DEVELOPMENT OF NON-POINT SOURCE POLLUTION MODEL FOR MAIZE CULTIVATION UNDER TROPICAL CONDITION

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By

RUSNAM

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirement for the Degree of Doctor of Philosophy

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DEDICATION

This work is dedicated to my family members who are always giving me encouragement and support

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the Degree of Doctor of Philosophy

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Chairman : Professor Ir. Mohd Amin Mohd Soom, PhD

Faculty : Engineering

Land development activities contribute to water quality impairment. The use of models plays an important role in the assessment of diffuse pollution sources and their delivery to the receiving water bodies. Pollutant export equations or event mean concentration (EMC) values are the basic requirement for storm water quality assessment and control. This is not yet available for tropical areas such as the Malaysian environment. This research project was carried out at the Precision Agriculture Experimental Plot in Universiti Putra Malaysia (UPM). It is located at latitude 3° 02′ N and longitude 101° 42′ E, with 31 m above mean sea level. The soil in the study area is Serdang series and the crop grown in the 0.56 ha area was maize (*Zea Mays*). The plot was isolated from the surrounding areas by building perimeter bunds to protect from runoff produced by the adjacent areas. Rainfall is mainly the driving force for non-point source (NPS) pollution. Therefore, the daily rainfall data was collected and analysed to study the distribution of daily

rainfall from 1985 to 2003. Twenty rain events in crop season I, nineteen events in crop season II and eight events in crop season III were monitored to calculate the EMC (event mean concentration) values of the parameters which contributed mostly from the NPS pollution. The median EMC values for BOD, COD, NO_3, TKN, TP, TSS and Turbidity were calculated to be 10.3, 101.2, 1.1, 2.6, 0.7, 1027.1 mg/L and 879.4 NTU in crop season I, 9.0, 88.1, 1.0, 2.1, 0.5, 867.8 mg/L and 856.2 NTU in crop season II and 10.5, 102.5, 0.5, 1.1, 2.6, 0.7, 950.8 mg/L and 886.5 NTU in crop season III, respectively. From the correlation study, it was observed that EMC values were significantly related to runoff quantity, dry period between the storm events and the day after fertilizer application. Multiple regression analyses among these four parameters were conducted to determine regression models for the selected pollutants. There was no significant difference between observed and model data for all parameters, after calibration and validation. It can be concluded that prediction by the regression model was satisfactory and can be applied to agricultural areas of similar characteristics. These pollutant export equations would be useful to predict EMC values and NPS pollution loading under tropical condition. First flush phenomenon was analyzed for selected parameters. The strongest first flush phenomenon was observed for Total Suspended Solid (TSS), where about 60% of pollutant mass (load) could be captured by isolating 42% of runoff volume. Other parameters exhibited weak and closed to uniform. The existing Water Quality Index (WQI) proposed by the Department of Environmental (DOE) Malaysia was reviewed and found to have a few limitations when applied to agricultural areas. A runoff quality index (RQI) was proposed to

assess the runoff quality an agricultural area such as a maize field, which includes Total Kjeldhal Nitrogen (TKN) and Total Phosphorous (TP).

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

PEMBANGUNAN MODEL PUNCA PENCEMARAN BUKAN TITIK UNTUK TANAMAN JAGUNG DI BAWAH IKLIM TROPIKA

Oleh

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Jun 2006

Pengerusi: Profesor Ir. Mohd Amin Mohd Soom, PhD

Fakulti : Kejuruteraan

Aktiviti pembangunan tanah menyumbang kepada kemerosotan kualiti air. Penggunaan model memainkan peranan penting dalam menaksir punca pencemaran berserak dan penghantaran ke sumber air. Persamaan eksport pencemar atau nilai kepekatan min peristiwa (EMC) adalah keperluan asas untuk penaksiran dan kawalan kualiti air hujan. Ini masih belum didapati bagi kawasan tropika seperti Malaysia. Projek penyelidikan ini telah dijalankan di Plot Eksperimen ladangan Presis di Universiti Putra Malaysia (UPM). Ia terletak di latitud 3° 02′ Utara dan longitud 101° 42′ Timur, dengan ketinggian 31 m di atas paras air laut. Tanah dalam kawasan kajian adalah siri Serdang dan ditanam dengan jagung (*Zea Mays*) di kawasan seluas 0.56 ha. Plot kajian diasingkan dari kawasan keliling dengan membinakan batas untuk menahankan air larian yang dihasilkan oleh kawasan yang berhampiran. Data hujan adalah pemandu utama bagi pencemaran punca bukan titik (NPS). Justeru, data hujan harian dikutip dan dianalisis untuk kajian pertaburan hujan harian dari tahun 1985 ke 2003. Dua

