IDENTIFICATION OF RELATIONSHIP BETWEEN WATER QUALITY RESPONSE AND LAND USE ATTRIBUTES: CASE STUDY, GOMBAK RIVER WATERSHED, MALAYSIA

By

FARIS GORASHI MOHAMED FARIS

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ABSTRACT

This study was conducted on Gombak River and its watershed. Gombak River is situated mainly in the Gombak District in Selangor state and its lower zone is situated in the Malaysian Capital Kuala Lumpur. The motivation of this study is to ensure sustainable development, which is essentially has effects on surface water quality as 97 per cent of Malaysia's water supply is sourced from it; and to find a low-end alternative for water quality monitoring techniques, which are typically expensive and tedious. This will allow decision makers to plan safely to improve the quality of life while maintaining sustainable development. The main aim of this study was to identify a relationship between water quality and land use attributes through selecting the appropriate data generation methods and model building that can enable prediction and forecast of water quality index with high accuracy. This model coupled by the data generation method, could later be utilized as an important extension to major planning software in order to assist planners and decision makers to plan and decide safely for watersheds zones.

The thesis examined the water quality of the river focusing on six water quality parameters, these were BOD, COD, AN, SS, pH, and DO in three monitoring stations as well as conducted laboratorial analysis in a fourth one. The data were then analyzed in order to understand its behavior and response to the activities within the watershed. The watershed of Gombak River was redefined using MapInfo from the recently updated coordinates of Gombak River, and the LU/LC data were extracted from the watershed for a discrete 20-years period. LU/LC data focused on five categories, these were build-up area, residential area, commercial area, industrial area and forest area.

Methodologically, the thesis used a quantitative method of analysis such as ANN's Back propagation algorithm in order to examine the correlation and magnitude of relationship between the chosen water quality and LU/LC indicators. The study introduced data generation method for the prediction and forecast of LU/LC data within the watershed. The method used exponential model equation, Lagrange model equation 3rd & fourth degree polynomial fit and saturation growth-rate model in order to generate the required data.

In order define the relationship between water quality response and land use attributes, the study introduced the LA-WQI model. This model was developed by associating the appropriate loading factors to a set of sub indices. The loading factors were obtained based on peak factor theorem by assigning weights to different categories of land use indices. The model was applied on the average values of the percentages of land use every year, and was compared with average values of yearly actual and predicted WQI.

The findings revealed that the water quality index of the three stations located along the Gombak River was deteriorating from upstream to downstream. Station 18 showed the highest fluctuation during the mentioned period. This is due to increasing number of ongoing development projects within this station. The mean WQI for monitoring stations along Gombak River, puts station 24 as clean river water, station 18 as slightly polluted and station 17 as polluted river water.

ANN's Back propagation algorithm was able to predict WQI with high accuracy at station 18 and 24. This high accuracy was due to the fact that the configured ANN was able to detect a

direct relation between sub indices used and the water quality index; in this case the relationship was the DOE-WQI model. On the other hand, when land use parameters were trained, the differences between predicted WQI and actual WQI were slightly higher than that of trained with water quality variables. This is due to the continuous changes in chemistry of water quality variables which doesn’t indicate the actual water quality. However, the training yielded high correlation between average values of predicted and actual WQI.

The findings also revealed that as the activities increased throughout the watershed, the values of WQI quality decreased accordingly. The accuracy of prediction of the proposed LA-WQI ranged from 94.3% to 99.3% between Actual DOE-WQI and LA-WQI for station 24 of Gombak River. The same approach was applied for station 18 at Gombak River. The results of predicted WQI obtained using LA-WQI, showed a continuous decrease of water quality. Prediction values of WQI for DOE, ANN and LA-WQI had an accuracy range of 97.9% to 99.5 %.

In order to test the sensitivity of data generation method and the LA-WQI model, withheld data were used for the first time for validation. The results indicated high precision in the prediction and forecast of WQI.

Generally, there is an appreciable effort to keep Malaysian rivers clean, however in order to achieve an accepted level of sustainability, all developmental schemes within a watershed vicinity should be conducted in accordance with a specific allocation of time and space which follows a certain model. This will help in producing more accurate forecasting of LU/LC sub-indices and hence WQI. Despite the high accuracy attained by the application of LA-WQI model on Gombak River; it has not yet been tested on other rivers due the limitation of the scope of this study. It is recommended that future studies should be able to further test the current model on a regional scale.

