UNIVERSITI PUTRA MALAYSIA

APPLICATION OF SWAT HYDROLOGICAL MODEL WITH GIS INTERFACE TO UPPER BERNAM RIVER BASIN

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Faculty : Engineering

Rising concern over the degradation of the environment due to rapid land development in recent years has created a need for watershed modeling. The Upper Bernam River Basin in South Perak and North Selangor, Malaysia was chosen for this study. This study was carried to evaluate the effectiveness of a GIS interface physically based hydrologic model (SWAT) in predicting surface runoff and sediment load from a basin scale watershed. The effects of land use changes on runoff and sediment loading rate were also studied.

The data required for this study is the topographical, hydrometeorological, soil, and the land use data. All of them are integrated in a GIS in tabular, vector and grid formats. The land use data in this study were derived from Landsat TM images. These images were enhanced and classified using a combination of different classification strategies.

The classified land use maps compares reasonably well with the map showing broad vegetation types of the river basin with an accuracy of 95%.

Due to recent rapid land use changes, the model was run in a short term basis. The results from model application and statistical analysis show that SWAT generally does a good job in predicting both runoff flow and sediment load with a an average gap of 22% and 34% respectively between observed and predicted results. The exception is for those days with very heavy rainfall (> 35 mm/day), SWAT seriously overestimated runoff.

Results from historical data, trend analysis, and calculated runoff rate and sediment loading rate due to open area have also shown the close relationship between surface runoff, sediment load and open area downstream of the upper river basin. It is found that the average increment of sediment loading rate for the study area ranges from 1.47 to 2.06 tonnes per millimeter of rainfall for each kilometer-square increase of open areas.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia
sebagai memenuhi keperluan untuk Ijazah Master Sains

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Oleh

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Mac 2001

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Kesedaran tentang ancaman pembangunan tanah yang pesat terhadap alam sekitar di Malaysia beberapa tahun ini mencetuskan keperluan pemodelan lembangan sungai. Hulu Lembah Bernam yang berada di Selatan Perak dan Utara Selangor, Malaysia telah dipilih untuk kajian ini. Kajian ini telah dijalankan untuk menguji keberkesanan satu model hidrologi yang berteraskan GIS untuk menganggar aliran permukaan dan endapan dari sebuah lembangan tadahan air. Kesan guna tanah terhadap aliran permukaan dan endapan juga telah dikaji.

Data yang diperlukan untuk kajian ini ialah data yang berkenaan dengan topografi, hidrocuaca, tanah, dan data guna tanah, dimana semua data tersebut telah diintegrasikan dalam satu pangkalan data GIS dalam bentuk jadual, vektor, dan grid. Data guna tanah yang digunakan dalam projek ini adalah diperolehi daripada imej Landsat TM. Imej tersebut telah diperbaiki dan dikelaskan dengan menggunakan satu kombinasi strategik

klassifikasi yang berlainan. Hasil peta guna tanah yang dikelaskan adalah baik setelah dibandingkan dengan peta yang menunjukkan jenis tumbuhan umum di lembangan tersebut dengan satu ketepatan 95%.

Disebabkan perubahan guna tanah yang kerap, permodelan telah dijalankan untuk satu tempoh yang singkat. Keputusan daripada pengunaan model dan analisis statistik menunjukkan bahawa SWAT secara umumnya adalah baik untuk menggangar kedua-duanya aliran permukaan dan endapan dengan satu jurang 22% dan 34% masing-masing di antara data data yang dipunggut dan data data yang dianggar, kecuali untuk hari-hari yang mempunyai hujan lebat (> 35 mm/day), SWAT telah lebih anggar aliran permukaan dengan serius.

Hasil dari data yang lepas, tren analisis, kadar aliran permukaan dan kadar endapan terhadap kawasan terbuka yang dikira juga telah menunjukkan perhubungan yang rapat di antara aliran permukaan, endapan, dan kawasan terbuka di bahagian hilir lembangan sungai tersebut. Adalah ditemui bahawa untuk setiap kilometer persegi pertambahan dalam kawasan terbuka, kadar endapan purata telah bertambah sebanyak 1.47 hingga 2.06 ton per milimeter air hujan.

