Evaluation of the Risk of Flood in Iskandar Malaysia Region, Using Fuzzy Logic and Weighted Linear Combination in Geographic Information System

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DEDICATION

To my beloved Mother and Father

with Regards…

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ABSTRACT

Recently, Iskandar Malaysia region have been affected by flood events, which cause environmental, social and economic impacts. Severe rainfall, natural situation, new unplanned developments, and insufficient drainage systems make the situation more remarkable.

This research is an approach of flood hazard assessment at regional scale. The objectives of this study are to find out the criteria which contribute to the risk of flooding based on the characteristic of the region to develop a GIS-aided urban flood susceptibility map. Fuzzy logic and Weighted Linear Combination (WLC) methods in Geographic Information System (GIS) are used to achieve the objectives. Defined criteria are evaluated by means of complexity, uncertainty and sensitivity analysis. The methodology emphasizes on uncertainty criteria which contribute to the risk of flood and increase the risk. Distance from main stream, elevation, slope, land use type, distance from river and distance from discharge channel are recognized as effective criteria within the region. Each criterion is evaluated based on fuzzy membership type and generated map are combined using weighted linear combination to produce the final flood susceptibility map. Final susceptibility map indicates that around 6.586 square kilometers within the region face high level of risk. Pulai, Senai Kulai, Tebrau and Johor Bahru can be considered as areas which face the risk. Natural and man-made situation influence the level of risk in each area. Generally the southern part of the region has high level of risk as a consequence of conjunction of location of stream, lowland and land use type. The model is evaluated by sensitivity analysis to analysis the uncertainty and degree of importance of input criteria. Finally the situation in 2025 is investigated based on the proposed plan for 2025.

ABSTRAK

Baru-baru ini wilayah Iskandar, Malaysia telah terjejas dengan kejadian-kejadian banjir yang menyebabkan impak alam sekitar, sosial dan ekonomi. Hujan yang sangat lebat, keadaan semulajadi, pembangunan baru yang tidak dirancang, dan sistem perparitan yang tidak mencukupi menjadikan keadaan lebih parah lagi.

Kajian ini adalah satu pendekatan penilaian bahaya banjir dalam skala wilayah. Objektif kajian ini ialah untuk mencari kriteria yang menyumbang kepada risiko banjir berdasarkan kepada ciri-ciri wilayah tersebut dan membangunkan peta kecenderungan banjir bandar dengan bantuan GIS. Kaedah *Fuzzy Logic* dan *Weighted Linear Combination* (WLC) dalam Sistem Maklumat Geografi (GIS) telah digunakan untuk mencapai objektif yang digariskan. Kriteria yang telah ditetapkan dinilai melalui kerumitan, ketidaktentuan, dan analisis sensitiviti. Kaedah yang digunakan menumpukan kepada ketidaktentuan kriteria yang menyumbang kepada risiko banjir dan meningkatkan lagi risiko ini. Jarak dari aliran utama, ketinggian, cerun, jenis penggunaan tanah, jarak dari sungai, dan jarak dari saluran pembuangan adalah ciri-ciri yang yang dikenalpasti sebagai kriteria yang efektif dalam wilayah ini. Setiap kriteria dinilai berdasarkan kepada jenis *Fuzzy membership* dan gabungan peta yang dijana adalah menggunakan kombinasi linear wajaran (*weighted linear combination*) untuk menghasilkan peta kecenderungan banjir yang terakhir. Peta kecenderungan banjir yang terakhir ini menunjukkan bahawa linkungan 6.586 kilometer persegi dalam wilayah yang dikaji berdepan dengan risiko tahap tinggi. Pulai, Senai, Kulai, Tebrau, dan Johor Bahru boleh dianggap sebagai kawasan yang berdepan dengan risiko ini. Keadaan semulajadi dan buatan manusia mempengaruhi tahap risiko dalam setiap kawasan. Secara umumnya, bahagian selatan wilayah ini mempunyai tahap risiko yang tinggi berdasarkan kepada lokasi sungai, tanah rendah, dan jenis penggunaan tanah. Model ini dinilai oleh analisis sensitiviti untuk menilai ketidaktentuan dan tahap kepentingan kriteria input. Akhirnya, situasi pada tahun 2025 dikaji berdasarkan pelan perancangan yang dicadangkan untuk tahun tersebut.

