the wood chip site is attributable in large extent to wood chip wash out observed during high rainfall conditions. A lower erosion control effectiveness of woodchips was reported by Kiepe (1996) who conducted the study in semi-arid Kenya where soil in the area is highly susceptible to erosion and precipitation is sporadic yet can be strong. Foltz and Copeland (2008) reported as much as nearly 100 percent reduction in soil loss when high application of wood shreds was used. Smets *et al.* (2008) reviewed a number of erosion control studies using wood-based mulching materials and reported a range of 40 percent to 78 percent soil loss reduction.

During the initial three months of the study, soil loss at the temporary seeding site is higher than that of wood chips, primarily due to the lag time required for grass growth. A decreased grass growth rate was observed at the beginning of the year coinciding with

Five types of BMPs	n	Subset for alpha = 0.01 1	 2
Temporary seeding	160	−9.3145	
Wood chips	160	−8.7736	
Straw bedding	160	−6.9518	
Geojute fabric	160		−2.7818
Curlex blanket	160		−1.5064
Sig. (*F*-value)		0.472	0.208

Notes: Means for groups in homogeneous subsets are displayed; uses harmonic mean sample size = 160

Table IV. Homogeneous subsets determined by Student Newman-Keuls Post-Hoc ANOVA analysis

	Controls (no BMPs)	Erosion control measures/BMPs Wood chips	 Temporary seeding	 Straw bedding	 Curlex blanket	 Geojute fabric
Soil erosion rate (tons acre^{-1}yr^{-1})	127.8	24.6	32.5	19.1	9.4	No loss[a]
Reduction in soil erosion rate (%)	NA	81	75	85	93	100
Ratio of soil erosion rate reduction to cost of BMPs (tons acre^{-1}yr^{-1}/\$)	NA	0.2	11.9	0.5	0.1	0.1

Note: [a]Slightly gain in soil level was observed, probably due to swelling of Geojute matt from moisture accumulation

Table V. Cost-effectiveness of five erosion control measures/BMPs an increase in soil loss during January to March. However, grass growth was revitalized with spring resulting soil loss rate decrease. A total of approximately seven tons/acre soil loss was observed at end of the study. This is substantially less that the soil loss of 16 tons/acre observed with wood chips as BMP. Many studies (Sudhishri *et al.*, 2008; Chen *et al.*, 2007; Robichaud *et al.*, 2006; Beyers, 2004; Grace, 2002) have examined the effectiveness of seeding on erosion control under various climate and topographical conditions. Conditions studied included hill slopes in north-central Washington, USA (Robichaud *et al.*, 2006), degraded hill slopes in eastern India (Sudhishri *et al.*, 2008), forest road sideslopes in central Alabama, USA (Grace, 2002) and hilly areas of China (Chen *et al.*, 2007). Soil loss reduction was found in the range of 68 percent to about 95 percent (Sudhishri *et al.*, 2008; Robichaud *et al.*, 2006; Grace, 2002), comparable to our result of 75 percent (Table V). Importance of grass development and use of native grass species were also emphasized (Beyers, 2004; Grace, 2002).

When straw bedding was employed as surface stabilization material, a total of seven tons/acre soil loss was observed at end of the study, similar to temporary seeding. However, not like temporary seeding which needs time to establish growth, straw bedding reduce soil loss effectively right after application. Studies on using straw for erosion control have been carried out in Nigeria (Adekalu, 2007), submontaneous tract of Punjib, India (Bhatt and Khera, 2006), and subtropical area of China (Barton, 2004). Soil loss reduction was found in the range of 40 percent to 86 percent (Bhatt and Khera, 2006; Barton, 2004) similar to our result of 85 percent (Table V).

No significant soil loss was observed when the Geojute bedding and Curlex wood fiber blanket were employed as BMPs under both high and low precipitation periods. Soil loss reduction was found to be greater than 90 percent for both BMPs. These findings are consistent with other studies carried out in Australia, Germany and the USA, with reported soil loss reduction in the range of 70-95 percent (Singh *et al.*, 2008; Saathoff *et al.*, 2007; Comoss *et al.*, 2002).

The most effective soil erosion protection was observed by Geojute fabric and Curlex blanket BMPs in this study. However, cost-effectiveness for these two BMPs was least attractive (Table V). The most cost effective BMP was observed with the temporary seeding using perennial rye grass. Since little studies have been reported on cost-effectiveness of various erosion control measures, results of this study provide construction industry with additional economic aspects of erosion control BMPs, therefore may allow for better selection and implementation of erosion control BMPs.

In this study, an increase in soil levels for the last few sampling events at woodchip site and temporary seeding site was observed, primarily due to variability and precision in the erosion bridge measurements. This variability is magnified by multiplication of a very large conversion constant to obtain ton/acre. For example, a total change in soil loss level of 2 mm in one sampling period will result in a difference of 30 ton/acre. This is the reason a very large number of measurements were made per plot (80/plot) to minimize this error. For Geojute beddings and Curlex blanket sites, apparent increased soil levels were observed at the end of the study primarily due to the swelling of Geojute beddings and Curlex blanket caused by moisture accumulation.

