Similarity based Spatial Modeling for Recreational Lakes Water Quality Management

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Assoc. Prof. Dr Aziz Shafie (UM)
OUTLINE PRESENTATION

- Introduction
- Issues
- Research Aim and Objective
- Review of Literature
- Research Framework
- Methodology
- Study Area
- Findings
- Discussion
- Research Significance
- Conclusion
- References
Property Value and Market Price

Aesthetic and Amenity Values

Quality of Life

Eco-tourism

Water Supply Alternative

Recreational Lakes

Changes of land use activities (Güereña et al., 2015; Sharip et al., 2010)

Impact of anthropogenic activities (Jeznach et al., 2016; Li et al., 2015)

Dissolved Oxygen Depletion (Zhang et al., 2015)

Algae bloom/Eutrophication (Ulrich et al., 2016 and Zhou et al., 2014)

Sedimentation. Hayakawa et al., 2015 and Luis et al., 2013
Challenges

- Absence of water quality monitoring programme
- Financial Constraint
- Unsuitable management tools
- Data and Information access
- Data/Information availability
- Data/Information Sharing

This research is to provide an alternative approach on a cost-effective, simple, reliable and lightweight tool to facilitate lake managers in making decision in a situation of:

- Data associated problems such as minimal data or data scarcity.
- Financial limitation in frequent monitoring or no WQMP (random one-off sampling)

Objective:

To develop a spatial based water quality prediction model using the similarity technique as a supporting tool to be used intently by recreational lake managers, and generally by relevant stakeholders to fortify implementation of integrated lake water quality management.
Watershed/Land Use Land Cover Management

- **PAMOLARE** (Nyarumbu and Magadza, 2016)
- **SWAT** (Dile et al., 2016; Zhu et al., 2015)
- **CLUE** (conversion of land use and its effects) (Anastasiadis et al., 2013)
- **CORINE** (Coordination of Information on the Environment) (Tayebi and Sameni, 2017)
- **BasinSim** (Erol and Randhir, 2013)
- **HSPF** (Hydrological Simulation Program – Fotran) (Lee and Chung, 2007)
- **GIBSI** (Strager et al., 2010)

Agriculture

- **AnnAGNPS** (Annualized Agricultural Non Point Source Pollution) (Li et al., 2015)
- **Object Modeling System** (Varga et al., 2015)
- **CREAMS** (chemical, runoff, erosion from Agricultural Management System) (Li et al., 2015)

Hydrologic

- **BASINS** (USEPA) (Strager et al., 2010)
- **System Dynamics (SD)** (Varga et al., 2015; Liu et al., 2015)
- **ANSWERS** (Areal Non point source watershed Environment Response Simulation) (Li et al., 2015)
- **L-THIA** Long term hydrologic impact assessment (Engel et al., 2015)

Nutrient/Contaminants

- **CLUES** (catchment land use for environment sustainability) – (Elliot et al., 2016)
- **SPARROW** – Booth et al. (2011)
- **WASP** (Wang et al., 2015)
- **MPIWQM** (Multiple Pattern Inverse Water Quality Modelling) (Zou et al., 2014)
- **EFDC** (Environmental Fluid Dynamics Code) (Liu et al., 2014)
- **Qsim** (Lindim et al., 2015)

Environment (General Applicable Modeling Frameworks)

- **MIKE** (Xue et al., 2015; Butts et al., 2008)
- **GIS Arc-Hydro** (ESRI, 2015)
- **Watershed Analysis Risk Management Framework (WARMF)** (Wang et al., 2015)
- **Generalised Watershed Loading Functions (GWLF)** (Giri and Qiu, 2016)
- **CE-QUAL-W2** (Cole and Wells, 2000; Zou et al., 2014)
- **ANN (Artificial Neural Networks)** (Maier and Dandy, 1996; Singh et al., 2009)
- **Ecopath with Ecosim (EwE)** (Chea et al., 2016)

Case specific models: Laguna De Bay (Barbosa et al., 2007), Lake Putrajaya (Sharip et al., 2016), Lake Chini (Sharip et al., 2016), ROTAN for lake Rotorua (Anastasiadis et al., 2013)