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Floodplains are recognized as desirable places for habitation and development due to the inherent advantages for water supply, irrigation system, power, food and defense (White, 2008). Also convenient navigation and transportation system for communication provide along coastal area and rivers (Tingsanchali, 2012). Despite the above mentioned advantages, this situation increases the risk of flooding and make flooding one of the most remarkable natural hazards (White, 2008).

During the last decade, flooding is recognized as the most common disaster in all over the world and causes nearly half of all victims of natural hazards. In addition to that, economic losses is estimated around US $185 billion (Alderman et al., 2012). More than 50 percent of global flood damages occur in Asian countries (Tingsanchali, 2012). Due to climate change and arising sea level flooding are expected to occur more frequent and intensive. In addition, more people will be put in jeopardy of flooding due to increasing levels of urbanization recently. Land use

change is associated with urban development and affects flooding in many ways (Alderman et al., 2012).

Natural hazards' threat in urban areas is mostly inscribed via land-use zoning and building regulation (Khailani and Perera, 2013). Deforestation, removing soil and vegetation, grading land surface and improper drainage system implementation intensify runoff. Volume, vehemence and frequency of flood will be increased as a result of the peak discharge. Capacity of stream channels for transmitting floodwater are affected and decreased due to the urban development. Constructing roads and building in place which are located in flood prone areas increase the risk of flooding, inundation and erosion. Surface water flooding management is impeded due to the urban drainage characteristic (Kaźmierczak et al., 2011).

Basically, some attributes can provide inherent resilience within the city. Impermeable surface within the cities such as buildings, parking and roads increase the surface runoff. On the other hand presences of green space and city surface which have high capacity to observe water reduce runoff volume (Kaźmierczak et al., 2011).

Apparently, land use and evapotranspiring surfaces proportion have effects on water behavior and flooding. Housing type as one of the city features affects the risk of flooding. Housing units which are located at or below ground level or housing with low floor are more frequently exposed to flood (Kaźmierczak et al., 2011). Lightweight constructions are more affected by flooding than solid masonry building. In addition, risk of flooding is associated with natural feature, slope, topography and land use as well (Kaźmierczak et al., 2011). As a result, urban area where once seen as a safety place, nowadays face to different disasters and risks (White, 2008).

Based on the above argument it can be inferred that various criteria might increase the risk of flooding and flood vulnerability. Hence to find the criteria that contribute to the risk of flooding and appropriate method to evaluate the criteria seems necessary to mitigate the risk. Therefore, providing effective geospatial information by using information and communication technology can provide proper basis to improve the decisions which are made in planning system and development (Chandio et al., 2012).

1.2 Background of the Study

In Malaysia floods are known as the most common natural hazards due to the heavy rainfall that causes some destruction every year. During 1956–2007, the number of victims of flooding has estimated around 2.7 million people. In Malaysia 9% of total land that occupies an area of 29,000 km^2 which includes 23% of total urban area are located in flood prone areas. Due to the lack of appropriate measure for development control, the annual cost of flooding in the country is estimated RM100 million (Khailani and Perera, 2013). Flood as a common natural hazard within the country has effects on environmental, economic and social aspects of people's life. Mitigating the effects of flood on different aspects of society can ensure more sustainable development.

Therefore, emphasis on physical adaptations and effective criteria to reduce the risk of flood in built environment and vulnerability of settlements through planning and development interventions for making the human settlement more sustainable during natural hazards is an essential term (Khailani and Perera, 2013).

Morphology, natural situation and artificial element must be considered in risk assessment and future development. Recognizing built and natural elements

which are affected the risk of flooding within the area can be considered as an important part of evaluating flood hazard. In addition, the risk of flooding is higher in more urbanized area (Morelli et al., 2012). Therefore, to find out the reasons and criteria that increase the risk of flood exposure must be considered.

Furthermore during last decade Malaysia accelerate urbanization trend and also deforestation can be observed within the country (Malaysia National Physical Plan, 2010). Due to this situation more area expose to the risk of flooding. Different urban features that can increase the amount of runoff and the risk of flooding can be observed within the urbanized area. Percentage of impervious surface is remarkably high in cities. This character can affect the rainfall infiltration, inundation and flood damages (Tingsanchali, 2012). Hence identifying all the criteria which are associated with the risk of flood can lead the planners toward sustainable development.

