Development of a Database System for Soil and Water Conservation in Bernam River Basin

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Introduction

The problems related to soil and water in the Bernam River basin are mainly related to the quantity and quality of water to satisfy the requirements of all the stakeholders. Rice irrigation is the biggest consumer of water. Since there is no dam, water supply from basin rainfall is sometimes insufficient for rice irrigation. Rice yield is affected. The river water quality is also unsuitable for recreation, and sediment load is high in the raw water supply at the treatment plants for domestic water supply. Uncontrolled land development and improper soil and water management are identified as the source of high sedimentation in rivers, reduced infiltration of rainfall and hence lower base flow during dry seasons. This then will ultimately reduce the availability of irrigation water for the 19,000 ha paddy area of Projek Barat Laut Selangor. In order to estimate river discharge i.e. flood volume as affected by changes in land use, a hydrologic model need to be developed and compared to measured data. A 66 sq km Trolak Watershed was chosen as a pilot study site because of the availability of rainfall and river discharge records for a reasonable size watershed. The 1090 sq km upper Bernam basin was next evaluated. Since the literature is lacking in crop cover factor values for use in soil erosion control models, a field study of various bioengineering treatments was needed to obtain C values in the USLE model. The Tanjung Karang Rice irrigation scheme with an on-farm water management needs to be improved in order to fully utilize available irrigation water during dry periods. A database in GIS is useful for the scheme managers to better manage the scarce irrigation water. The objectives of the study were as follows: 1. To determine the saturated hydraulic conductivity of selected agricultural soils. 2. To determine crop cover factor for various bioengineering treatments. 3. To develop a hydrological model for a river basin, and 4. To develop a water management program for Tanjung Karang Rice Irrigation Scheme.

Materials and Methods

A total of 15 standard USLE plots each measuring 22m long 1.8m wide and at 9% slope were constructed at the DBAE Field Station UPM. A pluviometer, an automatic recording rain gage was installed near the plots. The bioengineering erosion control techniques include vetiver (*Vetiveria zizanioides*), a legume (*Arachis pintoi*), spot turfing and close turfing with cowgrass (*Axonopus compressus*), hydroseeding and few combinations of hydroseeding with biomats such as "coco-fibromat", "fibromat" and "ge o-jute". A plot was left bare as a control. The saturated hydraulic conductivity (K_S) of several roadside cuttings with slope failure around Universiti Putra Malaysia was studied to see how the occurrence is related to the K_s. The study was to develop a model of Ks based on soil characteristics. K_s measurements were done by using Double Ring Infiltrometer and Guelph Permeameter. A model was then developed from the soil characteristics using SAS Stepwise (MAX-R) Analysis to predict the saturated hydraulic conductivity at the slopes. The soil parameters include particle size distribution, bulk density and soil moisture contents.

Several GIS and RS software were purchased for the project, viz. PC ArcInfo 3.5.1, ArcView 3.0, and Erdas Imagine Advantage. Satellite imagery purchased from MACRES include Landsat TM Satellite images of 1989, 1993, 1995, 1996, and 1998, Path 127/Row 57, Lat 3° 20' – 4° 20', Long 100° 50' – 101° 40'. Ancillary data include soils, rainfall, river discharge, sediment load, meteorological data and other relevant data were collected from various government departments and agencies. Input of all data into a GIS database was carried out. A hydrological model was developed and the relevant data was input into HuTVeC Hydrologic Model. The model was tested using data for 1993. Assessment of SWAT hydrological model to Upper Bernam Basin was also carried out. A water management program for Tanjung Karang Rice Scheme was then developed.

Results and Discussion

Results of the soil erosion control study on Serdang soil series show that close turfing with Axonopus compressus gave better soil protection than the other grass species, reducing soil loss by 99% compared to the bare plot. Hydroseeding is an acceptable technique provided care is taken in the application. The addition of "fibromat" to the hydroseeding plot resulted in significantly lower soil loss. All hydroseeding plots overlaid with biomats gave better protection, resulting in *C* factor lower than 0.002. Close turfing produced *C* factor of 0.004, compared to 0.017 for spot turfing, 0.011 for hydroseeding only, 0.122 for vetiver and 0.213 for the legume. Close turfing completely eliminate soil erosion. Hydroseeding + "fibromat" gives better protection among the plots treated with hydroseeding. This technique reduced soil loss by a factor of fifty-seven compared to hydroseeding only. Hydroseeding overlaid with "fibromat" gave the best protection with a *C* factor of 0.0003. The "fibromat" can be considered to be the most reliable erosion control technique among those tested since it provides a more secure cover to protect the soil surface from raindrop impact and enhance the growth and development of vegetation. Without biomat, hydroseeding alone requires 6 months to form about 90% cover in order to have effective protection. A combination of control measures usually improves protection from erosion. The best regression model developed has 5 variables for prediction of soil K_s value with R^2= 0.630. The variables are percent clay, silt and sand, bulk density and soil moisture content. This model gives good estimate of saturated hydraulic conductivity of clayey soils where there was occurrence of slope failure. The extrapolated terminal infiltration rate from Double Ring Infiltrometer also provides good estimate of K_s.