Conclusions

All five erosion control measures/BMPs evaluated, including wood chips, temporary seeding, straw bedding, Geo-jute fabric and Curlex blanket were very effective in reducing soil erosion. Results of Student New-Man-Keuls Post-Hoc ANOVA analysis indicated that effectiveness are similar among wood chips, temporary seeding and straw bedding, ranging from 75 percent to 85 percent reduction in soil erosion rate. The amount of soil loss at the wood chips site was significantly higher during high rainfall conditions as compared to low rainfall conditions due to wood chips wash out. When temporary seeding was employed as the surface stabilization method, effective erosion control was delayed until substantial grass growth was observed. Straw-bedding is able to provide as much as 85 percent reduction in soil erosion rate.

Results of Student Newman-Keuls Post-Hoc ANOVA analysis indicated that soil erosion protection provided by Geojute fabric and Curlex blanket BMPs are superior to wood chips, temporary seeding and straw bedding, with 93 percent–100 percent reduction in soil erosion rate. The effectiveness observed with these two BMPs has been consistent throughout the study period despite variation in precipitation intensity. However, after factoring in cost of BMPs, straw bedding was observed to be five times as cost-effective as Geojute fabric and Curlex. The most cost effective BMP is the temporary seeding using perennial rye grass. For each dollar spent, about 12 tons of soil will be prevented from erosion per acre per year. However, it is important to recognize that effectiveness of temporary seeding is dependent on grass development and this may take time based on geographical locations.

These findings indicated that selection of most appropriate soil erosion control measures have to take into consideration of cost of material as well as local geographical conditions. Proper selection of temporary seeding is also important in order to establish healthy and effective ground covers.

References

Adekalu, K.O., Olorunfemi, I.A. and Osunbitan, J.A. (2007), "Grass mulching effect on infiltration, surface runoff and soil loss of three agricultural soils in Nigeria", *Bioresource Technology*, Vol. 98, pp. 912-17.

Barton, A.P., Fullen, M.A., Mitchell, D.J., Hocking, T.J., Liu, L., Bo, Z.W., Zheng, Y. and Xia, Z.Y. (2004), "Effects of soil conservation measures on erosion rates and crop productivity on subtropical Ultisols in Yunnan Province, China", *Agriculture, Ecosystems & Environment*, Vol. 104, pp. 343-57.

Beyers, J.L. (2004), "Postfire seeding for erosion control: effectiveness and impacts on native plant communities", *Conservation Biology*, Vol. 18, pp. 947-56.

Bhatt, R. and Khera, K.L. (2006), "Effect of tillage and mode of straw mulch application on soil erosion in the submontaneous tract of Punjab", *India, Soil and Tillage Research*, Vol. 88, pp. 107-15.

Blaney, D.G. and Warrington, G.E. (1993), *Estimating Soil Erosion Using an Erosion Bridge*, USDA Forest Service, Watershed System Development group, Fort Collins, CO.

Chen, L., Huang, Z., Gong, J., Fu, B. and Huang, Y. (2007), "The effect of land cover/vegetation on soil water dynamic in the hilly area of the Loess plateau, China", *CATENA*, Vol. 70, pp. 200-8.

Clarke, M.A. and Walsh, R.P.D. (2006), "Long-term erosion and surface roughness change of rainforest terrain following selective logging, Danum Valley, Sabah, Malaysia", *Soil Erosion Research in Europe*, Vol. 68, pp. 109-23.

Colacicco, D., Osborn, T. and Alt, K. (1989), "Economic damage from soil erosion", *Journal of Soil and Water Conservation*, Vol. 44, pp. 35-9.

Comoss, E.J., Kelly, D.A. and Leslie, H.Z. (2002), "Innovative erosion control involving the beneficial use of dredge material, indigenous vegetation and landscaping along the Lake Erie shoreline", *Ecological Engineering*, Vol. 19, pp. 203-10.

Crawford, J.K. and Lenat, D.R. (1989), *Effects of Land Use on the Water Quality and Biota of Three Streams in the Pedomont Province of North Carolina*, US Geological Survey Water Resource Investigation Report 89-4007, USGS, Reston, VA.

Fennessey, L.A. and Jarrett, A.R. (1994), "The dirt in a hole: a review of sedimentation basins for urban areas and construction sites", *Journal of Soil and Water Conservation*, Vol. 49, pp. 317-23.

Foltz, R.B. and Copeland, N.S. (2008), "Evaluating the efficacy of wood shreds for mitigating erosion", *Journal of Environmental Management*, Vol. 88, pp. 451-60.

Goldman, S.J., Jackson, K. and Bursztynsky, T.A. (1996), *Erosion and Sediment Control Handbook*, McGraw-Hill Publishing Company, New York, NY.

Grace, J.M. (2002), "Effectiveness of vegetation in erosion control from forest road sideslopes", *Transactions of American Society of Agricultural Engineers*, Vol. 45, pp. 121-5.

