UNIVERSITI PUTRA MALAYSIA

MODELING THE EFFECT OF LAND USE AND LAND COVER CHANGES ON LONG-TERM RAINFALL/RUN-OFF AND NON-POINT SOURCE POLLUTION IN THE UPPER KELANTAN RIVER BASIN, MALAYSIA

JABIR HARUNA ABDULKAREEM

FPAS 2018 20

MODELING THE EFFECT OF LAND USE AND LAND COVER CHANGES ON LONG-TERM RAINFALL/RUN-OFF AND NON-POINT SOURCE POLLUTION IN THE UPPER KELANTAN RIVER BASIN, MALAYSIA

By

JABIR HARUNA ABDULKAREEM

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

September 2018

DEDICATION

This thesis is dedicated to my late parents, Mallam Haruna Abdulkarim and Hajiya Asmau Talatu Haruna through whom Allah brought me into this world. May your souls continue to rest in peace and may Aljannah Firdaus be your final resting home, Ameen.

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirements for the degree of Doctor of Philosophy

MODELING THE EFFECT OF LAND USE AND LAND COVER CHANGES ON LONG-TERM RAINFALL/RUN-OFF AND NON-POINT SOURCE POLLUTION IN THE UPPER KELANTAN RIVER BASIN, MALAYSIA

By

JABIR HARUNA ABDULKAREEM

September 2018

Chairman : Wan Nor Azmin Sulaiman, PhD
Faculty : Environmental Studies

Kelantan River basin, Malaysia is a tropical catchment receiving heavy monsoon rainfall coupled with intense land use and land cover (LULC) changes making the basin consistently flood prone. A study was conducted to model the effect of LULC changes on long-term rainfall-runoff and non-point (NPS) pollution in the upper portion of the basin. First, LULC maps corresponding to 1984, 2002 and 2013 were analyzed. The basin was delineated into four catchments (Galas, Pergau, Nenggiri and Lebir) due to it's and size for improved results accuracy. Flood hydrographs corresponding to 1984, 2002 and 2013 LULC condition were simulated using HEC-HMS. Relative changes in the peak flow of the three subsequent conditions were determined for different return periods (2, 5, 10, 20, 50 and 100 years). By using flood response approach, flood source areas were identified and ranked based on the values given by gross flood index (*F*), per unit area index (*f*) and flood area index (*fa*) where different results were obtained for each index. Long-term runoff dynamics due to LULC changes was determined using NRCS-CN model and its modifications. NPS pollution estimation was carried out using numeric integration in a GIS environment. Soil loss was estimated using RUSLE model. Result of land use analyses showed that deforestation for logging activities, agricultural purposes and urbanization were the major land use changes observed in the basin from 1984-2013. Lebir (48557.3 m^3/s) was the catchment with greatest contribution of peak discharge at the outlet under 2013 LULC condition. This is followed by Galas (43357.7 m^3/s), Pergau (33126.4 m^3/s) and Nenggiri (16729.1 m^3/s) in that order. The use of *fa* index gives better ranking and is therefore, recommended in ranking sub-basins with respect to their contribution to the outlet. Results of runoff dynamic reveal that proposed modified NRCS-CN model V (MNM V) was found to give the best runoff estimation based on model goodness of fit evaluation criteria. Thus, the MNM V was selected for runoff estimation from 1984-2014. It was observed from the results that runoff estimation increased with changes in LULC from 1984-2014 in all the selected runoff events and in all catchments.

Results of spatio-temporal variation of pollutant loads in all the catchments increased with changes in LULC condition as one moves from 1984-2014, with 2013 LULC condition found as the dominant in almost all cases. NPS pollutant loads among different LULC changes also increased with changes in LULC condition from 1984-2013; while urbanization was found to be the dominant LULC change with the highest pollutant load in all the catchments. This reveals the clear effect LULC changes on NPS pollution. Soil erosion results from RUSLE showed that 67.54% of soil loss is located under low erosion potential or 0-1ton ha-1 yr^{-1} otherwise known as reversible soil loss in Galas, 59.17% in Pergau, 53.32% in Lebir and 56.76% in Nenggiri all under the 2013 LULC condition. These results are higher than that of 1984 and 2002 LULC conditions.The novel methodologies developed in this study can be incorporated for regional hydrological studies and early warning systems for flood control.

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

PERMODELAN KESAN PERUBAHAN GUNATANAH UNTUK JANGKA MASA PANJANG HUJAN/LARIAN DAN SUMBER PENCEMAR BUKAN TITIK DI LEMBANGAN SUNGAI KELANTAN

Oleh

JABIR HARUNA ABDULKAREEM

September 2018

Pengerusi : Wan Nor Azmin Sulaiman, PhD
Fakulti : Pengajian Alam Sekitar

Lembangan Sungai Kelantan di Malaysia adalah kawasan tadahan tropika yang menerima hujan monsun yang tinggi. Perubahan guna tanah (LULC) yang pesat menjadikan kawasan tersebut terdedah kepada ancaman banjir. Satu kajian telah dijalankan di bahagian hulu Sungai Kelantan untuk memodelkan kesan perubahan guna tanah terhadap pencemaran air hujan jangka panjang dan pencemaran NPS. Pertamanya, peta guna tanah bagi tahun 1984, 2002 dan 2013 dianalisa. Lembagan Sungai Kelantan dibahagikan kepada empat sub-lembangan iaitu Galas, Pergau, Nenggiri dan Lebir. Hidrograf banjir pada tahun 1984, 2002 dan 2013 disimulasikan dengan menggunakan perisian HEC-HMS dan perubahan relatif pada aliran puncak bagi tiga keadaan berikutnya ditentukan untuk tempoh pulangan yang berlainan (2, 5, 10, 20, 50 dan 100 tahun). Dengan menggunakan pendekatan respon banjir, kawasan sumber banjir telah dikenal pasti dan disenaraikan berdasarkan nilai diberi oleh indeks (*F*) banjir, setiap indeks kawasan (*f*) unit dan indeks luas banjir (*fa*) di mana kesan berbeza telah diperolehi untuk setiap indeks. Dinamik larian air yang jangka panjang disebabkan perubahan LULC ditentukan menggunakan NRCS-CN model dan pengubahsuaian pengubahsuaiannya. Anggaran pencemaran NPS dijalankan menggunakan integrasi angka dalam persekitaran GIS. Kadar hakisan tanah dianggarkan menggunakan model RUSLE. Analisis penggunaan tanah menunjukkan bahawa penebangan hutan untuk kegiatan pembalakan, tujuan pertanian dan urbanisasi adalah perubahan penggunaan tanah utama yang dilihat di kawasan lembangan dari tahun 1984-2013. Bagi tahun 2013, Lebir merupakan kawasan sub lembangan yang paling tinggi menyumbangkan luahan air puncak dengan 48557.3 (m^3/s). Ini diikuti oleh Galas (43357.7 m^3/s), Pergau (33126.4 m^3/s) dan Nenggiri (16729.1 m^3/s). Penggunaan indeks fa disarankan dalam pengkelasan sub lembangan berdasarkan sumbangan setiap sub lembangan di outlet. Keputusan dinamik larian air menunjukkan bahawa model NRCS-CN yang dimodifikasi V (MNM V) yang dicadangkan didapati memberi larian air terbaik. Oleh itu, MNM V telah dipilih untuk anggaran larian air

dari 1984-2014. Hasil kajian menunjukkan bahawa anggaran larian air meningkat dengan perubahan dalam LULC dari 1984-2014 dalam semua peristiwa larian terpilih dan di semua kawasan tadahan. Keputusan variasi spatial-temporal beban pencemar di semua kawasan tadahan meningkat dengan perubahan keadaan LULC dari 1984-2014, dengan keadaan LULC 2013 didapati sebagai dominan dalam hampir semua kes. Beban pencemar NPS dengan perubahan LULC yang berbeza juga meningkat dengan perubahan dalam keadaan LULC dari tahun 1984-2013; manakala urbanisasi didapati perubahan LULC yang dominan dengan beban pencemar tertinggi di semua kawasan tadahan. Keputusan kajian ini jelas menunjukkan bahawa perubahan LULC memberi kesan terhadap pencemaran NPS. Keputusan hakisan tanah dari RUSLE menunjukkan bahawa 67.54% kehilangan tanah terletak di bawah potensi hakisan yang rendah atau 0-1 ton ha^{-1} yr^{-1} atau kehilangan tanah di Galas, 59.17% di Pergau, 53.32% di Lebir dan 56.76% di Nenggiri di bawah keadaan LULC 2013. Metodologi novel yang dibangunkan dalam kajian ini boleh digunakan untuk kajian hidrologi serantau dan sistem amaran serantau untuk kawalan banjir.

ACKNOWLEDGEMENTS

All praises are due to Almighty Allah, the Lord of everything and the Master of the Day of Judgement for granting me life and the opportunity to come this far in my academic quest. Specifically, I would like to express my invaluable and sincere gratitude to my major supervisor Prof. Dr. Wan Nor Azmin Sulaiman for his excellent advice, guidance, encouragement, support and unrelenting constructive criticisms in making this research work a good read throughout my period of studentship. To my co-supervisors, Prof. Dr. Biswajeet Pradhan for his teaching, mentorship, endless support and guidance. To Dr. Nor Rohaizah for all what you have done to me during the period of study.

I modestly remain grateful to my family members at large, who together have made life more beautiful in different ways by their love, attention, understanding and most importantly their Prayers. A few mentions are my brother Dr. Imran and his wife Ruqayya for their endless support towards the success of this work. Hajiya Rahilu Kabir and my brother Iyal, I say thank you for everything. Limitation of time and space will not enable me to mention all the people that contributed directly and indirectly towards the success of this study. May Allah reward you all abundantly, Ameen.

Part of this research was funded by the Fundamental Research Grant Scheme (FRGS) 2015-1 from the Ministry of Higher Education (MOHE), Malaysia. My profound appreciation goes to Department of Irrigation and Drainage (DID), Malaysia for providing the hydrological data Department of Agriculture, Malaysia (DOA) for the soil map as well as LULC maps and Department of Environment (DOE), Malaysia for the water quality data.