Reliable estimates of streamflows are important in hydrological modelling. Remote sensing data in GIS was used to estimate some parameters and simulate the effects of vegetation and climate on water yield of a vegetated watershed. A distributed modelling approach estimated the water transfers of different hydrologic phases and the discharge at the outlet of Trolak watershed. Landsat TM data was used to subdivide the watershed into hydrologically homogeneous ground response units in a GIS environment. Leaf area index (LAI) as an important structural variable to quantify energy and mass exchange was estimated from the TM data. A comparison of modelled water yield obtained from the satellite data and GIS estimates showed a good match from both annual and monthly water yields. Hence remote sensing and GIS are useful in environmental management as it reasonably estimate the vegetation and climatic changes, and good tools to initialise a regional water balance. Irrigation schemes, which usually use about 80% of the total fresh available water, will benefit from incorporation of remote sensing data in a GIS environment as a part of their management tools.

The developed HuTVeC (Humid Tropical Vegetation and Climate) Hydrological Model was run for Trolak Watershed as well as Slim River Watershed. SWAT hydrological model was run for the whole of upper Bernam River Basin. Good correlation was obtained for both models as compared to measured data. A comparison of the observed to the simulated runoff indicates that the HuTVeC hydrological model gives a reasonable estimate of the watershed runoff. A comparison between daily and monthly observed and simulated data also shows that a watershed hydrologic model such as HuTVeC on a daily time step using satellite-derived data with elements of GIS can achieve reasonable monthly and annual water yield estimates. A lumped model is still acceptable compared to a distributed model for watershed sizes less than 200 square km.

A GIS database for the Tanjung Karang Rice Irrigation Scheme was developed. A cropping calendar was prepared in seven-day interval for both cropping seasons. The daily data such as seepage and percolation, evaporation and rainfall were summed at weekly intervals. A water budget for the Tanjung Karang Rice Irrigation Project was successfully developed for normal and 1 in 5 dry year. An overall water management schedule was successfully developed for TASB 4 pilot study area. Using GIS, potential water stress areas of high deep percolation and seepage losses based on the soil type in the rice scheme were identified.

Conclusions

The runoff and soil loss measured from different treatments in standard USLE plots show that ground bioengineering erosion control techniques could significantly reduce soil loss. The "fibromat" can be considered to be the most reliable erosion control technique among those hydroseeding treatments tested since it provides a more secure cover to protect the soil surface from raindrop impact and enhance the growth and development of vegetation. Without biomat, hydroseeding alone requires 6 months to form about 90% cover in order to have effective protection. A combination of control measures usually improves protection from erosion. The best regression model developed has 5 variables for prediction of soil K_s value with R^2= 0.630. The variables are percent clay, silt and sand, bulk density and soil moisture content. Remote sensing and GIS are useful in environmental management as it can reasonably estimate the vegetation and climatic changes, and good tools to initialise a regional water balance. A lumped hydrologic model is still acceptable compared to a distributed model for watershed sizes less than 200 square km.

Benefits from the study

Reports, MS and PhD Thesis were written, presented and examined. Technical papers were written, presented in seminars and published in journals. Best management practices for ground bioengineering of soil erosion control were developed for application by land developers and contractors. The irrigation managers customized a water management program for Tanjung Karang Irrigation Scheme for use. The HuTVeC hydrologic Model was successfully developed for assessment of stream flow in an ungauged watershed using remote sensing and other ancillary data. For comparison a customized SWAT hydrologic model for assessing sediment load and stream flow resulting from land use changes in the upper Bernam River Basin has proven to be useful. Use of RSGIS saves time, cost and effort in providing means to test alternatives and controls before expensive measures are implemented, and enable effective planning and decision making of any development of erosion control strategies. Irrigation schemes, which usually use about 80% of the total fresh available water, will benefit from incorporation of remote sensing data in a GIS environment as a part of their management tools.

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