USGS

WATER RESOURCES RESEARCH GRANT PROPOSAL

Title: Erosion and Sedimentation Processes in Southern Guam

Focus Category: WQL, WQN, M&P

Keyword Numbers: Soil Erosion, Runoff, Geographic Information, Watershed Management

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Congressional District of University Performing the Research: N/A

Statement of the Critical Regional or State Problem

Surface runoff and sediment losses from soil erosion are major contributors to reduction in surface water quality in Southern Guam. A study of the Ugum watershed on Guam indicates that soil erosion from vegetated savanna grassland in the watershed is approximately 70 tons ha^{-1} yr^{-1} but can be as high as 547 tons ha^{-1} yr^{-1} in unvegetated sloping sites known as "badlands" (NRCS, 1996). Agricultural lands in the Ugum watershed were estimated to have an average soil erosion loss of 45 tons ha^{-1} yr^{-1} (NRCS, 1996). Additional problems associated with soil erosion include loss of soil productivity at the eroded site, reduced water storage capacity in streams and lakes, and loss of wildlife habitat. The negative impact of sediment loading on the aquatic environment of Guam has been recorded by several researchers (Rogers, 1990; Richmond, 1993). These researchers observed that coral reef decline, due to sediment deposition, is directly linked with reduction in the quantity and quality of solar radiation in part due to the sediment load from stream runoff. Concerns over degradation of coral reef include negative impacts on fish populations and tourism.

Effective land use planning and proper erosion control is a two-part process. First we must obtain a basic understanding of runoff and erosion rates at the plot, on hill slopes, and at small catchment scale and how these vary across the landscape. Next we must

have a means to identify areas that have the potential for high erosion so that corrective actions can be taken to reduce sediment production from these areas. Runoff and eroded sediment then have to be routed down through the stream network to the locations of interest. This is particularly difficult in the highly variable hydrological environments found in Guam. Current prediction tools have been largely developed in US mainlands and there is an urgent need to refine these models for use on Guam.

Statement of the Results and Benefits of the Information Expected

The first major result of this project will be the development of a Geographic Information System (GIS) based erosion potential model for use on a southern Guam Watershed. A detailed methodology of how to apply this GIS model to other Southern Guam watersheds will also be produced. The benefits of the model and the application methodologies will be that agencies such as Guam Department of Agriculture, Guam Environmental Protection Agency (GEPA) and the US Natural Resources Conservation Service (NRCS) will be able to more easily and accurately delineate areas of high erosion potential and to explore alternative management practices that could be used to eliminate or reduce erosion. This will ultimately mean that limited funds for erosion control will be better used and more effective. The second product from this project will be the development of a unique set of rainfall, runoff and erosion relationships for the selected watershed. These relationships will give us a better understanding of the sediment transport mechanisms within a watershed. For example, if sediment concentrations are usually high during the first part of a storm or after a sustained dry period, we can infer that there has been considerable storage of sediment taking place within the watershed. The ultimate benefit of the entire project will be that those agencies such as the Department of Agriculture, GEPA and the NRCS will be able to better manage Guam's fragile and thin soils. This will result in less loss of our valuable soil resources and reduction in the impact of sedimentation on the river, reef and estuary ecosystems.

This project is designed to serve as a seed project for a larger more comprehensive study of soil erosion on Guam. We are actively working with researchers at the Hawaii Districts of the USGS to develop a proposal for this comprehensive study. The recent reimplementation of Guam/USGS water resources monitoring project will make available a wealth of information that can be used for the study of the erosion and sedimentation process in Southern Guam watersheds.

Nature, Scope, and Objectives of the Research

The nature of this proposed research is the modeling and technical and field analysis of the process of soil erosion in southern Guam.

The scope of the studies will be confined to a selected watershed in Southern Guam. The results obtained will be applicable to other Southern Guam watersheds, and will be useful for estimating soil erosion on other of the Mariana and Western Pacific Islands with soils, vegetation and climate conditions similar to Guam. The GIS modeling techniques that

will be developed will be applicable to any watersheds where similar baseline data is available.

The objectives of the proposed research will be to:

1. Develop a GIS based erosion simulation model suitable for predicting soil erosion for the soils, vegetation and climate conditions of southern Guam.

2. Examine the relationship between actual sediment production and hydrologic factors such as streamflow and rainfall.

Methods, Procedures and Facilities

The project will be divided into two phases. Phase I will be to develop and apply a GIS based erosion simulation model to a southern Guam watershed. Phase II will be to examine and develop relationships between the measured sediment yield at the watershed outlet and measured streamflow and rainfall within the watershed.

The study watershed that will be examined in this proposed project is the La Sa Fua River basins in Southern Guam. This watershed is located near the village of Umatac. Recently, as part of the USGS/WERI cooperative data network, the USGS Hawaii District office has installed streamflow and continuous sediment load monitoring equipment at the outlet of this watershed. In addition, a continuous recording rain gage has been installed in the headwater of the La Sa Fua basin.