The thesis was 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 Supervisory Committee were as follows:

Wan Nor Azmin Sulaiman, PhD
Professor
Faculty of Environmental Studies
Universiti Putra Malaysia
(Chairman)

Biswajeet Pradhan, PhD
Professor
Faculty of Engineering
Universiti Putra Malaysia
(Member)

Nor Rohaizah Jamil, PhD
Senior Lecturer
Faculty of Environmental Studies
Universiti Putra Malaysia
(Member)

ROBIAH BINTI YUNUS, PhD
Professor and Dean
School of Graduate Studies
Universiti Putra Malaysia

Date:

Declaration by graduate student

I hereby confirm that:

- this thesis is my original work;
- quotations, illustrations and citations have been duly referenced;
- this thesis has not been submitted previously or concurrently for any other degree at any institutions;
- intellectual property from the thesis and copyright of thesis are fully-owned by Universiti Putra Malaysia, as according to the Universiti Putra Malaysia (Research) Rules 2012;
- written permission must be obtained from supervisor and the office of Deputy Vice-Chancellor (Research and innovation) before thesis is published (in the form of written, printed or in electronic form) including books, journals, modules, proceedings, popular writings, seminar papers, manuscripts, posters, reports, lecture notes, learning modules or any other materials as stated in the Universiti Putra Malaysia (Research) Rules 2012;
- there is no plagiarism or data falsification/fabrication in the thesis, and scholarly integrity is upheld as according to the Universiti Putra Malaysia (Graduate Studies) Rules 2003 (Revision 2012-2013) and the Universiti Putra Malaysia (Research) Rules 2012. The thesis has undergone plagiarism detection software

Signature: ___________________________ Date: __________________

Name and Matric No: Jabir Haruna Abdulkareem, GS43279

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

A	Soil erosion rate
AMC	Antecedent moisture condition
AN	Ammonia nitrogen
ANOVA	Analysis of variance
ASTER	Advanced Spaceborne Thermal Emission and Reflection Radiometer
C	Constant of channel maintenance
C	Land cover and management factor
C_k	Kurtosis
CN	Curve number
C_s	Skewness
D_d	Drainage density
DEM	Digital elevation model
DID	Department of Irrigation and Drainage
DOA	Department of Agriculture
EMC	Event mean concentration
F_f	Form factor
FR	Frequency ratio
GIS	Geographic Information System
H	Basin relief
HRU	Hydrologic response unit
HSG	Hydrologic soil group
IDW	Inverse distance weighted
K	Soil erodibility factor

K-S	Kolmogorov-Smirnov
L	Length of overland flow
LS	Terrain factors (slope length and steepness)
L_{sm}	Mean stream length
L_u	Stream length
LULC	Land use/land cover
MAE	Mean absolute error
MSE	Mean square error
NPS	Non-point source pollution
NRCS-CN	Natural Resource Conservation Service-Curve Number
NSE	Nash-Sutcliffe coefficient of efficiency
N_u	Stream number
PBIAS	Percent bias
P	Conservation practices factor
P_m	Mean
PMF	Probable maximum flood
P_r	Range
R^2	Coefficient of determination
R_{ann}	Rainfall runoff erosive factor
R	Correlation coefficient
R_b	Bifurcation ratio
RE	Relative error
R_e	Elongation ratio
R_h	Relief ratio

R_L	Stream length ratio
RMSE	Root mean square error
R_n	Ruggedness number
SD	Standard deviation
SEM	Standard error of mean
SSE	Sum squared error
T_c	Time of concentration
t_L	Lag time
TN	Total nitrogen
TP	Total phosphorus
TSS	Total suspended solids
u	Stream order

CHAPTER 1

INTRODUCTION

1.1 General Introduction

Distribution of water within a watershed is subject to complex spatio-temporal hydrological processes that are in turn related to several meteorological, surface and subsurface characteristics governed by land use and land cover (LULC) changes (Beighley et al., 2004; Entwisle, 2005). LULC changes due to deforestation, rapid increase in agriculture or urbanization have led to massive transformation of global landscape. Even though land use practices differ from one part of the world to another, the major aim is usually the same. It involves the possession of natural resource for instant human wants without repercussion to the environmental conditions and these have transformed a nearly 50% of planet's land surface (Foley et al., 2005; World Bank, 2008). In other words it is one of the major factors through which man impacts the environment (Lausch & Herzog, 2002). LULC transformation with time is among the life-threatening issues inducing various constituents of the hydrologic budget such as runoff, evaporation, surface infiltration, and groundwater recharge. As such, it is regarded as a major factor in various applications such as water resources management problems, flood prediction analyses, assessing of soil degradation and nutrient loss, and biodiversity conservation studies (DeFries & Eshleman, 2004; Thanapakpawin et al., 2006).

LULC changes have substantial influence on runoff and related hydrological characteristics of a watershed. Runoff process is particularly vital in urban areas due to the intensification of impervious surfaces. Weng (2001) and Ali et al. (2011) reported that LULC changes can have profound effect on runoff generation and flow patterns by changing hydrological features such as interception, infiltration and evaporation and thus causes changes in the frequency and intensity of surface runoff and flooding. The effect of LULC on runoff generation is very complicated. Several studies in the past have identified that LULC as having a strong impact on water quality (e.g Thanapakpawin et al., 2007; Zaimes et al., 2008; Shen et al., 2010) predominantly because of non-point source pollution (NPS). Therefore, a better understanding and assessment of LULC change impacts on watershed hydrologic process, is of great importance for predicting flood potential and mitigation of hazards has become a crucial issue for planning, management, and sustainable development of a watershed (Vorosmarty et al. 2000; DeFries & Eshleman, 2004; Wang et al. 2007; Chen et al. 2009).

Malaysia has an annual average rainfall of about 2,500 mm with several rivers and streams. This along with the tropical monsoon climate makes the country abundant in water resources making it more prone to the incidence of floods, which is the major natural disaster. Floods occur annually causing damages to lives and properties even though loss of lives is not as severe as that of other countries like Bangladesh. Floods are usually caused by northeast monsoon rain, which occur around November to March and the southwest monsoon rain from late May to September. There are several flood prone rivers in the country; and one of them is Kelantan river basin.

1.2 Statement of Research Problem

LULC change and climate change affects the natural hydrologic cycles in different parts of the world (Pachauri et al., 2014; Nobre et al., 2016). Changes in rainfall pattern alters the natural hydrologic cycle, which in turns affect the quantity and quality of water resources (Mujere & Moyce, 2016; Petersen et al., 2017). According to IPCC, (2014), effects of climate-related disasters such as floods expose the vulnerability of ecosystem as well as human lives to climate change.

Floods occurrence are common to Kelantan River and its tributaries. Noticeable dates include those that occurred in 1886, 1926, 1967, 1971, 2006, 2007, 2008, and 2014. The 1926 flood, regarded as “The storm forest flood” was responsible for the destruction of several areas of lowland forest located on the valleys of Kelantan state. In another incident, a flood caused by heavy rains in 2000 led to the death of about 15 people in Kelantan and Terengganu states and affected the lives of several thousand people by forcing them to evacuate their shelters (Chan, 2012). The most recent occurrence of flood is that of late December 2014, where heavy rainfall occurred for many days that resulted in catastrophic flooding in several parts of the west coast state of Peninsula Malaysia specifically Kelantan, Terengganu, Perak, Johor and Pahang. The flooding is one of the greatest in history that happens in Kelantan and its tributaries, which drains approximately 13,100 km^2 watersheds. There are several factors contributing to flood such as climate change, mismanaged drainage system, unpredictable nature of weather conditions and unplanned development by human activities. LULC changes and climate change have significant impact on the hydrologic conditions and ecological process of the watershed. LULC changes increase the occurrence of flooding, presenting a significant management problem. In addition, prolific LULC changes from the 1980s to 2000s, especially in relation to deforestation (for logging activities) and transformation to agricultural land (mostly for rubber and oil palm production) have been reported by several authors (Wan, 1996; Adnan & Atkinson, 2011). There is no concrete data to support or refute this argument for the basin. Hence, there is need for a comprehensive study of flood characteristics in the region to analyze and identify flood sub-basins that contribute the least and the most magnitude of flow downstream for further flood control and planning.

Runoff water draining during flood has the tendency to carry along with it residues of several types to the land. Under the first flush phenomena, surface runoff is a major source of NPS pollution. The type of contaminant depends on the runoff that is associated with the LULC and the event mean concentrations (EMC) of the pollutant load (Engel, 2001; Novotny, 2003; Choi, 2007). EMC quantifies the volume of pollutants conveyed per unit volume of runoff. For example, the major contaminants from runoff from agricultural land use will be nutrients (mostly nitrogen and phosphorus) and sediments. While runoff from highly urbanized areas may be polluted with rubber fragments, heavy metals, in addition to sodium and sulfate from road (Tong & Chen, 2002). The problem of NPS pollution is an issue of great concern as it poses a great risk to water quality in developed countries Malaysia inclusive (U.S EPA, 2009). To tackle this risk, it is vital to have precise simulations and estimations of NPS pollutants (Shen et al., 2012).

The tolerable rate at which soil erosion occurs in Kelantan River basin need to be ascertained. Since many parts of the watershed are under continuous development for over three decades (land clearing for logging, agricultural activities and urbanization as outlined earlier), coupled with the fact that the basin is under the influence of northeast monsoon characterized with extremely heavy rainfall. Although the rains are needed for agriculture, particularly for the wet paddy rice cultivation, they are also largely responsible for bringing seasonal floods in the region (Pradhan & Youssef, 2011). According to Pradhan, 2010; Pradhan & Buchroithner, 2012, very high rain splash erosion and surface runoff erosion are recorded in the equatorial areas. Since tropical rains are characteristically of high intensity with short duration, this gives their erosivity, the power to make the soil particles lose, thereby weakening slopes and increase rates of sediments in water bodies. This will eventually yield various types of mass movements such as soil creep, landslips and landslides (Pradhan et al., 2011). The massive deforestation carried out in the watershed without concern to the environmental consequences can be the backbone to erosion problems in the catchment. In view of this, the quantitative assessment of land degradation (soil erosion) becomes vital which can be achieved through several ways using detailed and spatially distributed data.

1.3 Research Questions

a. Is there climate change because of changes in long-term rainfall pattern that may significantly affect the hydrology of the watershed?
b. Are there LULC changes large enough to affect the water balance of the watershed?
c. Is there any effect of LULC change on peak flow and runoff volume?
d. How do different sub-basins contribute to magnitude of water to the outlet areas?
e. How do different sub-basins and locations of basins contribute to peak discharge?
f. Do long-term LULC changes have significant impact on runoff, soil erosion and NPS pollution?
g. Does runoff, NPS pollution and soil erosion vary among different LULC changes of the catchment?
h. Does flood problem arise from different LULC changes in the watershed?
i. Is there a way in which flood control in the watershed can be optimized?

1.4 General Objective

The main objective of this research it to model the effect of LULC changes on long-term rainfall/runoff and NPS pollution of Upper Kelantan River basin.