ملخص البحث

اجريت هذه الدراسة على نهر جومباك الوقع في حيّ جومباك بولاية سلانغوروالذي ينتهي في كوالالمبور عاصمة ماليزيا. ان الهدف من هذه الدراسة هو تامين نمو عمراني لا يؤثر سلباً على جودة المياه السطحية، اذ ان سبعة وتسعون بالمائة من امداد مياه ماليزيا يعتمد على هذه المياه؛ كما تهدف الدراسة ايضاً لايجاد بديل ذو تكلفة اقل من تقنيات مراقبة جودة المياه والتي دائماً تكون مكلفّة ومضنية. بهذه الطريقة يستطيع اصحاب القرار من التخطيط بطريقة اكثر اماناً من اجل حياة افضل نوعية وجودة. والهدف المباشر هنا، هو تعريف العلاقة بين ردة فعل جودة المياه لتداخلات الانشطة العمرانية عن طريق اختيار الطريقة المناسبة لتوليد البيانات وبناء نموذج يستطاع من خلاله التوقع والتنبؤ بمؤشر جودة المياه بدقة عالية. هذا النموذج المصحوب بطريقة توليد البيانات يمكن استخدامه فيما بعد مع معظم برامج التخطيط العمراني الحاسوبي بهدف مساعدة المخطط او صاحب القرارللتخطيط السليم الآمن حول مستجمعات الانهار.

ركزت الدراسة على فحص ست متغيرات لجودة المياه وهي: الاحتياج الحياكيميائي للأُكسيجين، الاحتياج الكيميائي للأُكسيجين ونيتروجين الامونيا، الشوائب العالقة، الرقم الهيدروجيني، والاكسيجين الذائب في ثلاث محطات لمراقبة المياه كما واجُريّ فحص مخبري على محطة رابعة. تم تحليل البيانات حتى يتثنى فهم طبيعة وردة فعل المياه للانشطة العمرانية المقامة حول المستجمع. كما قام البحث بتحديث حدود مستجمع نهر جومباك باستخدام برنامج *(ماب انفو)* من خلال الاحداثيات الحقيقية والحديثة لنهر جومباك، كما تم استخراج الانشطة العمرانية المطلوبة للمستجمع لفترة عشرون عاماً متقطعة. الانشطة العمرانية المختارة هي: المساحة المبنية، المساحات السكانية والتجارية والصناعية والمساحة الغابية.

من ناحية منهجية البحث فهي تتبع الاسلوب الكمّي من خلال اساليب التحليل المتبعة مثل لوغاريثم التردد المتراجع للشبكة العصبية الاصطناعية لفحص حجم التقارب في العلاقة بين فئات جودة المياه ومؤثرات الانشطة العمرانية. كما وقدمت الدراسة طريقة جديدة لتوليد البيانات المختلفة للانشطة العمرانية استُخدم فيها كل من نموذج لاجرانج، معادلات تعدد الحدود من الدرجة الثالثة والرابعة ونموذج معدل النمو. ومن اجل تعريف العلاقة بين ردة فعل مياه النهر مع تداخلات انشطة العمران، قدمت الرسالة نموذج ال LA-WQI والذي تم بناءه بادخال عوامل الثقل على مجموعة من عناصر المؤشرات وتم تطبيق هذا النموذج على القيم المتوسطة للنسب المئوية للانشطة العمرانية السنوية، و تمت مقارنته مع القيم المتوسطة لمؤشر جودة المياه الحقيقي والمتوقع.