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LIST OF ABBREVIATIONS

ρ	Correlation coefficient
3D	3 Dimensional
ADP	Average daily precipitation in month
ALB	Moist soil albedo
AWC	Available water capacity of soil layer
BARE	4 digit land use class – bare land
BD	Moist bulk density of soil layer
C	USLE crop management factor
CH_D	Average depth of main channel
CH_K	Effective hydraulic conductivity in tributary channel alluvium
CH_L	Length of main channel
CH_N	Manning's "n" value for the tributary channel
CH_W	Average width of tributary channels
CLAY	Clay content of soil layer
CN2	SCS curve number for moisture condition II
CO2	Carbon dioxide concentration
COEF	Skew coefficient of daily precipitation in month
DEWPT	Average dew point temperature in month
FRSE	4 digit land use class – forest
GPS	Global Positioning System
HHMX	Maximum 0.5 hour rainfall in month for the years with available data
HRU	Hydrologic Response Unit
HRU_FR	Fraction of total watershed area contained in HRU
HWQ	Hydrologic and water quality
HYDGRP	Soil Hydrologic group.
K	Saturated hydraulic conductivity of soil layer

OILP	4 digit land use class – oil palm
OV_N	Manning's "n" value for overland flow
Pcp98FTU	daily precipitation for 1998 recorded at station Felda Trolak Utara
Pcp98LTL	Daily precipitation for 1998 recorded at station Ladang Trolak
Pcp98LKY	Daily precipitation for 1998 recorded at station Ladang Ketoyang
Pcp98PTM	Daily precipitation for 1998 recorded at station Pekan Tanjung Malim
PCPD	Average number of days of precipitation in month
PRB_D	Probability of wet day following dry day in month
PRB_W	Probability of wet day following wet day in month
RUBB	4 digit land use class – rubber
SAND	Sand content of soil layer
SCRB	4 digit land use class – scrub
SCS	Soil Conservation Service
SDP	Standard deviation for daily precipitation in month
Sg	Sungai / river
SILT	Silt content of soil layer
SLOPE	Average slope steepness
SLSOIL	Slope length for lateral subsurface flow
SLSUBBSN	Average slope length
SOL	Average daily solar radiation for month
tmp98tmx	Daily maximum temperature recorded for year 1998
tmp98tmn	Daily minimum temperature recorded for year 1998
TMPCVT	Coefficient of variation for the average temperature for month
TMPMX	Average maximum air temperature for month
TMPMN	Average minimum air temperature for month
TIN	Triangulated Irregular Network
U	Theil's coefficient
URBN	4 digit land use class – urban area
USLEK	USLE equation soil erodibility (K) factor

WATR	4 digit land use class – water body
WDMUtil	Watershed Data Management Utility
WIND_AV	Average wind speed in month
Z	Depth of a certain soil horizon / layer

CHAPTER 1

INTRODUCTION

In recent years,

growth, urbanization, expansion of agriculture, logging activities, and industrialization. These changes have caused complex environmental problems and the most affected natural resource is water.

Rising concern over the degradation of the environment, such as our river water quality, has resulted in an increase in research on the identification and study of environmental problems. The rapid rise in the volume and quantity of data collected, and massive changes in technical capability have facilitated the development of Geographical Information System (GIS) and remote sensing to handle the diversity of information involved.

Inherent in the solution of the above problem and many environmental problems is the need to bring together dispersed data sets. The complexity and size of these databases make the requirement for application of GIS and remote sensing technology all the more necessary. The advantage of holding all the information together is to allow searches and queries to be made on a combination of information so that effective formulation and implementation of any strategies, policies and plans which are highly dependent on accurate, comprehensive and timely information can be achieved.

Statement of the Problem

In the study of watershed problems, it has been found that most of the distributed/physically based hydrologic and water quality (HWQ) model from developed countries are not suitable for local use due to different atmospheric conditions and availability of data. Another fact is that most of those models are too complex and thus, too difficult to use or not user friendly. In addition, very few of them are applicable to basin scale study. Knowing these, a simple GIS interface physically based and computationally efficient distributed model has been chosen for evaluation. By confirming the effectiveness of the selected model in the tropical watershed management, it provides an alternative to potential users such as hydrologists, environmentalists, policy makers and etc.

Through data overlaying technique, classified remote sensing data has been applied in this study. Necessary data set representing hydrology, weather, soil, elevation and surface characteristic were integrated in a GIS in tabular, vector and grid formats. By bringing key data and analytical components together "under one roof", it is hoped that the problems of lack of integration, limited coordination, and time-intensive execution typical of the more traditional assessment tools can be overcome. Similar studies in the future will become easier in terms of time, effort and cost saving to acquire and manage temporal as well as spatial data.