1.4.1 Specific objectives

1. To determine the impact of past and present LULC changes on flood peaks and volumes, particularly changes in flood peaks are of paramount importance in this study.
2. To assess the contribution of various sub-basins in each catchment on peak discharge and volumes under different LULC changes for further flood control planning.
3. To investigate long-term runoff dynamics due to LULC changes as well as how the extent of LULC changes will affect surface runoff generation for long-term watershed monitoring for the basin.
4. To examine the impact of long-term LULC changes on NPS pollution with a view of determining spatial and temporal differences in NPS among different catchments and temporal variation loads among different LULC changes.
5. To evaluate soil erosion risk due to long-term LULC changes and the relationship between soil erosion and different LULC changes in the area.

1.5 Significance of the studies

Ferquent occurrence of flood events, insufficient data and the complex behavior of floods in Malaysia leads to the initiation of this research. Although monitoring activities through forecasting are carried out and are continuously carried out from time to time for rising water using numerous monitoring stations installed around Kelantan River basin by Drainage and Irrigation Department (DID). It is vital to improve on the level of awareness and effectiveness in disaster response using hydrological parameters to study runoff changes due to LULC changes in a GIS environment (Pradhan, 2009; Pradhan & Youssef, 2011; Tehrany et al. 2014). In addition, the Kelantan River basin is known for its flood potential.

Trend analyses on long-term climatic data was conducted to have an idea of rainfall and discharge changes (increase or decrease). These changes are useful in determining whether climate change has occur in the watershed or flood has increase. Land use analyses conducted in the watershed gives an idea of past and present LULC changes that occurred during the period under study. This will give land use planners the knowledge on how to enact proper land use laws in the watershed and also the level as well as frequency of deforestation required for future control planning. This work will assist in analyzing and identifying flood source areas that have detrimental effect on flood peak (flood source areas) and their contribution to the cumulative catchment outlet using the Hydrologic Engineering Centre-Hydrologic Modeling System (HEC-HMS) model. Thus, assisting in reducing the risk of occurrence and consequences of flood. A novel index (*fa*) was developed and tested in this study. The index was found to rank sub-basins better than *f* index because it considers initial peak discharge per unit area and change in peak discharge per unit area occupied by each sub-basin before ranking.

This study will also be of benefit in improving the level of awareness and effectiveness in disaster response using hydrological parameters to study runoff dynamics due to long-term LULC changes in geographic information system (GIS) environment. The use of (GIS) used in this study was deemed as more desirable compared to conventional ways of quantifying surface runoff mainly due to its ability to store and analyze factors responsible for runoff.

This work also intends to quantitatively assess the spatio-temporal variation of NPS pollution using numerical integration in a GIS environment. Comprehensive knowledge of the areas' topography and NPS sources of each pollutant was identified, as such the identification and location of NPSs of pollution is desirable for pollutant loads.

This research will help in the quantitative assessment of land degradation (soil erosion) using GIS to integrate numerous spatial datasets to evaluate complex and dynamic system such as soil erosion. The use of GIS has proven to be an effective means in predicting soil erosion.

Soil erosion prediction in the watershed is imperative which was aimed at executing the efficiency of accurate forecast of soil conservation measures in a certain area of interest (Bagarello et al., 2012). This will assist in creating effective approaches in erosion control, rehabilitation planning, and accomplishing sustainable productivity on the long-term basis (Hajkowicz et al., 2005; Turpin et al., 2005; Lu et al., 2006).

1.6 Scope and Limitation

The scope of this study is limited to the upper part of the Kelantan River basin. The upper part that is boardered to South China Sea is not included in this study due to high intrusion of seawater that constantly altered the actual runoff activities of the basin. While one of the limitations is that, no feature prediction beyond the 2014 flood was carried out. In addition, low resolution ASTER DEM (with 30 m resolution) and SPOT 5 images were used in extracting the physiographic characteristics of the basin. Furthermore, hypothetical data was utilized in validating of NPS pollution prediction due to the absence NPS monitoring stations in the study area.

1.7 Thesis Outline

This thesis consists of five chapters. Chapter 1 gives the background of the study, the research problem, general and specific objectives, research hypothesis and the significance of the study. The literature review is presented in chapter two, which gives an insight on related literature on effects of LULC changes on hydrology as well as different hydrological models utilized in achieving the research objectives. Classification of hydrological models developed by Refsgaard (1996) was adopted and discussed fully in this chapter. The various processes involve in hydrological modelling and model performance and evaluation criteria were reviewed based on how they were applied in previous literatures. Literatures related to researches conducted with HEC-HMS models from Malaysia were critically reviewed giving emphasis on the various methods involved pointing out their limitations and strengths as well the research problems they were applied upon. The Natural Resource Conservation Service-Curve Number (NRCS-CN) model, which is a one othe most widely used models in runoff prediction, was also reviewed. The effect of LULC change and sources of NPS were critically examined in chapter two. The types of models used in predicting NPS pollution were also discussed. Problem of land degradation caused by soil erosion and how it is influenced by LULC changes has all being highlighted in this chapter. The USLE model and its various modifications were pointed out as they are applied in different parts of the world to proper solutions to different problems.

Chapter three discusses the detailed description of all the methodologies utilized in the study. The general description of the study area was clearly stated in this chapter. Data analysis that include missing data analysis and Mann Kendal and Sen slope's estimator were were explained. A brief description of digital elevation (DEM) used as well as its accuracy and validation procedures were assessed in this chapter. Morphometric analyses conducted in this study were discussed. The process of basin delineation and preprocessing, land use analyses and hydrologic soil group (HSG) were all highlighted. Methods of calibration and validation of HEC-HMS model that include selection of measured hydrograph, rainfall data collection, spatial distribution of rainfall, lag time calculation, flood routing etc. were all pointed out. A detailed describtion of how long-term runoff dynamics due to LULC changes carried out using NRCS-CN model in this study was discussed in this chapter. Various stages include determination of CN values, antecedent moisture condition (AMC), description of NRCS-CN model and its various modifications etc. Different procedures involved in pollutant load estimation were described in this chapter for determining the impact of long-term LULC changes on NPS pollution. Soil erosion prediction with RUSLE model, soil erosion prognosis and temporal assessment of soil erosion were all fully explained. The results and discussion of all the analyses described were discussed in chapter four. Comparisons were made with similar researches conducted from around the world. Lastly, chapter five presents the summary, conclusion and recommendations based on findings of the study.

REFERENCES

Abbott, M. B., Bathurst, J. C., Cunge, J. A., O'Connell, P. E., & Rasmussen, J. (1986). An introduction to the European Hydrological System Systeme Hydrologique European, "SHE", 1: History and philosophy of a physically based, distributed modelling system. *Journal of Hydrology*, *87*(1–2), 45–59.

Abdul Aziz, O. I., & Burn, D. H. (2006). Trends and variability in the hydrological regime of the Mackenzie River Basin. *Journal of Hydrology*, *319*(1–4), 282–294. http://doi.org/10.1016/j.jhydrol.2005.06.039

Abdullah, J. (2013). Distributed runoff simulation of extreme monsoon rainstorms in Malaysia using TREX. Colorado State University Fort Collins, Colorado.

Abood, M. M., Mohammed, T. A., Ghazali, A. H., Mahmud, A. R., & Sidek, L. M. (2012). Impact of infiltration methods on the accuracy of rainfall-runoff simulation. *Research Journal of Applied Sciences, Engineering and Technology*, *4*(12), 1708-1713.

Abushandi, E., & Merkel, B. (2013). Modelling rainfall runoff relations using HEC-HMS and IHACRES for a single rain event in an arid region of Jordan, *Water Resources Management*, *27*(7), 2391-2409. http://doi.org/10.1007/s11269-013-0293-4

Adams, B. J. (2000). Urban stormwater management planning with analytical probabilistic models. *Canadian Journal of Civil Engineering*, *28*(3), 545.

Addis, H. K., & Klik, A. (2015). Predicting the spatial distribution of soil erodibility factor using USLE nomograph in an agricultural watershed, Ethiopia. *International Soil and Water Conservation Research*, *3*(4), 282–290. http://doi.org/10.1016/j.iswcr.2015.11.002

Addiscott, T. M., & Whitmore, A. P. (1987). Computer simulation of changes in soil mineral nitrogen and crop nitrogen during autumn, winter and spring. *The Journal of Agricultural Science*, *109*(1), 141–157.

Adenan, N. H., & Noorani, M. S. M. (2016). Multiple time-scales nonlinear prediction of river flow using chaos approach. *Jurnal Teknologi*, *78*(7), 1–7.

Adhikary, P. P., Tiwari, S. P., Mandal, D., Lakaria, B. L., & Madhu, M. (2014). Geospatial comparison of four models to predict soil erodibility in a semi-arid region of Central India. *Environmental Earth Sciences*, *72*(12), 5049–5062. http://doi.org/10.1007/s12665-014-3374-7

Adinarayana, J., Gopal Rao, K., Rama Krishna, N., Venkatachalam, P., & Suri, J.K.(1999). A rule-based soil erosion model for a hilly catchment. *Catena*, *37*(3–4), 309–318. http://doi.org/10.1016/S0341-8162(99)00023-5

Adnan, N. A., & Atkinson, P. M. (2011). Exploring the impact of climate and land use changes on streamflow trends in a monsoon catchment. *International Journal of Climatology*, *31*(6), 815–831. http://doi.org/10.1002/joc.2112

Adnan, N. A., Basarudin, Z., & Che Omar, N. (2014). Variation in hydrological responses estimation simulations due to land use changes. In *International conference on civil, biological and environmental engineering* (CBEE), Istanbul, Turkey (pp. 11–15).

Agresti, A. (2002). *Categorical data analysis* (Vol. 2). Wiley, New York.

Aher, P. D., Adinarayana, J., & Gorantiwar, S. D. (2014). Quantification of morphometric characterization and prioritization for management planning in semi-arid tropics of India: A remote sensing and GIS approach. *Journal of Hydrology*, *511*, 850–860. http://doi.org/10.1016/j.jhydrol.2014.02.028

Ahmad, Z. U., Sakib, S., & Gang, D. D. (2016). Nonpoint source pollution. *Water Environment Research*, *88*(10), 1594-1619.

Ajmal, M., Moon, G., Ahn, J., & Kim, T. (2015). Investigation of SCS-CN and its inspired modified models for runoff estimation in South Korean watersheds. *Journal of Hydro-Environment Research*, *9*(4), 592–603. http://doi.org/10.1016/j.jher.2014.11.003

Ajmal, M., Waseem, M., Ahn, J. H., & Kim, T. W. (2016). Runoff estimation using the NRCS slope-adjusted curve number in mountainous watersheds. *Journal of Irrigation and Drainage Engineering*, *142*(4), 04016002.

Al-Juboori, A. M., & Guven, A. (2016). Hydropower plant site assessment by integrated hydrological modeling, gene expression programming and visual basic programming. *Water Resources Management*, *30*(7), 2517–2530. http://doi.org/10.1007/s11269-016-1300-3

Al-Wagdany A. S. & Rao A. R. (1994). Drainage network simulation using digital elevation models. *In Proceeding of the International Conference on Remote Sensing and GIS*. Tata McGraw-Hill.