Harbor, J.M., Snyder, J. and Storer, J. (1995), "Reducing nonpoint source pollution from construction sites using rapid seeding and mulching", *Physical Geography*, Vol. 16, pp. 371-88.

Herzog, M. (1997), "Reducing erosion problems from land development: an economic incentive for erosion control", Master of Science thesis, Department of Earth and Atmospheric Sciences, Purdue University, West Lafayette, IN.

Holt, G.A., Buser, M.D., Pelletier, M.G., Harmel, R.D., Potter, K.N. and Lee, E. (2004), "The COBY process: erosion control study results", *Proceedings of Beltwide Cotton Conference, San Antonio, TX, January 7-10, 2004*.

Indiana Department of Natural Resources (1996), *Handbook for Erosion Control in Developing Areas*, Indiana Department of Natural Resources, Indianapolis, IN.

Jin, G., Englande, A.J. Jr and Liu, A. (2003), "A preliminary study on coastal water quality monitoring and modeling", *Journal of Environmental Science and Health*, Vol. A38, pp. 493-509.

Kiepe, P. (1996), "Cover and barrier effect of *Cassia Siamea* hedgerows on soil conservation in semi-arid Kenya", *Soil Technology*, Vol. 9, pp. 161-71.

Lemly, D.A. (2002), "Erosion control at construction sites on red clay soils", *Environmental Management*, Vol. 16, pp. 343-52.

Nash, M.S., Jackson, E. and Whitford, W.G. (2003), "Soil microtopography on grazing gradients in Chihuahuan desert grasslands", *Journal of Arid Environments*, Vol. 55, pp. 181-92.

Novotny, V. and Chesters, G. (1999), "Delivery of sediment and pollutants from non-point sources: a water quality perspective", *Journal of Soil and Water Conservation*, Vol. 44, pp. 568-76.

Novotny, V. and Olem, H. (1994), *Water Quality: Prevention, Identification, and Management of Diffuse Pollution*, Van Nostrand Reinhold, New York, NY.

NRDC (2007), *The 35th Anniversary of the Clean Water Act: Successes and Future Challenges*, Natural Resources Defense Council, New York, NY.

Olivera, F. and DeFee, B.B. (2007), "Urbanization and its effect on runoff in the Whiteoak Bayou watershed", *Journal of the American Water Resources Association*, Vol. 43, pp. 594-604.

Robichaud, P.R., Lillybridge, T.R. and Wagenbrenner, J.W. (2006), "Effects of postfire seeding and fertilizing on hillslope erosion in north-central Washington, USA", *CATENA*, Vol. 67, pp. 56-67.

Saathoff, F., Oumeraci, H. and Restall, S. (2007), "Australian and German experiences on the use of geotextile containers", *Geotextiles and Geomembranes*, Vol. 25, pp. 251-63.

Shakesby, R.A. (2006), "The soil erosion bridge: a device for micro-profiling soil surfaces", *Earth Surface Processes and Landforms*, Vol. 18, pp. 823-7.

Singh, A., Bicudo, J.R. and Workman, S.R. (2008), "Runoff and drainage water quality from geotextile and gravel pads used in livestock feeding and loafing areas", *Bioresource Technology*, Vol. 99, pp. 3224-32.

Smets, T., Poesen, J. and Knapen, A. (2008), "Spatial scale effects on the effectiveness of organic mulches in reducing soil erosion by water", *Earth-Science Reviews*, Vol. 89, pp. 1-12.

Sudhishri, S., Dass, A. and Lenka, N.K. (2008), "Efficacy of vegetative barriers for rehabilitation of degraded hill slopes in eastern India", *Soil and Tillage Research*, Vol. 99, pp. 98-107.

Tennessee Department of Environment and Conservation (2002), *Erosion and Sediment Control Handbook – A Guide for Protection of State Waters through the Use of Best Management Practices during Land Disturbing Activities*, Tennessee Department of Environment and Conservation, Nashville, TN.

USEPA (2002), *Federal Construction Projects Need Erosion and Sediment Controls*, US Environmental Protection Agency, Seattle, WA, EPA-910-F-03-004.

USEPA (2007), *National Water Quality Inventory: Report to Congress – 2002 Reporting Cycle*, US Environmental Protection Agency, Office of Water, Washington, DC, EPA841-R-07-001.

Van de Nguyen, N., Douglas, I., McMorrow, J., Lindley, S., Binh, D.K.N.T., Van, T.T., Thanh, L.H. and Tho, N. (2008), "Erosion and nutrient loss on sloping land under intense cultivation in southern Vietnam", *Geographical Research*, Vol. 46, pp. 4-16.

Whicker, J.J., Breshears, D.D., Wasiolek, P.T., Kirchner, T.B., Tavani, R.A., Schoep, D.A. and Rodgers, J.C. (2002), "Temporal and spatial variation of episodic wind erosion in unburned and burned semiarid shrubland", *Journal of Environmental Quality*, Vol. 31, pp. 599-612.

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