Ecosystem Model: **DYRESM** (Dynamic Reservoir Model) – **CAEDYM** (Computational Aquatic Ecosystem Dynamics Model)

Spatial Model: Spatial Regression Model (Herrig et al., 2015; Bu et al., 2014); **WEAP** (Stockholm Institute of Environment) (Assaf and Saadeh, 2008); **PLOAD** (Lee and Chung, 2007); **IGAS** (Integrated GIS-based Analysis System) (Liu et al., 2007)
REVIEW OF LITERATURE

Geographic location:
- Residential, Commercial, Community
- High impermeable area


Littoral Zone:
- Highly Sensitive to runoff

Crook et al. (2015); Liu et al., (2015); Erol and Randhir (2013); Sharip and Jusoh (2010) and Price et. al (2006)
Distance of land use activities
Population Density factor
Built-up area
WQS = f (S+ W+ P) ......(1)

WQS = Lake Water Quality Condition
f = coefficient
S  = Social factor
W  = Parameters of Water Quality
P  = Physical factor
Methods used in model development, enables anticipate values at an unsampled location based on its environmental similarity with the observed or control site.

The similarity method is suitable for analysis with limited parameters.

The spatial based model in this research is developed using similarity method designed to anticipate lake water quality conditions in the situation of medium to serious data scarcity.

This approach was adopted because of the management and decision-making support characteristics of the model and most importantly because this approach can be achieved within this research scope of limitation.
Similarity technique of modelling is to similarly assess the studied lake water quality with water quality of lake chosen as the “control point”.

The physical, environment and social variables of the controlled point lake act as the referral point to be similarly evaluated with the physical, environment and social variables of studied lake.

If the physical, environment and social variables are closely similar between control point and the studied lake, then the water quality of the studied lake will be closely similar to the water quality of the control point lake.

If the similarity between the selected variables between the studied and the control point lake is lesser, then the scale of similarity of lake water quality will be lessened.

Categorisation of lake water quality to bad, poor, medium, good and excellent will depend on the percentages of similarity between studied lake and the control point.
METHODOLOGY:
STUDY AREA

93 Recreational Lakes

Selangor

Source: Federal Department of Town and Country Planning Peninsular Malaysia, 2013

Kuala Lumpur

Source: Federal Department of Town and Country Planning Peninsular Malaysia, 2013

Putrajaya

Source: PPJ, 2015
Key Features

- Putrajaya covers an area of 4,931 hectare (12,184.7 acre/49 km²)
- Man-made lake as micro-climate moderator & serve as sports and recreational purpose
- Water Quality Status Class 1 or Class IIA (15 years)
- Stringent Water Quality Standard
- Long term water quality monitoring
- One of the seven Operational Demonstration Site of UNESCO-IHP Ecohydrology Programme (since Feb 2010)
<table>
<thead>
<tr>
<th>Spatial Data (shapefile)</th>
<th>Land Use</th>
<th>Population Density</th>
<th>Lake Location</th>
<th>Rainfall Intensity</th>
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<td>Water Quality Data</td>
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</table>
1) Recreational Lakes in Selangor and Kuala Lumpur (identified based from land use map)
2) Built up area
3) Buffer 1.0 km Radius
4) Spatial Scale – model database
1 Identify recreational lakes

2 Designated a 1.0 km Buffer

3 Clip land use with buffer 1.0km

4 Quantify Physical and Social Factor within the 1.0km buffer
SIMILARITY MODEL DEVELOPMENT

Step: 1 + 2 + 3 + 4

+ Similarity Assessment with Tasik Putrajaya

→ Similarity Model

→ Similarity Index

- Similarity Model: index development based on specified range or rank

- Similarity Spatial modeling: assess water quality status of other lakes based from a "base model" lake with comprehensive series of data.
  - Tasik Putrajaya is the baseline of model development

- Similarity Index: gauge range of water quality status
  → Recreational Lakes in Kuala Lumpur and Selangor
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<th>Built up</th>
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</table>