Alam, M. J., Meah, M. A., & Noor, M. S. (2011). Numerical modeling of ground water flow and the effect of boundary conditions for the hsieh aquifer. *Asian J. Math. Stat*, *4*, 33–44.

Alatorre, L. C., Beguería, S., Lana-Renault, N., Navas, A., & García-Ruiz, J. M. (2012). Soil erosion and sediment delivery in a mountain catchment under scenarios of land use change using a spatially distributed numerical model. *Hydrology and Earth System Sciences*, *16*(5), 1321.

Ali, M., Khan, S. J., Aslam, I., & Khan, Z. (2011). Simulation of the impacts of land-use change on surface runoff of Lai Nullah Basin in Islamabad, Pakistan. *Landscape and Urban Planning*, *102*(4), 271–279. http://doi.org/10.1016/j.landurbplan.2011.05.006

Ali, S. A., & Hagos, H. (2016). Estimation of soil erosion using USLE and GIS in Awassa Catchment, Rift valley, Central Ethiopia. *Geoderma Regional*, *7*(2), 159–166. http://doi.org/10.1016/j.geodrs.2016.03.005

Andersen, J., Refsgaard, J. C., & Jensen, K. H. (2001). Distributed hydrological modelling of the Senegal River Basin - Model construction and validation. *Journal of Hydrology*, *247*(3–4), 200–214. http://doi.org/10.1016/S0022-1694(01)00384-5

Arnold, J. G., Neitsch, S. L., Kiniry, J. R., Williams, J. R., & King, K. W. (2005). Soil and Water Assessment Tool Theoretical Documentation version 2005. Agriculture Research Service US. Texas. (terhubung Berkala). Http://www. Http. Brc. Tamus. Edu/swat/document.Html

ASCE Task Committee on Definition of Criteria for Evaluation of Watershed Models of the Watershed Management Committee, Irrigation and Drainage Division. (1993). Criteria for evaluation of watershed models. *Journal of Irrigation and Drainage Engineering*, *119*(3), 429–442.

Asmat, A., Mansor, S., Saadatkhah, N., & Adnan, N. A. (2016). Land use change effects on extreme flood in the Kelantan basin using hydrological model. In *ISFRAM*. http://doi.org/10.1007/978-981-10- 0500-8

Athmania, D., & Achour, H. (2014). External validation of the ASTER GDEM2, GMTED2010 and CGIAR-CSI-SRTM v4. 1 free access digital elevation models (DEMs) in Tunisia and Algeria. *Remote Sensing*, *6*(5), 4600–4620.

Baban, S. M., & Yusof, K. W. (2001). Modelling soil erosion in tropical environments using remote sensing and geographical information systems. *Hydrological Sciences Journal*, 46(2), 191–198. http://doi.org/10.1080/02626660109492815

Babu, B. S. (2016). Comparative Study on the Spatial Interpolation Techniques in GIS. *International Journal of Scientific & Engineering Research*, *7*(2), 550–554.

Bagarello, V., Di Stefano, V., Ferro, V., Giordano, G., Iovino, M., & Pampalone, V. (2012). Estimating the USLE soil erodibility factor in Sicily, South Italy. *Applied Engineering in Agriculture*, *28*(2), 199–206. http://doi.org/10.13031/2013.41347

Bagherzadeh, A. (2014). Estimation of soil losses by USLE model using GIS at Mashhad plain, Northeast of Iran. *Arabian Journal of Geosciences*, *7*(1), 211–220. http://doi.org/10.1007/s12517-012-0730-3

Bai, X., Ma, K.-M., Yang, L., & Zhang, X.-L. (2008). Simulating the impacts of land-use changes on non-point source pollution in Lugu Lake watershed. *International Journal of Sustainable Development & World Ecology*, *15*(1), 18–27. http://doi.org/10.1080/13504500809469764

Baláž, M., Danáčová, M., & Szolgay, J. (2010). On the use of the Muskingum method for the simulation of flood wave movements. *Slovak Journal of civil engineering*, *18*(3), 14-20.

Baltas, E. A., Dervos, N. A., & Mimikou, M. A. (2007). Determination of the SCS initial abstraction ratio in an experimental watershed in Greece. *Hydrology and Earth System Sciences Discussions*, *11*(6), 1825–1829.

Bárdossy, A. (2006). Calibration of hydrological model parameters for ungauged catchments. *Hydrology and Earth System Sciences Discussions*, *3*(3), 1105–1124. http://doi.org/10.5194/hessd-3-1105-2006

Basarudin, Z., Adnan, N. A., Latif, A. R. A., Tahir, W., & Syafiqah, N. (2014). Event-based rainfall-runoff modelling of the Kelantan River Basin. In *IOP conference series: earth and environmental science* (Vol. 18, No. 1, p. 012084). IOP Publishing. http://doi.org/10.1088/1755-1315/18/1/012084

Basnyat, P., Teeter, L. D., Lockaby, B. G., & Flynn, K. M. (2000). The use of remote sensing and GIS in watershed level analyses of non-point source pollution problems. *Forest Ecology and Management*, *128*(1–2), 65–73. http://doi.org/10.1016/S0378-1127(99)00273-X

Bathrellos, G. D., Gaki-Papanastassiou, K., Skilodimou, H. D., Papanastassiou, D., & Chousianitis, K. G. (2012). Potential suitability for urban planning and industry development using natural hazard maps and geological-geomorphological parameters. *Environmental Earth Sciences*, *66*(2), 537–548. http://doi.org/10.1007/s12665-011-1263-x

Bathrellos, G. D., Gaki-Papanastassiou, K., Skilodimou, H. D., Skianis, G. A., & Chousianitis, K. G. (2013). Assessment of rural community and agricultural development using geomorphological-geological factors and GIS in the Trikala prefecture (Central Greece). Stochastic *Environmental Research and Risk Assessment*, *27*(2), 573–588. http://doi.org/10.1007/s00477-012-0602-0

Bathurst, J. C. (2011). Predicting impacts of land use and climate change on erosion and sediment yield in river basins using SHETRAN. In *Handbook of Erosion Modelling* (pp. 263–288). School of Civil Engineering and Geosciences, Newcastle University, New castle upon Tyne NE17RU, United Kingdom. http://doi.org/10.1002/9781444328455.ch14

Bayley, T., Elliot, W., Nearing, M. A., Guertin, D. P., Johnson, T., Goodrich, D., & Flanagan, D. (2010). Modeling erosion under future climates with the WEPP model. *In*: *Hydrology and sedimentation for a changing future: Existing and emerging issues; Proceedings of the 2nd Joint Federal Interagency Conference [9th Federal interagency sedimentation conference and 4th Federal interagency hydrologic modeling conference]; 27 June-1 July; Las Vegas, NV. 12 p.*

Beheshti, Z., Firouzi, M., Shamsuddin, S. M., Zibarzani, M., & Yusop, Z. (2016). A new rainfall forecasting model using the CAPSO algorithm and an artificial neural network. *Neural Computing and Applications*, *27*(8), 2551–2565. http://doi.org/10.1007/s00521-015-2024-7

Beighley, R. E., Melack, J. M., & Dunne, T. (2003). Impacts of California's climatic regimes and coastal land use change on streamflow characteristics. *Journal of the American Water Resources Association, 39*(6), 1419–1433.

Bellocchi, G., Rivington, M., Donatelli, M., & Matthews, K. (2011). Validation of biophysical models: issues and methodologies. *In Sustainable Agriculture* Volume 2 (pp. 577–603). Springer, Dordrecht. http://doi.org/10.1051/agro/2009001

Bewket, W., & Teferi, E. (2009). Assessment of soil erosion hazard and prioritization for treatment at the watershed level: Case study in the Chemoga watershed, Blue Nile basin, Ethiopia. *Land Degradation & Development*, *20*(6), 609–622. http://doi.org/10.1002/ldr.944

Bhadra, A., Bandyopadhyay, A., Singh, R., & Raghuwanshi, N. S. (2010). Rainfall-runoff modeling: Comparison of two approaches with different data requirements. *Water Resources Management*, *24*(1), 37–62. http://doi.org/10.1007/s11269-009-9436-z

Bhaduri, B., Harbor, J., Engel, B., & Grove, M. (2000). Assessing watershed-scale, long-term hydrologic impacts of land-use change using a GIS-NPS model. *Environmental Management, 26*(6), 643–658. http://doi.org/10.1007/s002670010122

Bhat, S. A., & Romshoo, S. A. (2008). Digital Elevation Model based watershed characteristics of upper watersheds of Jhelum basin. *Journal of applied hydrology, 21*(2), 23–34.

Bhattarai, R., & Dutta, D. (2007). Estimation of Soil Erosion and Sediment Yield Using GIS at Catchment Scale. *Water Resources Management*, *21*(10), 1635–1647. http://doi.org/10.1007/s11269-006-9118-z

Birkhead, A. L., & James, C. S. (2002). Muskingum river routing with dynamic bank storage. *Journal of Hydrology*, *264*(1), 113–132.

Birsan, M. V., Molnar, P., Burlando, P., & Pfaundler, M. (2005). Streamflow trends in Switzerland. *Journal of Hydrology, 314*(1–4), 312–329. http://doi.org/10.1016/j.jhydrol.2005.06.008

Bonnet, M. P., Barroux, G., Martinez, J. M., Seyler, F., Moreira-Turcq, P., Cochonneau, G., & Seyler, P. (2008). Floodplain hydrology in an Amazon floodplain lake (Lago Grande de Curuaí). *Journal of Hydrology, 349*(1–2), 18–30. http://doi.org/10.1016/j.jhydrol.2007.10.05

Borah, D. K., & Bera, M. (2003). Watershed-scale hydrologic and nonpoint-source pollution models: Review of mathematical bases. *Transactions of the ASAE, 46*(6), 1553.

Boughton, W. C. (1989). A review of the USDA SCS curve number method. *Soil Research, 27*(3), 511–523. Retrieved from https://doi.org/10.1071/SR9890511

Boughton, W. C. (2007). Effect of data length on rainfall-runoff modelling. *Environmental Modelling and Software, 22*(3), 406–413. http://doi.org/10.1016/j.envsoft.2006.01.001

Box, G. E. P., & Jenkins, G. M. (1970). Time series analysis: forecasting and control, 1976. *ISBN: 0-8162-1104-3.*

Bradshaw, C. J., Sodhi, N. S., Peh, K. S. H., & Brook, B. W. (2007). Global evidence that deforestation amplifies flood risk and severity in the developing world. *Global Change Biology, 13*(11), 2379–2395.