اظهرت النتائج ان المحطة رقم 18 حصلت على اعلى قيم للتأرجح خلال الفترة المذكورة وهذه نتيجة للانشطة العمرانية الكثيفة الدائرة في تلك المنطقة حالياً. اما متوسط مؤشر المياه يُصنف مياه المحطة رقم 24 بالنظيفة، و18 بمتوسطة التلوث و المحطة رقم 17 بالملوثة. واستطاع لوغاريثم التردد المتراجع للشبكة العصبية الاصطناعية ان يتنبأ بقيم مؤشر جودة المياه بدقة عالية في المحطات 18 و 24، وهذه الدقة هي نتيجة ان الشبكة استطاعت ان تستنبط العلاقة من النموذج الذي يستخدمه قسم البيئة (DOE-WQI). من ناحية اخري، قلّت دقة التنبؤ عندما تم استخدام متغيرات الانشطة العمرانية وهذا نتيجة لان درجة ثبات الانشطة العمرانية اعلى بكثير من متغيرات المياه والتي بدورها تخضع لعدد من التفاعلات الكيميائية اللحظية اثناء الجريان. ولقد ارتفعت دقة التنبؤ بدرجة عالية عندما تم استخدام القيم المتوسطية للانشطة العمرانية. واظهرت النتائج ايضاً، الدقة العالية للنموذج المقترح في الرسالة والذي تراوحت دقته بين 94.3 الى 99.3 بالمائة عند مقارنته بنموذج قسم البيئة في المحطة رقم 24. وطُبّق نفس النموذج على المحطة رقم18 حيث تراوحت درجة الدقة للنموذج المقترح (LA-WQI) بين 97.9 الى 99.5 بالمائة عند مقارنته بقيم (DOE-WQI) و (ANN-WQI).

من اجل التحقق من صلاحية هذا النموذج، تم اختباره على مجموعة من البيانات لم تُستخدم اطلاقا وحفظت لاختبار صلاحية النموذج وطريقة توليد البيانات والشبكة العصبية الاصطناعية واظهرت النتائج درجة اعتمادية عالية لنموذج ال (LA-WQI) والطرق المصاحبة المذكورة.

بصورة عامة، هنالك جهود مقدرة تبذلها الحكومة الماليزية للحفاظ على جودة مياه الانهار ولكن للحصول على درجة مقبولة من المحافظة على البيئة، فانه لابد من ربط كل الانشطة العمرانية حول مستجمعات الانهار بنموذج معين يحدد الزمان والمكان المحدد لاقامة الانشطة المختلفة ومن ثم يتثني التنبؤ بمؤشر جودة المياه للنهر قبل الشروع الحقيقي في العمران وبدقة اكبر. بالرغم من ان النموذج المقترح اظهر قدرة عالية للتنبؤ بمؤشر جودة المياه، الا انه لم يتم اختباره على انهار اخري وذلك بسبب نطاق حيّز البحث المحدد للدراسة. يقترح الباحث دراسة هذا النموذج على نطاق اقليمي اوسع في الدراسات المستقبلية.

APPROVAL PAGE

The thesis of Faris Gorashi Mohamed Faris has been approved by the following:

____

Alias Abdullah

Supervisor

____

Muhammad Abu Eusuf

Supervisor

____

Internal Examiner

____

Internal Examiner

____

External Examiner

____

Chairman

DECLARATION

I hereby declare that this dissertation is the result of my own investigations, except where otherwise stated. I also declare that it has not been previously or concurrently submitted as a whole for any other degrees at IIUM or other institutions.

Faris Gorashi Mohamed Faris

Signature …………………………… Date ……………………………..

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Affirmed by Faris Gorashi Mohamed Faris.

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Signature　　　　　　　　　　　　　　　　Date

TO

MY FATHER WHO ANSWERED THE CALL OF ALLAH, TO MY MOTHER WHO I MISSED FOR A LONG PERIOD OF TIME DUE TO MY STRUGGLE FOR KNOWLEDGE OUTSIDE THE COUNTRY, TO MY WIFE, DAUGHTER AND ALL MY FAMILY

MAY ALLAH (S.W.T.) ACCEPT THIS HUMBLE WORK AS AN ACT OF *IBADAH* TO HIM AND GIVE ME THE INSPIRATION TO BE A SOURCE OF STRENGTH FOR ISLAM THROUGHOUT MY LIFE AND MY ACADEMIC ENDEAVORS (AMIN).