A GIS is a generalized computer program that provides quick and relatively easy visualization, cross tabulation, and computation on and between spatially varied parameters. A GIS can be visualized as a series of transparent overlays placed over a map of an area being investigated. Each overlay contains data describing a particular parameter of interest, e.g. one overlay for rainfall amount, a second for ground slope, etc., etc. The relationship and interactions between parameters can be easily modeled and explored.

PHASE I. GIS Erosion Model

The actual erosion model will be a GIS implementation of the Universal Soil Loss Equation (USLE). The USLE is an empirical equation that was developed and established at the National Runoff and Soil Loss data Center in 1954 by the Science and Educational Administration (Wischmeir and Smith 1978). The USLE, derived empirically is

A = RxKxLSxCxP

A is the estimated sheet and rill erosion for a watershed in tons/acre-year. R is the rainfall erosivity factor that accounts for differences in rainfall intensity, volume, duration, and frequency at different locations. K is soil erodibilty factor that includes the combined effects of soil's characteristics that influence water intake and its ability to resist

detachment and transport by rainfall and runoff. C is cropping management factor that accounts for effects of plant or mulch cover and soil surface conditions. P is management factor that accounts for the effects of conservation practices such as interceptor terraces and contour strips of vegetation. SL is slope length that accounts for length of the watershed and for the increased erosiveness of runoff as slope steepens. The USLE was designated “universal” because it is free of some of the generalized and geographic and climatic restrictions inherent in earlier models (Lal, 1994).

The GIS implementation of the USLE will be developed using the ArcView GIS program. The model will be developed by first inputting the USLE parameters describing the erosion process and performing the required calculation between these parameters.

Slope/Slope Length

Recently developed digital elevation model (DEM) data will be used as the starting point for modeling the topographic aspects of the test basins. Triangular Irregular Networks (TINs) will be developed from the DEM data and these TINs will be used to develop slope, slope aspect and slope length coverages for the study basins.

Ground Cover

Digital ortho photography produced for the Government of Guam, Bureau of Planning will be used to develop digital maps of ground cover factors.

Soil Erodability

The NRCS has recently completed a study of soil erodability factors for the soils of southern Guam. We will combine this data with the already available digital soil maps of Guam to produce soil erodability coverage for our selected watershed.

Rainfall Erosivity

Recent studies by Dumaliang (M.S. thesis, 1998) and Khosrowpanah and Dumaliang (1998) have developed maps of rainfall erosivity for southern Guam. These maps will be converted to an appropriate GIS format.

The final step in the model development will be to form up the equational relationships between the overlays. This will result in the actual GIS erosion simulation model. Each of the input parameter maps will be formed into identical grid coverages. An output grid of potential erosion rate will be calculated by combining algebraically the USLE parameters at each grid location. Next contouring and like parameter grouping techniques will be used to identify areas of similar erosion potential rates. Maps identifying high erosion potential areas will be produced.

We will document the methodology required to produce the erosion potential maps. This documentation will be included in the completion report so that the process can be applied to other watersheds in Guam and in other areas where similar data is available.

PHASE II. Sediment production vs. streamflow and rainfall

In this phase we will compare sediment production to streamflow and average basin rainfall. Sediment production data will be collected at the newly activated USGS sediment gage on La Sa Fua River. Streamflow values will be obtained from the same site. Rainfall data will be collected at a site in the headwaters of the basin. First we will make time plots of all three of the measured values. Next we will make regressions of monthly average streamflow versus monthly sediment production. We will examine these relationships to determine if there is any statistical significance in these relationships.

Related Research

Wischmeier and Smith (1978) introduced the components of USLE and the important role which each component can have. They recommended that the USLE could be used for estimating rainfall-erosion soil losses for sheet and rill erosion on construction sites and similarly disturbed and unvegetated areas.

Campbell (1979) through a case study showed how the combination of satellite data, which can give accurate land cover/land-use information, and a GIS can assess nonpoint pollution at a regional scale.

El-Swaify et. al. (1984) did an extensive field study at the University of Hawaii to determined the rainfall intensity and soil erodibility factors that are applicable to Hawaii's soil. They developed an isoerodent map for the quantitative values of rainfall factor.
J.K. Berry et al (1987) developed a GIS storm runoff prediction model that used the SCS method of predicting runoff volumes and timing. While the model seemed to do a satisfactory job of modeling the runoff process no effort was made to extend the model into the sediment production area.

Roland, M. and J.A. Fernandez (1993) developed a methodology for watershed management practices using the USLE and the GIS for a selected site in northern Spain. Using the USLE-GIS model they produced a series of maps showing the present erosion potential areas. Then they implied various management factors such as changing the ground cover, location of roads, and construction site and etc. By comparing the erosion potential maps they recommended the best management practice for the selected watershed.

Dumaliang P.P. and Khosrowpanah (1998) measured soil loss of the Akina silty clay from USLE plots with no vegetative cover and observed an average loss of approximately 1 ton soil ha^{-1} wk^{-1}developed. They also developed isoerodent map of the average annual rainfall erosivity factor (R) for southern Guam. They used continuos 1-minutes rainfall data for this study.