Brath, A., Montanari, A., & Moretti, G. (2006). Assessing the effect on flood frequency of land use change via hydrological simulation (with uncertainty). *Journal of Hydrology, 324*(1–4), 141–153. http://doi.org/10.1016/j.jhydrol.2005.10.001

Bronstert, A., Niehoff, D., & Burger, G. (2002). Effects of climate and land-use change on storm runoff generation: Present knowledge and modelling capabilities. *Hydrological Processes, 16*(2), 509–529. http://doi.org/10.1002/hyp.326

Brueckner, J. K. (2009). *International Regional Science Review*. http://doi.org/10.1177/016001700761012710

Burn, D. H., & Taleghani, A. (2013). Estimates of changes in design rainfall values for Canada. *Hydrological Processes, 27*(11), 1590–1599. http://doi.org/10.1002/hyp.9238

Buttafuoco, G., Conforti, M., Aucelli, P. P. C., Robustelli, G., & Scarciglia, F. (2012). Assessing spatial uncertainty in mapping soil erodibility factor using geostatistical stochastic simulation. *Environmental Earth Sciences, 66*(4), 1111–1125. http://doi.org/10.1007/s12665-011-1317-0

Chan, N. W. (2012). Impacts of disasters and disasters risk management in Malaysia: The case of floods. In *Resilience and Recovery in Asian Disasters* (pp. 239–265). Springer, Tokyo. http://doi.org/10.1007/978-4-431-55022-8

Chang, C., Sun, D., Feng, P., Zhang, M., & Ge, N. (2017). Impacts of Nonpoint Source Pollution on Water Quality in the Yuqiao Reservoir. *Environmental Engineering Science*, *34*(6), 418–423. http://doi.org/10.1089/ees.2016.0124

Chang, T. K., Talei, A., Alaghmand, S., & Ooi, M. P.-L. (2017). Choice of rainfall inputs for event-based rainfall-runoff modeling in a catchment with multiple rainfall stations using data-driven techniques. *Journal of Hydrology*, *545*, 100–108. http://doi.org/10.1016/j.jhydrol.2016.12.024

Chen, Y., Xu, Y., & Yin, Y. (2009). Impact of land use change scenarios on storm-runoff generation in Xitiaoxi basin, China. *Quaternary International*, *208*(1–8), 121–128.

Cho, J., Oh, C., Choi, J., & Cho, Y. (2016). Climate change impacts on agricultural non-point source pollution with consideration of uncertainty in CMIP5. *Irrigation and Drainage*, *65*, 209–220. http://doi.org/10.1002/ird.2036

Choi, J. Y., Engel, B. A., & Chung, H. W. (2002). Daily streamflow modelling and assessment based on the curve-number technique. *Hydrological Processes*, *16*(16), 3131–3150. http://doi.org/10.1002/hyp.1092

Choi, W. (2007). Estimating land-use change impacts on direct runoff and non-point source pollutant loads in the Richland Creek basin (Illinois, USA) by applying the L–THIA model. *Journal of Spatial Hydrology*, *7(*1).

Chopra, R., Dhiman, R. D., & Sharma, P. K. (2005). Morphometric analysis of sub-watersheds in Gurdaspur district, Punjab using remote sensing and GIS techniques. *Journal of the Indian Society of Remote Sensing*, *33*(4), 531–539. http://doi.org/10.1007/BF02990738

Chow, V. T., Maidment, D. R., & Mays, L. W. (1988). *Applied hydrology*, 572 pp. Editions McGraw-Hill, New York.

Chow, V. T. (1964). Handbook of applied hydrology. New York: McGraw-Hill.

Clarke, J. I. (1966). Morphometry from maps. Essays in geomorphology, 252, 235-274.

Correa, S. W., Mello, C. R., Chou, S. C., Curi, N., & Norton, L. D. (2016). Soil erosion risk associated with climate change at Mantaro River basin, Peruvian Andes. *Catena*, *147*, 110–124. http://doi.org/10.1016/j.catena.2016.07.003

Coutu, G. W., & Vega, C. (2007). Impacts of Land Use Changes on Runoff Generation in the East Branch of the Brandywine Creek Watershed Using a GIS-Based Hydrologic Model. *Middle States Geographyer*, *40,* 142–149.

Dai, Z., Du, J., Li, J., Li, W., & Chen, J. (2008). Runoff characteristics of the Changjiang River during 2006: effect of extreme drought and the impounding of the Three Gorges Dam. *Geophysical Research Letters, 35*(7).

Darshana, D., & Ashish, P. (2012). Long term trends in rainfall pattern over Haryana, India. *International Journal of Research in Chemistry and Environment, 2*(1), 283–292.

De Girolamo, A. M., D'Ambrosio, E., Pappagallo, G., Rulli, M. C., & Lo Porto, A. (2017). Nitrate concentrations and source identification in a Mediterranean river system. *Rendiconti Lincei, 28*(2), 291–301. http://doi.org/10.1007/s12210-016-0593-8

DeFries, R., & Eshleman, K. N. (2004). Land-use change and hydrologic processes: a major focus for the future. *Hydrological Processes, 18*(11), 2183–2186. http://doi.org/10.1002/hyp.5584

Demirci, A., & Karaburun, A. (2012). Estimation of soil erosion using RUSLE in a GIS framework: A case study in the Buyukcekmece Lake watershed, northwest Turkey. *Environmental Earth Sciences, 66*(3), 903–913. http://doi.org/10.1007/s12665-011-1300-9

Desmet, P. J. J., & Govers, G. (1996). A GIS procedure for automatically calculating the USLE LS factor on topographically complex landscape units. *Journal of Soil and Water Conservation, 51*(5), 427–433.

Devi, G. K., Ganasri, B. P., & Dwarakish, G. S. (2015). A Review on Hydrological Models. *Aquatic Procedia, 4,* 1001–1007. http://doi.org/10.1016/j.aqpro.2015.02.126

Dhanoa, M. S., Lister, S. J., France, J., & Barnes, R. J. (1999). Use of mean square prediction error analysis and reproducibility measures to study near infrared calibration equation performance. *Journal of Near Infrared Spectroscopy, 7,* 133–144.

DID. (Drainage and Irrigation Department). (2010). *Guideline for Erosion and Sediment Control Plan.*

DID. (Drainage and Irrigation Department). (2012). *Urban Stormwater Manual for Malaysia.*

Dlamini, N. S., Rowshon, M. K., Fikhri, A., Lai, S. H., & Mohd, M. S. F. (2017). Modelling the streamflow of a river basin using enhanced hydro-meteorological data in Malaysia. *Acta Horticulturae, 1152*, 291–298. http://doi.org/10.17660/ActaHortic.2017.1152.39

Dooge, J. C. I. (1972). Mathematical models of hydrologic systems.

Dzikiewicz, M. (2000). Activities in nonpoint pollution control in rural areas of Poland. Ecological Engineering, 14(4), 429–434.

Elfert, S., & Bormann, H. (2010a). Simulated impact of past and possible future land use changes on the hydrological response of the Northern German lowland "Hunte" catchment. *Journal of Hydrology, 383*(3–4), 245–255. http://doi.org/10.1016/j.jhydrol.2009.12.040

Elfert, S., & Bormann, H. (2010b). Simulated impact of past and possible future land use changes on the hydrological response of the Northern German lowland "Hunte" catchment. *Journal of Hydrology, 383*(3–4), 245–255. http://doi.org/10.1016/j.jhydrol.2009.12.040

Emam, A. R., Mishra, B. K., Kumar, P., Masago, Y., & Fukushi, K. (2016). Impact assessment of climate and land-use changes on flooding behavior in the upper Ciliwung River, Jakarta, Indonesia. *Water, 8*(12). http://doi.org/10.3390/w8120559

Engel, B. A. (2001). L-THIA NPS Long-Term Hydrologic Impact Assessment and Non Point Source Pollutant Model, version 2.1. *Purdue University and US Environmental Protection Agency.*

Engel, B. A., Choi, J.-Y., Harbor, J., & Pandey, S. (2003). Web-based DSS for hydrologic impact evaluation of small watershed land use changes. *Computers and Electronics in Agriculture, 39*(3), 241–249.

Entwisle, B. (2005). Population land use and environment: Research directions. Washington, DC: National Academics Press.

EPA. (Environmental Protection Agency). (2017). Polluted Runoff: Nonpoint Source Pollution. Retrieved from https://www.epa.gov/nps/whatnonpoint-source 23 March 2017.

Eshleman, K. N. (2004). Hydrological consequences of land use change: A review of the state-of-science. *Geophysical Monograph, 153*, 13–29. Retrieved from http://cat.inist.fr/?aModele=afficheN&cpsidt=16393453 12 April 2017.

Evans, K. G., Loch, R. J., Aspinall, T. O., & Bell, L. C. (1992). Spoil pile erosion prediction- how far have we advanced?.

Ewen, J., & Parkin, G. (1996). Validation of catchment models for predicting land-use and climate change impacts. 1. Method. *Journal of Hydrology, 175*(1–4), 583–594. http://doi.org/10.1016/S00221694(96)80026-6

Fan, F., Deng, Y., Hu, X., & Weng, Q. (2013). Estimating composite curve number using an improved SCS-CN method with remotely sensed variables in Guangzhou, China. *Remote Sensing, 5*(3), 1425–1438. http://doi.org/10.3390/rs5031425

FAO (Food and Agricultural Organization). (1997). *Report on World Food Summit, Rome.*

Fleifle, A., Saavedra, O., Yoshimura, C., Elzeir, M., & Tawfik, A. (2014). Optimization of integrated water quality management for agricultural efficiency and environmental conservation. *Environmental Science and Pollution Research, 21*(13), 8095–8111. http://doi.org/10.1007/s11356-014-2712-3

Fleming, G. (1972). Computer simulation techniques in hydrology. In *Computer simulation techniques in hydrology*. Elsevier

Fohrer, N., Haverkamp, S., Eckhardt, K., & Frede, H.-G. (2001). Hydrologic Response to land use changes on the catchment scale. Physics and Chemistry of the Earth, Part B: *Hydrology, Oceans and Atmosphere, 26*(7–8), 577–582. http://doi.org/10.1016/S14641909(01)00052-1

Foley, J. a, Defries, R., Asner, G. P., Barford, C., Bonan, G., Carpenter, S. R. & Snyder, P. K. (2005). Global consequences of land use. *Science 309*(5734), 570–574. http://doi.org/10.1126/science.1111772

Fox, D. G. (1981). Judging air quality model performance. Bulletin of the American *Meteorological Society, 62*(5), 599–609.