Besides the destructive environmental effect flood hazard also has economic and social effect especially in urban area that affect the development in direct and indirect ways (Tingsanchali, 2012). Hence, evaluating the data about stream flow and the effects of land use can help us to reduce loss of social capital and property.

1.3 Problem Statement

Iskandar Malaysia is situated on the South of Peninsular Malaysia and it is considered as a very special and strategic location. Because of its location, it became the most popular gateway from South. Based on National Physical Plan rapid urban growth can be observed in the area.

In terms of weather, study area is under tropical weather with the different daily temperature from 24ºC until 32ºC. Overall, the topographic condition is up to 640 meters above sea level and the lowest is about 2 meters from sea level. Average annual rainfall is 1778 mm with average temperature of between 25.5 °C (78 °F) and 27.8 °C (82 °F). Humidity is between 82% and 86% (www.mbjb.gov.my). Basically, in recent years due to the heavy rainfall the region faced several damages because of flood. Therefore, to find the character within the study area which are increased the risk of flooding can be helpful to reduce the number of victims and property loss.

In addition, rapid urban growth and deforestation within the region make the situation more remarkable. Flood hazard recognizes as environmental phenomenon but it can affect other components of sustainability including social and economic aspects as well. One of the main goals of Malaysia National Physical Plan is promote the current situation toward the sustainable development (Malaysia National Physical Plan, 2010). Therefore, going through sustainability strategy and following the National Physical Plan framework needs to find out effective criteria which are associated with sustainability and risk of flooding. Evaluating the identified criteria can provide an appropriate basis for future development especially in developing area and mitigate the risk in current and future situation.

1.4 Research Questions

This research is conducted to find out the appropriate answer for questions below:

- Which criteria contribute to the risk of flooding?
- To what extent do criteria associate with the risk of flooding?
- Which place within the study area face higher risk of flooding?

- How to mitigate the flood vulnerability with respect to flood susceptibility map?

1.5 Objectives of Study

This study aims to evaluate the effect of urban form on the flood vulnerability in urban areas. Objectives of the study are mentioned below:

- To investigate the main criteria which are associated with flood risk
- To evaluate degree of importance for criteria that increase the risk of flooding
- To generate flood susceptibility map with respect to defined criteria
- To examine the impact of significant criteria which contribute to the flood vulnerability for evaluating future development

1.6 Significance of Study

Flood is identified as the most common type of natural disaster and has occurred more intensive and recurrent in recent year (Alderman et al., 2012). Different conditions such as climate change, global warming, heavy rainfall, rising level of sea, high tides and manmade factors including more urbanized area, inappropriate land use, deforestation, aggravation of drainage channels and etc. increase the risk of flood occurrence (Tingsanchali, 2012). Environmental devastation, social and economic loss can be observed obviously as an outcome of

this phenomenon. Actually different environmental, social and economic aspects of society are affected by flooding. Therefore, addressing the measures that can mitigate the effects of the flood seems necessary.

This study carries out in the Southern Malaysia where flood is a dominant natural disaster. Also rapid urbanization and deforestation can be observed within the area clearly. Furthermore, this area is coastal area in which the risk of flooding is high due to the low lying level (Tingsanchali, 2012). Moreover urbanized area experience more social and property loss when the flood hazard occurs. Due to the many changes which are happened during urbanization trend such as green space devastation and generating more impervious surfaces, risk of flooding has been increased in urban area (Tingsanchali, 2012). Hence, it can be concluded that natural and manmade situation affect the risk of flooding in the study area. Therefore investigating the criteria which contribute to the risk of flooding is necessary to find out the appropriate direction for future development and measures for mitigating the risk of flooding and its effect.

1.7 Research Methodology

Methodology is a systematic process of collecting, organizing and analyzing data which is selected based on the research objective. Methods that will be used through conducting the research are described below. Research methodology to conduct the research will be elaborated in chapter 3.

I. To investigate the main urban form criteria which are associated with flood risk in urban area, different sources is reviewed to find out relevant criteria which contribute to the risk of flood.

II. To evaluate degree of importance for criteria, Fuzzy logic can be operated to analyze the criteria and alternatives which are extracted through literature review.

III. To examine the impact of significant criteria combination between Geographical Information Systems (GIS) and Fuzzy Logic by using Weighted Linear Combination (WLC) can be carried out to create flood susceptibility map. GIS provide basis for criteria computation and can be used in spatial analysis and modeling while a Fuzzy logic provide basis for categorizing and ranking the criteria.