puluh peristiwa hujan dalam musim tanaman I, sembilan belas peristiwa hujan dalam musim tanaman II dan lapan peristiwa hujan dalam musim III telah diperhati untuk mengira EMC bagi parameter yang banyak disumbang oleh pencemaran NPS. Nilai midian EMC bagi BOD, COD, NO_3, TKN, TP, TSS dan kekeruhan yang dikira terdapat 10.3, 101.2, 1.1, 2.6, 0.7, 1027.1 mg/L dan 879.4 NTU bagi musim tanaman I, 9.0, 88.1, 1.0, 2.1, 0.5, 867.8 mg/L and 856.2 NTU bagi musim tanaman II dan 10.5, 102.5, 0.5, 1.1, 2.6, 0.7, 950.8 mg/L and 886.5 NTU bagi musim tanaman III. Dari kajian korelasi, ia dapat diperhatikan bahawa nilai EMC berhubungan penting terhadap jumlah air larian, tempoh kemarau di antara peristiwa hujan dan hari selepas pembajaan. Analisis multi-regresi di antara empat parameter telah dilakukan untuk menentukan model regresi bagi pencemaran yang terpilih. Tidak ada perbezaan di antara data model dan data pengamatan untuk semua parameter, selepas kalibrasi dan validasi. Ia boleh disimpulkan bahawa ramalan dengan mengguna model regresi adalah memuaskan dan boleh diguna untuk kawasan tropika seperti Malaysia bagi kawasan pertanian yang serupa. Persamaan eksport pencemaran ini berguna untuk meramalkan nilai EMC dan muatan pencemaran NPS di bawah iklim tropika. Fenomena pancur pertama telah pun dianalisis bagi parameter terpilih. Fenomena pancur pertama yang paling kuat telah diperhatikan bagi jumlah pepejal terampai (TSS), yang mana sekitar 60% bagi berat pencemaran (muatan) boleh ditangkap dengan mengasingkan 42% bagi isipadu air larian dan parameter lain mempamerkan hubungan lemah dan hampir seragam. Indeks Kualiti Air (WQI) Jabatan Alam Sekitar (DOE) Malaysia telah ditinjau balik dan didapat ada

kelemahan jika diaplikasikan untuk kawasan pertanian. Indeks Kualiti Larian (RQI) telah dicadangkan untuk anggaran kualiti air larian bagi kawasan pertanian seperti ladang jagung yang mencakupi Total Kjeldhal Nitrogen (TKN) dan Total Phosphorous (TP).

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I certify that an Examination Committee has met on the 14th of June 2006 to conduct the final examination of Rusnam on his Doctor of Philosophy thesis entitled "Development of Non Point Source Pollution Model for Maize Cultivation under Tropical Condition" in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the candidate be awarded the relevant degree. Members of the Examination Committee are as follows:

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This thesis submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Doctor of Philosophy. The members of the Supervisory Committee are as follows:

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DECLARATION

I hereby declare that the thesis is based on my original work except for quatations and citations which have been duly acknowledged. I also declare that it has not been previously or currently submitted for any other degree at UPM or other institutions.

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RUSNAM

Date: 22 AUG 2006

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LIST OF ABBREVIATIONS

AN	Ammoniacal Nitrogen
ANOVA	Analysis of Variance
APHA	American Public Health Association
ARI	Average Recurrence Interval
BMP	Best Management Practice
BOD	Biological Oxygen Demand
COD	Chemical Oxygen Demand
CV	Coefficient of Variation
D_d	Dry duration between two consecutive rain events
DID	Department of Irrigation and Drainage
DOE	Department of Environment
EMC	Event Mean Concentration
EC	Electrical Conductivity
EMI	Electromagnetic Induction
IDF	Intensity-Duration-Frequency
JICA	Japan International Cooperation Agency
L	Pollution Load
L_r	Pollution Loading Rate
MMS	Malaysian Meteorological Services
MPN	Most Probable Number
MSMA	Manual Saliran Mesra Alam

NPS	Nonpoint Source
NTU	Nephelometric Turbidity Unit
NURP	Nationwide Urban Runoff Program
PS	Point Source
RMSE	Root Mean Square Error
RQI	Runoff Quality Index
SIAN	Sub-index of Ammoniacal Nitrogen
SIBOD	Sub-index of Biochemical Oxygen Demand
SICOD	Sub-index of Chemical Oxygen Demand
SIDO	Sub-index of Dissolved Oxygen
SIpH	Sub-index of pH
SITP	Sub-index of Total Phosphorus
SITSS	Sub-index of Total Suspended Solids
SITUR	Sub-index of Turbidity
SPSS	Statistical Package for Social Sciences
TKN	Total Kjeldhal Nitrogen
TP	Total Phosphorus
TSS	Total Suspended Solids
TUR	Turbidity
UPM	Universiti Putra Malaysia
USA	United States of America
USAEC	United States Atomic Energy Commission
USGS	United States Geological Survey

USMM	Urban Stormwater Management Manual for Malaysia
WQI	Water Quality Index