Fu, B., Liu, Y., Lü, Y., He, C., Zeng, Y., & Wu, B. (2011). Assessing the soil erosion control service of ecosystems change in the Loess Plateau of China. *Ecological Complexity, 8*(4), 284–293. http://doi.org/https://doi.org/10.1016/j.ecocom.2011.07.003

Ganasri, B. P., & Ramesh, H. (2016). Assessment of soil erosion by RUSLE model using remote sensing and GIS - A case study of Nethravathi Basin. *Geoscience Frontiers, 7*(6), 953–961. http://doi.org/10.1016/j.gsf.2015.10.007

Garbrecht, J., & Martz, L. W. (1997). The assignment of drainage direction over flat surfaces in raster digital elevation models. *Journal of Hydrology, 193*(1–4), 204–213. http://doi.org/10.1016/S0022-1694(96)03138-1

Garnero, G., & Godone, D. (2013). Comparisons between different interpolation techniques. *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences - ISPRS Archives, 40*(5W3), 139–144. http://doi.org/10.5194/isprsarchives-XL-5-W3-139-2013

Geetha, K., Mishra, S. K., Eldho, T. I., Rastogi, A. K., & Pandey, R. P. (2008). SCS-CN-based continuous simulation model for hydrologic forecasting. *Water Resources Management, 22*(2), 165–190. http://doi.org/10.1007/s11269-006-9149-5

Ghuge, H. K., & Regulwar, D. G. (2013). Artificial neural network method for estimation of missing data. International Journal of Advanced Technology in Civil Engineering, 2, 1–4.

Gilbert, R. O. (1987). *Statistical methods for environmental pollution monitoring*. New York: John Wiley.

Girmay, G., Singh, B. R., Nyssen, J., & Borrosen, T. (2009). Runoff and sediment-associated nutrient losses under different land uses in Tigray, Northern Ethiopia. *Journal of Hydrology, 376*(1–2), 70–80. http://doi.org/http://dx.doi.org/10.1016/j.jhydrol.2009.07.066

Glaeser, E. L., & Kahn, M. E. (2004). Sprawl and urban growth. In T. J. Henderson V (Ed.), *Handbook of regional and urban economics*: cities and geography, handbooks in economics. Elsevier, Amsterdan.

Goh, Y. C., Zainol, Z., & Mat Amin, M. Z. (2016). Assessment of future water availability under the changing climate: case study of Klang River Basin, Malaysia. *International Journal of River Basin Management, 5124*, 1–9. http://doi.org/10.1080/15715124.2015.1068178

Gottschalk, L. C. (1964). Reservoir sedimentation. In V. T. Chow (Ed.), *Handbook of Applied Hydrology* (p. Section 7-1.). New York: McGraw Hill Book Company.

Green, I. R. A., & Stephenson, D. (1986). Criteria for comparison of single event models. *Hydrological Sciences Journal, 31*(3), 395–411.

Grimaldi, S., Petroselli, A., & Romano, N. (2013). Curve-Number/Green-Ampt mixed procedure for streamflow predictions in ungauged basins: Parameter sensitivity analysis. *Hydrological Processes, 27*(8), 1265–1275. http://doi.org/10.1002/hyp.9749

Grimaldi, S., Petroselli, A., Tauro, F., & Porfiri, M. (2012). Time of concentration: a paradox in modern hydrology. *Hydrological Sciences Journal, 57(*March 2015), 217–228. http://doi.org/10.1080/02626667.2011.644244

Gumindoga, W., Rwasoka, D. T., Nhapi, I., & Dube, T. (2017). Ungauged runoff simulation in Upper Manyame Catchment, Zimbabwe: Application of the HEC-HMS model. *Physics and Chemistry of the Earth, 100*, 371–382. http://doi.org/10.1016/j.pce.2016.05.002

Gupta, H. V., Sorooshian, S., & Yapo, P. O. (1999). Status of automatic calibration for hydrologic models: Comparison with multilevel expert calibration. *Journal of Hydrologic Engineering, 4*(2), 135–143.

Hadley, R.F. & Schumm, S. A. (1961). Sediment sources and drainage basin characteristics in upper Cheyenne river basin. *US Geological Survey Water-Supply Paper*, 1531, 198.

Hajkowicz, S., Perraud, J. M., Dawes, W., & DeRose, R. (2005). The strategic landscape investment model: A tool for mapping optimal environmental expenditure. *Environmental Modelling and Software*, *20*(10), 1251–1262. http://doi.org/10.1016/j.envsoft.2004.08.009

Halwatura, D., & Najim, M. M. M. (2013). Environmental modelling & software application of the HEC-HMS model for runoff simulation in a tropical catchment. *Environmental Modelling and Software, 46*, 155–162. http://doi.org/10.1016/j.envsoft.2013.03.006

Hamed, K. H. (2008). Trend detection in hydrologic data: The Mann-Kendall trend test under the scaling hypothesis. *Journal of Hydrology*, *349*(3–4), 350–363. http://doi.org/10.1016/j.jhydrol.2007.11.009

Harbor, J. M. (1994). A practical method for estimating the impact of land-use change on surface runoff, groundwater recharge and wetland hydrology. *Journal of the American Planning Association*, *60*(1), 95–108. http://doi.org/10.1080/01944369408975555

Hassan, Z., Shamsudin, S., Harun, S., Malek, M. A., & Hamidon, N. (2015). Suitability of ANN applied as a hydrological model coupled with statistical downscaling model: a case study in the northern area of Peninsular Malaysia. *Environmental Earth Sciences*, *74*(1), 463–477. http://doi.org/10.1007/s12665-015-4054-y

He, C., Demarchi, C., & Croley, T. E. (2008). Modeling spatial distributions of nonpoint source pollution loadings in the Great Lakes Watersheds by using the Distributed Large Basin Runoff Model 1. In *Proceedings of the Papers of American Water Resources Association GIS and Water Resources 2008 Spring Specialty Conference, San Matteo, California* (pp. 1–7).

Hess, A., Iyer, H., & Malm, W. (2001). Linear trend analysis: a comparison of methods. *Atmospheric Environment*, *35*(30), 5211–5222.

Hirsch, R M, Slack, J R, & Smith, R. A. (1992). Techniques of trend analysis for water quality data. *Water Resources Research*, *18*(1), 107–121.

Holman, I. P., Hollis, J. M., Bramley, M. E., & Thompson, T. R. E. (2003). The contribution of soil structural degradation to catchment flooding: a preliminary investigation of the 2000 floods in England and Wales. *Hydrology and Earth System Sciences Discussions*, *7*(5), 755–766. http://doi.org/10.5194/hess-7-755-2003

Hörmann, G., Horn, A., & Fohrer, N. (2005). The evaluation of land-use options in mesoscale catchments: Prospects and limitations of eco-hydrological models. *Ecological Modelling*, *187*, 3–14. http://doi.org/10.1016/j.ecolmodel.2005.01.022

Horton, R. E. (1932). Drainage-basin characteristics. *Transactions, American Geophysical Union*, *13*(1), 350. http://doi.org/10.1029/TR013i001p00350

Horton, R. E. (1945). Erosional development of streams and their drainage basins; Hydrophysical approach to quantitative morphology. *Bulletin of the Geological Society of America*, *56*(3), 275–370. http://doi.org/10.1130/0016-7606(1945)56[275:EDOSAT]2.0.CO;2

Hou, Y., Chen, W., Liao, Y., & Luo, Y. (2017). Modelling of the estimated contributions of different sub-watersheds and sources tophosphorous export and loading from the Dongting Lake watershed, China. *Environmental Monitoring and Assessment*, *189*(12). http://doi.org/10.1007/s10661-017-6293-8

Huang, M., Gallichand, J., Wang, Z., & Goulet, M. (2005). A modification tothe Soil Conservation Service curve number method for steep slopes in the Loess Plateau of China. *Hydrological Processes*, *20*(3), 579–589. http://doi.org/10.1002/hyp.5925

Huber, W. C. (1993). Contaminant transport in surface water. *Handbook of Hydrology*, 11–14.

Hundecha, Y., & Bárdossy, A. (2004). Modeling of the effect of land use changes on the runoff generation of a river basin through parameter regionalization of a watershed model. *Journal of Hydrology*, *292*(1–4), 281–295. http://doi.org/10.1016/j.jhydrol.2004.01.002

Hurkmans, R.T.W.L., Terink, W., Uijlenhoet, R., Moors, E. J., Troch, P. A., & Verburg, P. H. (2009). Effects of land use changes on streamflow generation in the Rhine basin. *Water Resources Research*, *45*, 1–15.

Ibrahim-Bathis, K., & Ahmed, S. A. (2016). Rainfall-runoff modelling of Doddahalla watershed — an application of HEC-HMS and SCN-CN in ungauged agricultural watershed. *Arabian Journal of Geosciences*, 1–16. http://doi.org/10.1007/s12517-015-2228-2

IPCC. (Intergovernmental Panel on Climate Change). (2014). *Climate Change 2014–Impacts, Adaptation and Vulnerability: Regional Aspects.* Cambridge University Press.

Jain, M. K., Mishra, S. K., & Shah, R. B. (2010). Estimation of sediment yield and areas vulnerable to soil erosion and deposition in a Himalayan watershed using GIS. *Current Science*, *98*(2), 213–221.

Jakeman, A. J., Letcher, R. A., & Norton, J. P. (2006). Ten iterative steps in development and evaluation of environmental models. *Environmental Modelling & Software*, *21*(5), 602–614. http://doi.org/http://dx.doi.org/10.1016/j.envsoft.2006.01.004

Jamaliah, J. (2007). Emerging Trends of Urbanization in Malaysia. Journal of the Department of Statistics, Malaysia. Retrieved from http://www.statistics.gov.my/eng/images/stories/files/journalDOSM/V104 Article Jamaliah.pdf. 2nd November 2016.

Jang, C., Kum, D., Jung, Y., Kim, K., Shin, D., Engel, B., & Lim, K. (2013). Development of a Web-Based L-THIA 2012 Direct Runoff and Pollutant Auto-Calibration Module Using a Genetic Algorithm. *Water*, *5*(4), 1952–1966.http://doi.org/10.3390/w5041952

Jang, T. I., Kim, H. K., Im, S. J., & Park, S. W. (2010). Simulations of storm hydrographs in a mixed-landuse watershed using a modified TR-20 model. *Agricultural Water Management*, *97*(2), 201–207. http://doi.org/10.1016/j.agwat.2009.09.004

Javed, A., Yousuf, M., & Rizwan, K. (2009). Prioritization of Sub-watersheds based on Morphometric and Land Use Analysis using Remote Sensing and GIS Techniques. *Journal of the Indian Society of Remote Sensing*, *37*(June), 261–274. http://doi.org/10.1007/s12524-009-0016-8

Johnson, R. R. (1998). An investigation of curve number applicability to watersheds in excess of 25000 hectares (250 km^2). *Journal of Environmental Hydrology*, *6*, 10.