1.8 Research Design and Organization

A research design can be recognized as blueprint or framework for shedding light into the procedure and provide bases for conducting the research. It can be defined as a tool to gain the research questions. Six factors which are mentioned below identified by Sekaran (1992) as research design elements:

i. Type of investigation: Type of investigation includes experimental, descriptive or comparative research.

ii. Purpose of the study: Purpose of study indicates the goal of research that can be descriptive, exploratory or hypothesis testing.

iii. Research limitation: each research has its own limitation in terms of researcher and specific field of science where the research will be carried out; a research design defines all limitation.

iv. Setting the goals of the study: Goals of the study must be adjusted before beginning the research. Study goals give the researcher clear direction and also it is necessary part of research design.

v. Measures that are related to analysis: Each research includes various indicators as input or output to be measured. These indicators must be defined clearly in research design.

vi. Research scheduling regards to time: The final part of research design is recognized as time scheduling. In some experimental research different factors such as production life span or perishable material can be affected by timing. All the research must follow the scheduling which can be used as helpful tools to get output from the process by regarding to the time.

Chapter1

Chapter 1 includes an introduction to the research and its significance. Research question and objectives are introduced in this chapter as well, followed by research methodology to conduct the research.

Chapter 2

Chapter 2 discusses about relevant terms to provide clear understanding about the subject. Causes and effects of flooding are investigated. Relevant researches are revised to find out the criteria which are associated with the risk of flooding to be the source of criteria and indicators selection.

Chapter 3

Chapter 3 presents the research structure and main method that are used to conduct the research. Data preparation trend by using Fuzzy method and Weighted Linear Combination in Geographic Information system environment discusses as well.

Chapter 4

Chapter 4 elaborates the data analysis, result and finding of the research. The main aim of this chapter is to indicate the area with high level of risk and find out the significant criteria which contribute to the risk and compare the different situation.

Chapter 5

Chapter 5 sums up the research finding, also presents some potential for uses of the outcome of the research and recommend suggestions regarding the current and future situation.

REFERENCE

Alderman, K., Turner, L. R., and Tong, S. (2012). Floods and human health: a systematic review. *Environment international*. 47: 37_47.

Al-Hanbali, A. (2011). Using GIS-Based Weighted Linear Combination Analysis and Remote Sensing Techniques to Select Optimum Solid Waste Disposal Sites within Mafraq City, Jordan. *Journal of Geographic Information System*. 03(04): 267_278.

AS Badrul Hisham, Marzukhi, MI., Daud. AR. (2009). The Worst Flood in 100 Years : Johore Experience. *Somatosensory & Motor Research*. 21(2): 145_145.

Azlina, N., Aziz, A., Aziz, K.A. (2011). Managing Disaster with Wireless Sensor Networks. *13th International Conference on Advanced Communication Technology (ICACT)* 13-16 Feb. Seoul: IEEE, 202_207.

Boroushaki, S. and Malczewski, J. (2008). Implementing an extension of the analytical hierarchy process using ordered weighted averaging operators with fuzzy quantifiers in ArcGIS. *Computers & Geosciences*. 34(4): 399–410.

Calianno, M., Ruin, I. and Gourley, J.J. (2013). Supplementing flash flood reports with impact classifications. *Journal of Hydrology*. 477: 1_16.

Camarasa Belmonte, A.M., López-García, M.J. and Soriano-García, J. (2011). Mapping temporally-variable exposure to flooding in small Mediterranean basins using land-use indicators. *Applied Geography*. 31(1):.136–145.

Chandio, I. A., Matori, A. N. B., WanYusof, K. B., Talpur, M. A. H., Balogun, A.-L., and Lawal, D. U. (2012). GIS-based analytic hierarchy process as a multicriteria decision analysis instrument: a review. *Arabian Journal of Geosciences.*

Chang, H. and Franczyk, J. (2008). Climate Change , Land-Use Change , and Floods : Toward an Integrated Assessment. *Geography Compass*. 5(2): 1549_1579.

Chang.K, Introduction to Geographic information system (sixth edition), 2012. Mc Graw-Hill companies. New York

Crosetto, M. and Tarantola, S. (2001). Tools for GIS-based model Implementation. *International Journal of Geographical Information Science*. 15(5): 415_437.