**Similarity Class (1 Lake WD)**

- 0-20%: **bad**
- 21-40%: **poor**
- 41-60%: **medium**
- 61-80%: **good**
- 81-100%: **excellent**

**Table:**

- **SIMILARITY INDEX CALCULATION**
- **LAHPT**
- **Kod**
- **Rainfall**
- **Built up**
- **Population**
- **Area**
- **Total**
- **Average**
- **Similarity**

**Note:** The table above shows the similarity index calculation for various LAHPT codes, with corresponding values for Rainfall, Built up, Population, Area, and Total. The similarity is calculated using a percentage index, ranging from bad (0-20%) to excellent (81-100%).
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<th>Similarity</th>
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<tr>
<td>2 (21-40%)</td>
<td>Poor</td>
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<td>3 (41-60%)</td>
<td>Medium</td>
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<td>4 (61-80%)</td>
<td>Good</td>
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<td>5 (81-100%)</td>
<td>Excellence</td>
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Lake Water Quality Status:

1. Bad
2. Poor
3. Medium
4. Good
5. Excellent
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</table>
1. Uncertainty (error)

2. Data sparsity (no temporal scale of water quality is considered in the development of the model)

3. Similarity based technique offer an overview of early assessment and not extensive details nor nor precision of accuracy

4. Anticipate water quality status with changing independent variables (i.e. geomorphology, percentage of built-up, population density and rainfall intensity)

5. The model output is reliable to give early indication on the lake status with data limitation and restriction faced by lake management (validation analysis)
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<td>Integrated Environmental Assessment and Management (IEAM)</td>
<td>Similarity Based Technique to Facilitate Integrated Lake Water Quality Management: Recreational Lakes in Klang Valley. Bashirah Fazli, Aziz Shafie, Mohd Fauzi Mohamad, Nasehir Khan E.M Yahaya, Syazrin Syima Sharifuddin, Mohd Fadhil Kasim and Muhammad Azroie Mohamed Yusoff.</td>
<td>Status: Accepted with correction Impact factor: 2.23 ISI Journal Citation Reports @ Ranking: 2017:111/241 (Environmental Sciences) ISI Journal Citation Reports @ Ranking: 2017:55/94 (Toxicology) Online ISSN: 1551-3793</td>
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Special appreciation and big thanks to:

- National Hydraulic Research Institute of Malaysia (NAHRIM),
- Federal Department of Town and Country Planning Peninsular Malaysia (PLAN Malaysia),
- Department of Statistics Malaysia,
- Environment, Lake and Wetland Division, Perbadanan Putrajaya (PPJ);

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TERIMA KASIH

THANK YOU

Why should the aquatic life?
THEORETICAL PRINCIPLE

DRIVING FORCES
Anthropogenic activities, land use types driving changes in lake water quality

PRESSURES
Stresses that human activities and land use types places on the lake water

STATE
State or condition of the lake water

RESPONSES
Responses by lake managers to the lake water quality situation (imperative measures/remedial action)

IMPACTS
Environment, economic and social effects causing water quality changes (physical, chemical, biological state of water quality)

DPSIR
(Driver-Pressure-State-Impact-Responses)

(Tsuzuki et al, 2015; Quevauviller, 2014)
Because of the intricate nature of lakes, modelling approaches is highly utilized as a management support tool.

However, choosing an appropriate model is critical, in order for the modeling analysis to provide reliable assessment as each lake has its own unique problems which will require different approach.

The alternative approach of similarity technique is deemed suitable in the situation of absence of relevant data or severe data scarcity. Method of similarity modeling is considered an alternative option as it enables lake managers to anticipate values at an unsampled location based on similarity assessment of certain attributes with the control lake.

The developed model enables lake managers to make informed decision for it allows them to assess the effects exerted by activities based on distance; hence using proximity as a basis of integrated sustainable planning even with limited data. This can help them to relate to the sources of lake water quality problems directly and indirectly affecting the lake waterbody.

The developed model is based on ArcGIS and it is intended to be applied to lake catchment with limited data availability as a pragmatic early assessment tool to identify potential water quality and conservation issues. It enables estimating the effects exerted by activities close to lake shores providing a basis for sustainable planning and development around recreational lakes.