Jun, C. L., Mohamed, Z. S., Peik, A. L., Razali, S. F., & Sharil, S. (2016). Flood forecasting model using empirical method for a small catchment area. *Journal of Engineering Science and Technology*, *11*(5), 666-672.

Kabiri, R., Chan, A., & Bai, R. (2013). Comparison of SCS and Green-Ampt methods in surface runoff-flooding simulation for Klang Watershed in Malaysia. *Open Journal of Modern Hydrology*, *3*(3), 102–114. http://doi.org/10.4236/ojmh.2013.33014

Kahya, E., & Kalaycı, S. (2004). Trend analysis of streamflow in Turkey. *Journal of Hydrology*, *289*(1), 128–144.

Kalita, D. N. (2008). A study of basin response using HEC-HMS and subzone reports of CWC. In *Proceedings of the 13th National Symposium on Hydrology. National Institute of Hydrology*, Roorkee, New Delhi. http://doi.org/10.1007/SpringerReference_28205

Garnero, G., & Godone, D. (2013). Comparisons between different interpolation techniques. *Proceedings of the international archives of the photogrammetry, remote sensing and spatial information sciences XL-5 W, 3*, 27-28.

Ghorbani, K., Wayayok, A., & Abdullah, A. F. (2016). Simulation of flood risk area in Kelantan Watershed, Malaysia using numerical model. *Jurnal Teknologi*, *78*(1–2), 51–57.

Karki, R., Tagert, M. L. M., Paz, J. O., & Bingner, R. L. (2017). Application of AnnAGNPS to model an agricultural watershed in East-Central Mississippi for the evaluation of an on-farm water storage (OFWS) system. *Agricultural Water Management, 192*, 103–114. http://doi.org/10.1016/j.agwat.2017.07.002

Karpouzos, D., Kavalieratou, S., & Babajimopoulos, C. (2010). Trend analysis of precipitation data in Pieria Region (Greece). *European Water, 30*, 31–40.

Khaleghpanah, N., Shorafa, M., Asadi, H., Gorji, M., & Davari, M. (2017). Corrigendum to "Modeling soil loss at plot scale with EUROSEM and RUSLE2 at stony soils of Khamesan watershed, Iran". *Catena, 151,* 259. http://doi.org/10.1016/j.catena.2016.11.012

Khalid, K., Ali, M. F., Faiza, N., Rahman, A., Mispan, M. R., Haron, S. H., & Hamim, N. M. (2016). Application of the SWAT Hydrologic Model in Malaysia : *Recent Research, 1*(May), 237–246.

Khalid, K., Ali, M. F., & Rahman, N. F. A. (2015). The development and application of Malaysian soil taxonomy in SWAT Watershed Model. In *ISFRAM* 2014 (pp. 77–88). http://doi.org/10.1007/978-981-287-365-1

Khosrokhani, M., & Pradhan, B. (2013). Spatio-temporal assessment of soil erosion at Kuala Lumpur metropolitan city using remote sensing data and GIS. *Geomatics, Natural Hazards and Risk, 5705* (December), 1–19. http://doi.org/10.1080/19475705.2013.794164

King, K. W., Balogh, J. C., & Balogh, J. C. (2008). Curve numbers for Golf Course Watersheds. *Transactions of the ASABE, 51*(3), 987–996.

Klein, J., Jarva, J., Frank-Kamenetsky, D., & Bogatyrev, I. (2013). Integrated geological risk mapping: A qualitative methodology applied in St. Petersburg, Russia. *Environmental Earth Sciences, 70*(4), 1629– 1645. http://doi.org/10.1007/s12665-013-2250-1

Knebl, M. R., Yang, Z. L., Hutchison, K., & Maidment, D. R. (2005). Regional scale flood modeling using NEXRAD rainfall, GIS, and HEC-HMS/ RAS: A case study for the San Antonio River Basin Summer 2002 storm event. *Journal of Environmental Management*, *75*, 325–336. http://doi.org/10.1016/j.jenvman.2004.11.024

Kollongei, K. J., & Lorentz, S. A. (2015). Modelling hydrological processes, crop yields and NPS pollution in a small sub-tropical catchment in South Africa using ACRU-NPS . *Hydrological Sciences Journal*, *60*(11), 2003–2028. http://doi.org/10.1080/02626667.2015.1087644

Koomen, E., Rietveld, P., & Nijs, T. (2008). Modelling land-use change for spatial planning support. *The Annals of Regional Science*, *42*(1), 1–10. http://doi.org/10.1007/s00168-007-0155-1

Kouli, M., Soupios, P., & Vallianatos, F. (2009). Soil erosion prediction using the Revised Universal Soil Loss Equation (RUSLE) in a GIS framework, Chania, Northwestern Crete, Greece. *Environmental Geology*, *57*(3), 483–497. http://doi.org/10.1007/s00254-008-1318-9

Koutroulis, A. G., & Tsanis, I. K. (2010a). A method for estimating flash flood peak discharge in a poorly gauged basin: Case study for the 13-14 January 1994 flood, Giofiros Basin, Crete, Greece. *Journal of Hydrology*, *385*(1–4), 150–164. http://doi.org/10.1016/j.jhydrol.2010.02.012

Koutroulis, A. G., & Tsanis, I. K. (2010b). A method for estimating flash flood peak discharge in a poorly gauged basin: Case study for the 13–14 January 1994 flood, Giofiros Basin, Crete, Greece. *Journal of Hydrology*, *385*(1), 150–164.

Krause, P., Boyle, D. P., & Bäse, F. (2005). Comparison of different efficiency criteria for hydrological model assessment. *Advances in Geosciences*, *5*, 89–97.

Kundzewicz, Z. W., & Robson, A. J. (2004). Change detection in hydrological records—a review of the methodology / Revue méthodologique de ladétection de changements dans les chroniques hydrologiques. *Hydrological Sciences Journal*, *49*(1), 7–19. http://doi.org/10.1623/hysj.49.1.7.53993

Kuntiyawichai, K., Dau, Q. V, Sri-Amporn, W., & Suryadi, F. X. (2016). An assessment of flood hazard and risk zoning in the lower nam phong River basin, Thailand. *International Journal of Technology*, *7*(7), 1147–1154. http://doi.org/10.14716/ijtech.v7i7.4871

Kwin, C. T., Talei, A., Alaghmand, S., & Chua, L. H. C. (2016). Rainfall-runoff Modeling Using Dynamic Evolving Neural Fuzzy Inference System with Online Learning. *Procedia Engineering*, *154*, 1103–1109. http://doi.org/10.1016/j.proeng.2016.07.518

Lai, Y. C., Yang, C. P., Hsieh, C. Y., Wu, C. Y., & Kao, C. M. (2011). Evaluation of non-point source pollution and river water quality using a multimedia two-model system. *Journal of Hydrology*, *409*(3–4), 583–595.

http://doi.org/10.1016/j.jhydrol.2011.08.040

Lambin, E. F. (2004). Linking socioeconomic and remote sensing data at the community or at the household level. In *People and the Environment* (pp. 223–240). Springer, Boston, MA.

Lambin, E. F., Turner, B. L., Geist, H. J., Agbola, S. B., Angelsen, A., Bruce, J. W., & Xu, J. (2001). The causes of land-use and land-cover change: Moving beyond the myths. *Global Environmental Change, 11*(4), 261–269. http://doi.org/10.1016/S0959-3780(01)00007-3

Laouacheria, F., & Mansouri, R. (2015). Comparison of WBNM and HEC-HMS for Runoff Hydrograph Prediction in a Small Urban Catchment. *Water Resources Management*, *29*(8), 2485-2501. http://doi.org/10.1007/s11269-015-0953-7

Laurance, W. F. (2007). Forests and floods. *Nature, 449*, 409–410.

Lausch, A., & Herzog, F. (2002). Applicability of landscape metrics for the monitoring of landscape change: Issues of scale, resolution and interpretability. *Ecological Indicators, 2*(1–2), 3–15. http://doi.org/10.1016/S1470-160X(02)00053-5

Lazzari, M., Gioia, D., Piccarreta, M., Danese, M., & Lanorte, A. (2015). Sediment yield and erosion rate estimation in the mountain catchments of the Camastra artificial reservoir (Southern Italy): A comparison between different empirical methods. *Catena, 127*, 323–339.

Lee, S. (2004). Soil erosion assessment and its verification using the Universal Soil Loss Equation and Geographic Information System: a case study at Boun, Korea. *Environmental Geology, 45*(4), 457–465. http://doi.org/10.1007/s00254-003-0897-8

Legates, D. R., & McCabe, G. J. (1999). Evaluating the use of "goodness- of- fit" measures in hydrologic and hydroclimatic model validation. *Water Resources Research*, *35*(1), 233–241.

Li, T., Bai, F., Han, P., & Zhang, Y. (2016). Non-Point Source Pollutant Load Variation in Rapid Urbanization Areas by Remote Sensing, GIS and the L-THIA Model: A Case in Bao'an District, Shenzhen, China. *Environmental Management*, *58*(5), 873–888. http://doi.org/10.1007/s00267-016-0743-x

Lin, Y. P., Hong, N.M., Wu, P. J., & Lin, C. J. (2007). Modeling and assessing and-use and hydrological processes to future land-use and climate change scenario in watershed land-use planning. *Environmental Geology, 53*, 623–634.

Linsley, R. K., Kohler, M. A., & Paulus, J. L. H. (1982). *Hydrology for Engineers.* McGraw-Hill. New York, USA.

Liu, Y., Bralts, V. F., & Engel, B. A. (2015). Evaluating the effectiveness of management practices on hydrology and water quality at watershed scale with a rainfall-runoff model. *Science of the Total Environment, 511*, 298–308. http://doi.org/10.1016/j.scitotenv.2014.12.077

Liu, Z., Yao, Z., Huang, H., Wu, S., & Liu, G. (2014). Land use and climate changes and their impacts on runoff in the Yarlung Zangbo river basin, China. *Land Degradation & Development, 25*(3), 203–215.

Lu, H., Moran, C. J., & Prosser, I. P. (2006). Modelling sediment delivery ratio over the Murray Darling Basin. Environmental *Modelling and Software, 21*(9), 1297–1308. http://doi.org/10.1016/j.envsoft.2005.04.021

Ma, Y. (2004). L-THIA: a useful hydrologic impact assessment model. *Nature and Science, 2*(1), 68–73.

Magesh, N. S., Jitheshlal, K. V, Chandrasekar, N., & Jini, K. V. (2012). GIS based morphometric evaluation of Chimmini and Mupily watersheds, parts of Western Ghats, Thrissur District, Kerala, India. *Earth Science Informatics, 5*(2), 111–121. http://doi.org/10.1007/s12145-012-0101-3

Maidment, D. R. (1993). *Handbook of hydrology* (Vol. 1). McGraw-Hill NewYork.