Drobne, S. and Lisec, A. (2009). Multi-attribute Decision Analysis in GIS : Weighted Linear Combination and Ordered Weighted Averaging. *Informatica*. 33: 459_474.

Fernández, D.S. and Lutz, M. A. (2010). Urban flood hazard zoning in Tucumán Province, Argentina, using GIS and multicriteria decision analysis. *Engineering Geology*. 111(1-4): 90_98.

Hajek, Petr, "Fuzzy Logic" *The Stanford Encyclopedia of Philosophy* (Fall 2010 Edition).

Hock, K.M. and Ramli, A.T. (2006). Iso dose-rate contour map of terrestrial gamma radiation in johor bahru district, johor. *Fiz. UTM.* (1): 22–26.

Jianfen, L., Xingnan, Z. and Huimin, W. (2013). Flood Risk Mapping for Different Landuse Senarios Based on RS and GIS. *Applied Mechanics and Materials*. 298: 2415–2419.

Joerin, F., The´riault, M. and Musy,A. (2001). Using GIS and outranking multicriteria analysis for land-use. *Geographical Information Science*. 15(2): 153–174.

Julien, P.Y., Ghani, A. Ab., Zakaria, N. A., Abdullah, R.and Chang, C. K. (2010). Case Study : Flood Mitigation of the Muda River, Malaysia. *Journal of Hydraulic Engineering*. 136(April): 251–261.

Kamsin, A. (2008). A Real Time Simulation and Modeling of Flood Hazard Faculty of Computer Science and Information Technology. *12th WSEAS International Conference on SYSTEMS*, Heraklion, Greece. July 22-24, 438–443.

Kaźmierczak, A., and Cavan, G. (2011). Surface water flooding risk to urban communities: Analysis of vulnerability, hazard and exposure. *Landscape and Urban Planning*. 103(2): 185–197.

Khailani, D. K., and Perera, R. (2013). Mainstreaming disaster resilience attributes in local development plans for the adaptation to climate change induced flooding: A study based on the local plan of Shah Alam City, Malaysia. *Land Use Policy*. 30(1): 615–627.

Kia, M.B., Pradhan,B., Pirasteh,S., Azmin Sulaiman,W.N, Mahmud,A.R., and Moradi, A. (2012). An artificial neural network model for flood simulation using GIS: Johor River Basin, Malaysia. *Environmental Earth Sciences*. 67(1): 251–264. •

Konrad, C.P. (2002). Hydrologic Trends Associated with Urban Development for Selected Streams in the Puget Sound Basin , Western Washington Hydrologic Trends Associated with Urban Development for Selected Streams in the. *U.S. Department of the Interior U.S. Geological Survey*: 1–38.

Konrad, C.P. (2003). Effects of Urban Development on Floods. *U.S. Department of the Interior U.S. Geological Survey*: 1–4.

Kubal,C., D. Haase,D., Meyer,V. and Scheuer,S. (2009). Integrated urban flood risk assessment, adapting a multicriteria approach to a city. *Natural Hazards and Earth* System Sciences. 9: 1881–1895.

Lamond, J., Booth, C., Hammond, F. and Proverbs, D. (2012). FLOOD HAZARDS Impact and Responses for the Built Environment. Taylor and Francis Group: CRC press.

Levy, J.K., Hartmann,J., Kevin W. Li, Yunbi, A. and Asgari,A. (2007). Multi-Criteria Decision Support Systems for Flood Hazard Mitigation and Emergency Response in Urban Watersheds. *Journal of the American Water Resources Association*. 43(2): 346–358.

Mackenzie, L.D. and David, A.C: Hydrology. Introduction to Environmental Engineering. Third Edition. USA: Mc Graw Hill. (1998):81.

Malaysia : Floods. (2007). *International Federation of Red Cross and Red Crescent Societies*. (July): 1–7.

Malaysia National Physical Plan, Federal Department of Town and Country Planning, Ministry of Housing and Local Government, 2010.

Malczewski J. (1999). GIS and Multicriteria Decision Analysis, John Wiley and Sons, Toronto.

Mohd, M.S, Alias,B. and Daud, D. (2006). GIS Analysis for flood Hazard Mapping : Case Study ; Segamat, Johor, West Malaysia. Seminar Nasional GIS: 1–15.

Montz, B.E. and Tobin, G. A. (2011). Natural hazards: An evolving tradition in applied geography. *Applied Geography*. 31(1): 1–4.