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LIST OF ACRONYMS

AN	Ammonia-Nitrogen
ANN	Artificial Neural Network
APHA	American Public Health Association, American Water works Association
ARTMAP	Adaptive Resonance Theory Map Algorithm
ASEAN	Association (of) South East Asian Nations
BMP	Best Management Practice
BOD	Biochemical Oxygen Demand
BU*si*	Build up Area Sub Index
COD	Chemical Oxygen Demand
C*si*	Commercial Area Sub Index
DBMS	Database Management System
DO	Dissolved Oxygen
DOE	Department of Environment
EIA	Environmental Impact assessment
EQA	Environmental Quality Act
F*si*	Forest Rea Sub Index
GIS	Geographical Information System
INWQS	Interim National Water Quality Standards
I*si*	Industrial Area Sub Index
LA-*WQI*	Land Use Attributes Water Quality Index
LU/LC	Land Use / Land Cover
MLR	Multi linear Regression
NPSD	Non Point Source Discharge
POC	particulate organic carbon
PSD	Point Source Discharge
RAN	Harkin’s Rank for Ammonia-Nitrogen
RBOD	Harkin’s Rank for Biochemical Oxygen Demand

RCOD	Harkin’s Rank for Chemical Oxygen Demand
RDO	Harkin’s Rank for Dissolved Oxygen
RPH	Harkin’s Rank for pH
R*si*	Residential Area Sub Index
RSS	Harkin’s Rank for Suspended Solids
SAFE	Strategic Assessment of Florida's Environment
SFAM	Simplified Fuzzy Adaptive Resonance Theory Map
SIAN	Ammonia-Nitrogen Sub Index
SIBOD	Biochemical Oxygen Demand Sub Index
SICOD	Chemical Oxygen Demand Sub Index
SIDO	Dissolved Oxygen Sub Index
SIPH	pH Sub Index
SISS	Suspended Solids Sub Index
SS	Suspended Solids
STP	Sewage Treatment Plant
SWAT	Soil and Water Assessment Tool
UNEP	United Nations Environment Programme
WCED	World Commission on Environment and Development
WQI	Water Quality Index
WQMP	Water Quality Management Practice

LIST OF NOMENCLATURES

OPk	Output from the k^{th} node of the output layer of the network for the P^{th} vector
xPi	Input to the network for P^{th} vector
$w^0{}_{jk}$	Connection weight of the communication strand between the j^{th} node of the hidden layer and the k^{th} node of the output layer
$w^h{}_{ij}$	Connection weight between the i^{th} node of the input layer and the j^{th} node of the hidden layer
$b^j{}_1$ and $b^k{}_2$	Bias terms;
f1(.) and *f2(.)*	Activation functions
g_i	Activation function of neuron *i*
u_i	External input imposed on neuron *i;*
w_{ij}	Synaptic connectivity value between neuron *i* and neuron *j*;
N	Number of neurons in the networks.
x = $(x_1, x,\ldots, x\ N)$	Neuron states
y = $(y_1, y_{12},\ldots, y\ N)$	Local fields
W = $\left(w_{ij}\right)_{N\times N}$	Synaptic weight matrix
G : $\mathbb{R}^N \rightarrow \Omega \subseteq \mathbb{R}^N$	Nonlinear activation mapping
Ω	Convex subset of$\mathbb{R}^N$.

CHAPTER 1

INTRODUCTION

BACKGROUND

Water is the basic substance in the general composition, and functions for all living organisms. It plays an important role in choosing settlements areas, and it has a great influence in nourishment of civilizations. Many approaches toward achieving sustainable exploitation of surface water watersheds has been developed globally; however fresh water streams remain vulnerable and suffer major deterioration in water quality. The earth summit in Rio de Janeiro held in 1992, adopted a conceptual statement concerning water. The statement which was referring to water pollution control and management, defined fresh water as a finite and vulnerable resource, essential to sustain life, development and the environment.

Rapid development in peninsular Malaysia has begun to put a strain on existing water resources. Environmental problems such as deterioration of surface water quality, flash floods and heavy sedimentation are mainly associated with development activities carried within the basin. Water quality parameters respond to myriad direct and/or in-direct pollutants. These pollutants come from different activities such as land clearing, uncontrolled earthworks, mining and logging activities in water catchments area. These developmental projects bring along other activities that alter the dynamics of response of water quality. The state of Selangor can be considered as one of the fastest developing states in Malaysia. Rapid development is one of the major reasons in causing water pollution to surface water, which is the main source of drinking water supply in the country.