With the ability of a selected model to predict or generate simulated rainfall, stream flow and water quality from a river basin, these provide quantitative means to test alternatives and controls before expensive measures are implemented. These also enable effective planning and decision making of any development of pollution control strategies, plan or policy for better water management of a humid tropical river basin.

It is envisaged that the database generated and the water quality output of the simulation as well as maps, charts, or tables generated can be used to advance the knowledge on the existing environment during the study period. This is to allow comparison with the present or future situation of the river basin and also allow a continual trend analysis for any further similar studies.

Objectives of the Study

In view of the issues and problems discussed above, this study aims to evaluate the effectiveness of a GIS interface physically based hydrologic and water quality (HWQ) model in predicting daily stream flow and water quality from a tropical river basin.

The specific objectives:

1. To carry out a preliminary research into combining remote sensing data, GIS a watershed model for hydrologic evaluation purposes;
2. To evaluate the effectiveness of selected model in a river basin using remote sensing data and GIS-derived inputs.

CHAPTER II

LITERATURE REVIEW

Geographical Information System (GIS)

GIS in the general context of the environmental applications can be defined as a computer-assisted and integrated environment for geographical data creation, storage and retrieval, management, manipulation, analysis and display (Norlin Jaafar, 1997). It is able to provide effective and efficient functions for handling large spatial database and aids data inventory, management, problem solving and decision making.

Concept of GIS

According to Holdstock (1998), one of the world's leading GIS software vendors organizes data in such a way that they can be envisioned as digital layers or coverages of information. Each coverage is registered to the same common map base; each has a distinct type of feature such as points, polylines or polygons.

data and attribute data. A coverage represents a single theme, such as land-use (polygon), soils type (polygon), rivers (line), roads (line), and buildings (point) as shown in Figure 2.1.

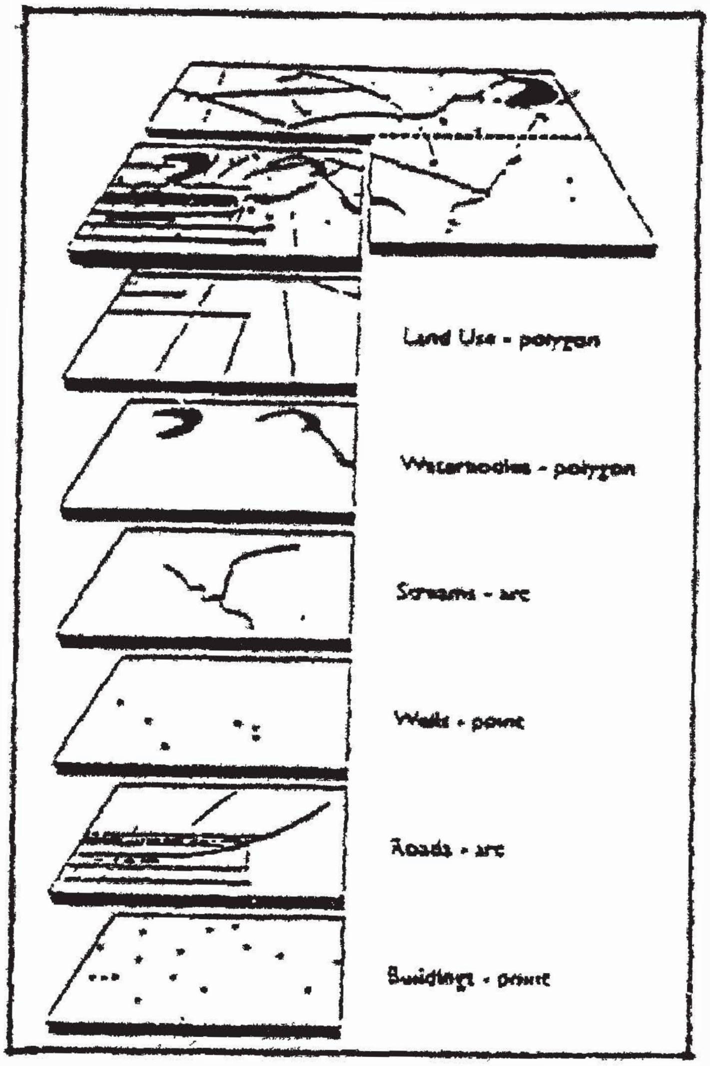

Figure 2.1: Spatial Data
(Source:
Transportation Research and Education (ITRE), North Carolina State University)