Morelli, S., Segoni, S., Manzo, G., Ermini, L., and Catani, F. (2012). Urban planning, flood risk and public policy: The case of the Arno River, Firenze, Italy. *Applied Geography*. 34: 205–218.

Musungu, K., Motala, S. and Smit, J. (2012). Using Multi-criteria Evaluation and GIS for Flood Risk Analysis in Informal Settlements of Cape Town : The Case of Graveyard Pond. *South African Journal of Geomatics*. 1(1): 77–91.

Ologunorisa, T E and Abawua, M.J. (2005). Flood Risk Assessment : A Review. *Appl. Sci. environ. Mgt*. 9(1): 57–63.

Ologunorisa,T. (2004). An Assessment of Flood Vulnerability Zones in the Niger Delta, Nigeria. *International Journal of Environmental Studies*. 61(1): 31–38.

Paquette, J. and Lowry, J. (2012). Flood hazard modelling and risk assessment in the Nadi River Basin , Fiji , using GIS and MCDA. *The South Pacific Journal of Natural and Applied Sciences*. 30(Fms 2009): 33–43.

Popovska, C. and Ivanoski, D. (2009). Flood risk assessment of urban areas. *Risk Management of Water Supply and Sanitation Systems*: 101–113.

Pradhan, B. (2009). Flood susceptible mapping and risk area delineation using logistic regression, GIS and remote sensing. *Journal of Spatial Hydrology*. 9(2): 1–18.

Saini, S.S, and Kaushik, S.P. (2012). Risk and vulnerability assessment of flood hazard in part of Ghaggar Basin : A case study of Guhla block , Kaithal , Haryana , India. *International journal of geomatics and geosciences*. 3(1): 42–54.

Sadeghi-niaraki, A., Varshosaz, M., Kyehyun, K., Jung,J.J. (2011). Expert Systems with Applications Real world representation of a road network for route planning in GIS. *Expert Systems with Applications*. 38(10): 11999–12008.

Scheuer, S., Haase, D. and Meyer, V. (2011). Exploring multicriteria flood vulnerability by integrating economic, social and ecological dimensions of flood risk and coping capacity: from a starting point view towards an end point view of vulnerability. *Natural Hazards*. 58(2): 731–751.

Sekaran, U. (1992). Research Methods for Business – A skill building approach (2nd Ed). John Wiley & Sons, New Yourk.

Shafie, A. (2009). Extreme Flood Event: A Case Study on Floods of 2006 and 2007 in Johor, Malaysia. Technical report for Department of Civil and Environmental Engineering, Colorado State University.

Shaluf, I.M. and Ahmadun, F. R. (2006). Disaster types in Malaysia: an overview. *Disaster Prevention and Management*.15(2): 286–298.

Smyth, C.G. and Royle, S.A. (2000). Urban landslide hazards : incidence and causative factors in Nitero´i, Rio de Janeiro, State, Brazil. *Applied Geography*.20: 95–117.

Stefanidis, S. and Stathis, D. (2013). Assessment of flood hazard based on natural and anthropogenic factors using analytic hierarchy process (AHP). *Natural Hazards*: 1_17.

Sulaiman, N.A., Faizah, H., Afendy, H.K and Manan, S.A. (2012). A study on flood risk assessment for Bandar Segamat sustainability using remote sensing and GIS approach. *Control and System Graduate Research Colloquium* (ICSRC): 386–391.

Tingsanchali, T. (2012). Urban flood disaster management. *Procedia Engineering*. 32: 25–37.

White, I. (2008). The absorbent city: urban form and flood risk management. *Proceedings of the ICE - Urban Design and Planning*. 161(4): 151–161.

Yaoyao. H, Jianzhong, Z., Pangao, K., Ning, L. and Qiang, Z. (2011). A fuzzy clustering iterative model using chaotic differential evolution algorithm for evaluating flood disaster. *Expert Systems with Applications*.38(8): 10060–10065.

Youssef, A.M., Pradhan, B. and Tarabees, E. (2010). Integrated evaluation of urban development suitability based on remote sensing and GIS techniques:

contribution from the analytic hierarchy process. *Arabian Journal of Geosciences*. 4 (3-4): 463–473.

Zadeh, L.A. (1965). Fuzzy Sets. *Information and Control*. 8: 338–353.

Zadeh, L. A. (1988). Fuzzy logic. *Computer*. 21(4): 83–93.