Malek, M. A., Heyrani, M., & Juneng, L. (2015). Stream flow projection for Muar River in Malaysia using precis-HEC-HMS model. *ASM Science Journal, 9*(1).

Mallick, J., Alashker, Y., Mohammad, S. A.-D., Ahmed, M., & Hasan, M. A. (2014). Risk assessment of soil erosion in semi-arid mountainous watershed in Saudi Arabia by RUSLE model coupled with remote sensing and GIS. *Geocarto International, 29*(8), 915–940.

Maniquiz, M. C., Lee, S. Y., & Kim, L. H. (2010). Long-Term Monitoring of Infiltration Trench for Nonpoint Source Pollution Control. *Water Air and Soil Pollution, 212*(1–4), 13–26. http://doi.org/10.1007/s11270-009-0318-z

Maroju, S. (2007). Evaluation of five GIS based interpolation techniques for estimating the radon concentration for unmeasured zip codes in the State of Ohio.

Martz, L. W., & Garbrecht, J. (1993). Automated extraction of drainage network and watershed data from digital elevation models. *Journal of the American Water Resources Association, 29*(6), 901–908. http://doi.org/10.1111/j.1752-1688.1993.tb03250.x

Masoud, M. H. (2016). Geoinformatics application for assessing the morphometric characteristics' effect on hydrological response atwatershed (case study of Wadi Qanunah, Saudi Arabia). *ArabianJournal of Geosciences, 9*(4), 280. http://doi.org/10.1007/s12517-015-2300-y

Mateos, E., Edeso, J. M., & Ormaetxea, L. (2017). Soil erosion and forests biomass as energy resource in the basin of the Oka River in Biscay, Northern Spain. *Forests*, *8*(7). http://doi.org/10.3390/f8070258

McCuen, R. H. (1989*). Hydrologic Analysis and Design*. Prentice Hall.

McCuen, R. H. (2004). *Hydrologic Analysis and Design*. Prentice Hall, Upper Saddle River.

McCuen, R. H., Knight, Z., & Cutter, A. G. (2006). Evaluation of the Nash–Sutcliffe Efficiency Index. *Journal of Hydrologic Engineering*, *11*(6), 597–602. http://doi.org/10.1061/(ASCE)1084-0699(2006)11:6(597)

McCuen, R. H. (2009). Uncertainty Analyses of Watershed Time Parameters. *Journal of Hydraulic Engineering*, *14*(5), 490–498. http://doi.org/10.1061/(ASCE)HE.1943-5584.0000011

Meals, D. W., Richards, R. P., & Steven, A. D. (2013). Pollutant Load Estimation for Water Quality Monitoring Projects. *National Nonpoint Source Monitoring Program*, 1–21.

Melesse, A. M., Graham, W. D., & Jordan, J. D. (2003). Spatially distributed watershed mapping and modeling: GIS-based storm runoff response snad hydrograph analysis: part 2. *Journal of Spatial Hydrology, 3*(2), 1–28.

Melesse, A. M., & Shih, S. F. (2002). Spatially distributed storm runoff depth estimation using Landsat images and GIS. *Computers and Electronics in Agriculture,* *37*(1–3), 173–183. http://doi.org/10.1016/S0168-1699(02)00111-4

Mello, C. R. De, Norton, L. D., Pinto, L. C., Beskow, S., & Curi, N. (2016). Agricultural watershed modeling : a review for hydrology and soil erosion processes. *Ciência Agrotecnologia*, *40*(1), 7-25. http://doi.org/10.1590/S1413-70542016000100001

Melton, M. N. (1957). *An analysis of the relations among elements of climate surface properties and geomorphology*. (No. CU-TR-11). Columbia Univ New York.

Merritt, W. S., Letcher, R. A., & Jakeman, A. J. (2003). A review of erosion and sediment transport models. *Environmental Modelling and Software, 18*(8–9), 761–799. http://doi.org/10.1016/S1364-8152(03)00078-1

Meyer, W. B. (1995). Past and present land use and land cover in the USA. Consequences, Spring. Retrieved from http://www.gcrio.org//CONSEQUENCIES/spring95/index.html 17th April 2016

Mishra, S. K. & Singh, V. P. (1999). Another look at SCS-CN method. *Journal of Hydrologic Engineering, 2*(July), 257–264.

Mishra, S. K., & Singh, V. P. (2002). SCS-CN-based hydrologic simulation package. *Mathematical models in small watershed hydrology and applications, 2841*, 391-464.

Mishra, S. K., Geetha, K., Rastogi, A. K., & Pandey, R. P. (2005). Long-term hydrologic simulation using storage and source area concepts. *Hydrological Processes, 19*(14), 2845–2861. http://doi.org/10.1002/hyp.5735

Mishra, S. K., Jain, M. K., & Singh, V. P. (2004). Evaluation of the SCS-CN-based model incorporating antecedent moisture. *Water Resources Management, 18*(6), 567–589. http://doi.org/10.1007/s11269-004-8765-1

Mishra, S. K., Sahu, R. K., Eldho, T. I., & Jain, M. K. (2006). An improved Ia-S relation incorporating antecedent moisture in SCS-CN methodology. *Water Resources Management, 20*(5), 643–660. http://doi.org/10.1007/s11269-005-9000-4

Mishra, S. K., & Singh, V. P. (2004). Long-term hydrological simulation based on the Soil Conservation Service curve number. *Hydrological Processes, 18*(7), 1291–1313. http://doi.org/10.1002/hyp.1344

Mohammad, F. S., & Adamowski, J. (2015). Interfacing the geographic information system, remote sensing, and the soil conservationservice–curve number method to estimate curve number and runoff volume in the Asir region of Saudi Arabia. *Arabian Journal of Geosciences, 8*(12), 11093–11105. http://doi.org/10.1007/s12517-015-1994-1

Mondal, A., Khare, D., Kundu, S., Mukherjee, S., Mukhopadhyay, A., & Mondal, S. (2017). Uncertainty of soil erosion modelling using open source high resolution and aggregated DEMs. *Geoscience Frontiers, 8*(3), 425–436. http://doi.org/10.1016/j.gsf.2016.03.004

Moretti, G., & Montanari, A. (2008). Inferring the flood frequency distribution for an ungauged basin using a spatially distributed rainfall-runoff model. Hydrology and *Earth System Sciences Discussions, 5*(1), 1–26. http://doi.org/10.5194/hessd-5-1-2008

Moriasi, D. N., Arnold, J. G., Liew, M. W. Van, Bingner, R. L., Harmel, R. D., & Veith, T. L. (2007). Model evaluation guidelines for systematic quantification of accuracy in watershed simulations. *Transactions of the ASABE, 50*(3), 885-900.

Moriasi, D., & Wilson, B. (2012). Hydrologic and water quality models: use, calibration, and validation. *American Society of Agricultural and Biological Engineers, 55*(4), 1241–1247. http://doi.org/10.13031/2013.42265

Mujere, N., & Moyce, W. (2016). Climate Change Impacts on surface water quality. *Environmental Sustainability and Climate Change Adaptation Strategies*, 322.

Mullan, D. (2013). Soil erosion under the impacts of future climate change: Assessing the statistical significance of future changes and the potential on-site and off-site problems. *Catena*, *109*, 234–246. http://doi.org/10.1016/j.catena.2013.03.007

Müller, D., & Munroe, D. K. (2014). Current and future challenges in land-use science. *Journal of Land Use Science*, *9*(2), 133–142. http://doi.org/10.1080/1747423X.2014.883731

Mustafa, Y. M., Amin, M. S. M., Lee, T. S., & Shariff, A. R. M. (2012). Evaluation of Land Development Impact on a tropical watershed hydrology using remote sensing and GIS. *Journal of Spatial Hydrology, 5*(2), 16–30. Retrieved from http://www.spatialhydrology.net/index.php/JOSH/article/view/40 7th July 2016

Mustapha, A. (2013). Detecting surface water quality trends using Mann-Kendall tests and sen slope estimates. *International Journal of Advanced and Innovative Research*, *2*(1), 108–114.

Naef, F., Scherrer, S., & Weiler, M. (2002). A process based assessment of the potential to reduce flood runoff by land use change. *Journal of Hydrology, 267*(1–2), 74–79. http://doi.org/10.1016/S0022-1694(02)00141-5

Nagarajan, N., & Poongothai, S. (2012). Spatial Mapping of Runoff from a Watershed Using SCS-CN Method with Remote Sensing and GIS. *Journal of Hydrologic Engineering*, *17*(11), 1268–1277. http://doi.org/10.1061/(ASCE)HE.1943-5584.0000520

Naoum, S., & Tsanis, I. K. (2004). Ranking spatial interpolation techniques using a GIS-based DSS. Global Nest: *The International Journal*, *6*(1),1–20.

Nash, J. E. (1959). Systematic determination of unit hydrograph parameters. *Journal of Geophysical Research*, *64*(1), 111. http://doi.org/10.1029/JZ064i001p00111

Nash, J. E., & Sutcliffe, J. V. (1970). River flow forecasting through conceptual models part I - A discussion of principles. *Journal of Hydrology, 10*(3), 282–290. http://doi.org/10.1016/0022-1694(70)90255-6

Nasir, K. A. M., Hashim, N. B., Kazemi, Z., & Aslani, H. (2015). Application of the HEC-HMS Model for Storm Events Case Study : Pendas River, Malaysia. In *International Congress on Civil Engineering, Architecture and Urban Development.*

Nazahiyah, R., Yusop, Z., & Abustan, I. (2007). Stormwater quality and pollution loading from an urban residential catchment in Johor, Malaysia. *Water Science and Technology, 5*6(7), 1–9. http://doi.org/10.2166/wst.2007.692

Nearing, M. A. (2013). *Soil Erosion and Conservation. Environmental Modelling: Finding Simplicity in Complexity: Second Edition.* http://doi.org/10.1002/9781118351475.ch22

Nejadhashemi, A. P., Wardynski, B. J., & Munoz, J. D. (2011). Evaluating the impacts of land use changes on hydrologic responses in the agricultural regions of Michigan and Wisconsin. *Hydrology and Earth System Sciences Discussions, 8*(2), 3421–3468. http://doi.org/10.5194/hessd-8-3421-2011

Neupane, R. P., & Kumar, S. (2015). Estimating the effects of potential climate and land use changes on hydrologic processes of a large agriculture dominated watershed. *Journal of Hydrology, 529*(AUGUST), 418–429. http://doi.org/10.1016/j.jhydrol.2015.07.050

Nie, W., Yuan, Y., Kepner, W., Nash, M. S., Jackson, M., & Erickson, C. (2011). