TOOLS FOR REMOTELY ASSESSING THE IMPACT OF RIPARIAN BUFFERS PROTECTING STREAMS FROM SEDIMENT POLLUTION

H. Ssegane[1] and E.W. Tollner[2]

AUTHORS: [1]Graduate Student and [2]Professor, Biological & Agricultural Engineering. Department, The University of Georgia
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Abstract. A software package was assembled and evaluated for assessing the potential of soil erosion due to agricultural development within the Nzoia River basin (Kenya). Google Earth Pro was used to define site characteristics. An extensive analysis of the components of the Universal Soil Loss Equation (USLE) and the US Forest Service sediment delivery ratio method was made to determine erosion potential and sediment yield respectively. The paired t-test comparison between GPS elevation and Google earth derived elevation showed difference between the elevations but the error margin was within the GPS unit's error margin of 5 meters. The ground truth results obtained from measured data for Watkinsville (US) and Bukora (Uganda) watersheds compared to the predicted values yielded 6 % average deviation and 10.5 % average deviation respectively with R^2 of 0.995. The Moore and sergoit bridge sites located near Eldoret, Kenya were analyzed. The predicted average soil loss at Moore's bridge site was 192 tons ha^{-1} yr^{-1} with a stream sediment yield of 1.8 tons ha^{-1} yr^{-1} while at Sergoit site is 5.3 tons ha^{-1} yr^{-1} with a stream sediment yield of 0.05 tons ha^{-1} yr^{-1}. It was deduced that Google Earth Pro is useful for the initial surveys in extracting site topographic and land use patterns. The Preliminary results suggested that agricultural pollution is not a threat in this particular region but would become as more riparian zones are cleared. Also, the rainfall energy of the region is close to that in the US, common crops of the US are in production, and the soils of the region are of the Ultisol and Oxisol classification (southeast US). Therefore, the US experience would be applicable.

INTRODUCTION

The global intensification of agriculture has led to the deterioration of the water quality draining from agricultural catchments to the receiving surface waters. Nonpoint source (NPS) pollution from agricultural land runoff, urban areas, and construction sites introduces harmful amounts of sediment, nutrients, organic wastes, and chemicals into surface waters. The financial cost due to damage on streams, lakes, and estuaries from NPS pollution in the US was estimated to be about $7 to $9 billion per year in the mid-1980s (Ribaudo, 1986).

The accelerated soil erosion has encouraged global trend of promoting sustainable agriculture (Oldeman, 1994). Target areas for promoting sustainable utilization of natural resources have included conservation and restoration of wetlands and riparian buffers as control measures in the reduction of NPS pollutants. With exponential population growth, riparian buffers are destroyed due to increased demand for agricultural land. This explains the increased degradation of the surface water quality due to sedimentation. Lake Victoria, the second largest source of fresh water on the earth is among the affected water bodies. Lake Victoria is shared by Kenya, Uganda, and Tanzania. Massive blooms of algae and the water hyacinth are blocking waterways and water supply intakes due to nutrient discharge (LVEMP, 1995). River Nzoia that drains several western districts of Kenya is a significant pollution contributor to Lake Victoria with estimated total suspended solids in magnitude of 2,504,367 tons per year (Okungu and Opango, 2001).

There are environmental laws prohibiting agricultural activities within 30 m radius of the river but the pressure for agricultural land forces small scale farmers to encroach onto the riparian zones. Financial and human resource constraints have limited the possibility of conserving areas under the threat of erosion. For practical purposes, vulnerable areas under severe conditions should be priotized. The priotization process involves assessment of the erosion problem. Therefore the study outlines the approaches used in identifying areas depicting severe erosion problems within the Nzoia River basin (Moiben sub-basin), assesses the effectiveness of Google ™ Earth Pro as a tool for defining site characteristics, and predicts soil erosion from the site agricultural lands as well as sediment.

METHODOLOGY

<u>2.1 Basin Reconnaissance Survey:</u> The basin reconnaissance survey targeted the Sergoit and Moiben sub-watersheds (upper Nzoia). Sites along the rivers were selected for analysis based on agricultural intensity, heavy cattle grazing, and accessibility. The site geographical position system (GPS) coordinates, and the elevations were recorded. Also, site photos were taken.

<u>2.2 Google ™ Earth Pro and basin Characteristics</u>
Google ™ Earth Pro is a program that maps the earth by pasting images obtained from satellite imagery, and aerial

photography over a three dimensional (3D) globe. The degree of resolution for most land is at least 15 meters. Using the GPS generated coordinates of the selected sites, Google ^{TM} Earth Pro was used to extract: (1) slope length, (2) gradient, (3) area under cultivation, (3) riparian buffer width, and (4) elevation for desired site features. Then, Surfer, 3D modeling software was used generate contours and flow direction vital for length and gradient determination. These dileniations are shown in Figures 1 through 3.

2.3 Estimation of soil erosion using the USLE: According to Oliviera *et al* (2004), the USLE model performs better than the WEPP model. The finding coupled with the world wide acceptance of the USLE, explain the choice of USLE as the soil erosion prediction model for this study. The USLE predicts soil loss as a product of six factors; rainfall factor (*R*); soil erodibility (*K*); slope length (*L*); slope steepness (*S*); crop management (*C*); and support practice (*P*). The rainfall factor quantifies the interrelated erosive forces of rainfall and runoff that are direct results of the rainstorms. For this study, the equation used to predict *R* was developed by Renard and Freimund (1994). The soil erodibility factor estimates the long term soil response to rainfall and runoff erosive forces. The global erodibility equation recommended by Torri *et al* (1997) was used. In absence of relevant data, tabulated *K* values were used based on the soil texture. The crop management (*C*) factor was calculated using the approach proposed by Haan *et al* (1994). Tabulated *C* values were used in absence of detailed rainfall distribution data. Tabulated *P* values were used. The slope length and slope steepness factors were calculated using the Renard *et al* (1997) approach. Data from Watkinsville (US) and Bukora (Uganda) watershed was used for ground-truthing.

2.4 Determination of Sediment Yield**:** The sediment delivery ratio (SDR) model developed by the US Forestry Services (USFS) was preferred because the method accounts for more site specific variables than other models. The variables include ground cover, texture of eroded material, surface run-off, slope gradient, surface roughness, delivery distance, and slope shape as depicted on a stiff graph (USEPA, 1980). Using Google Earth Pro and the computerized form of the stiff diagram the SDR was predicted.

RESULTS AND DISCUSSION

The paired t-test comparison between GPS elevation and Google earth derived elevation showed difference between the elevations. However the error margin of 4 meters was within the GPS unit's error margin of 5 meters. The ground truth results obtained from measured data for Watkinsville and Bukora watersheds compared to the predicted values yielded mean absolute errors of 0.78 tons acre^{-1} yr^{-1} (6 % average deviation) and 1.95 tons acre^{-1} yr^{-1} (10.5 % average deviation) respectively with R^2 of 0.995 (refer to figure 4 and table 1). The accuracy at Watkinsville is attributed to readily available data and high resolution images that provide for accurate assessment of the site. Thus the integration of Google Earth and USLE provide a feasible approach for predicting soil erosion to acceptable order of magnitude. 2nd Order Heading (Upper/lowercase)

The Sergoit and Moore bridge sites were analyzed for erosion in Nzoia basin. The sites are characterized by shrubs, rangeland, forests, and cultivated land. The main crops grown are corn, wheat, and sunflower with corn covering about 80% of the cultivated land. The predicted average soil loss at Moore's bridge site is 192 tons ha^{-1} yr^{-1} with a stream sediment yield of 1.8 tons ha^{-1} yr^{-1} (table 2) while at Sergoit site is 5.3 tons ha^{-1} yr^{-1} with a stream sediment yield of 0.05 tons ha^{-1} yr^{-1} (table 3). The erosion level at Moore's bridge site is severe though the sediment yield is low. The low sediment yield is attributed to the riparian buffer. Further encroachment into the buffer zone will yield high stream sediment yield. The high soil loss at Moore site is attributed to greater rainfall erosivity and high slope of 5% compared to 1.6% at Sergoit.

There are miles of streams placed on the USEPA 303d impaired streams list in Georgia and the nation in part due to sediment impairments since sediment is the leading pollutant in terms of pollutant mass. The approach developed for Nzoia River in Kenya may be useful in TMDL related assessment in Georgia and US. The combination of Google Earth Pro, sediment prediction, and riparian buffer evaluation may enable the needed fine grained approach to setting workable setbacks that account for parameters affecting erosion and sedimentation compared to the coarse grained approach of dictating via "rule a setback". This combination of tools may be very useful for assessing areas for receiving agricultural wastes such as poultry liter as part of a comprehensive nutrient management planning. Thus, this work has much promise for Georgia and the US agriculture as well as for the developing countries.

CONCLUSIONS

An extensive analysis of the components of the Universal Soil Loss Equation and the US Forest Service sediment delivery ratio method was made. The soil loss at Moore site of 192 tons ha^{-1} yr^{-1} is severe while at Sergoit site is low (5.3 tons ha^{-1} yr^{-1}). However, the sediment yield at both sites is low in the magnitudes of 1.8 and 0.05 tons ha^{-1} yr^{-1}. This depicts the effectiveness of the riparian buffers. Therefore, the buffers should be protected from future encroachment. The rainfall energy of the region is close to that in the US, common crops of the US are in production, and the soils of the region are of the Ultisol and Oxisol classification (southeast US). Therefore, the US experience would be applicable. Using Google Earth Pro, the USLE model coupled with the US Forest Service sediment delivery ratio method, it was determined that topography could be mapped and predictions of erosion potential made. It can be deduced that Google Earth Pro appears useful for the initial surveys in extracting site topographic and land use patterns.

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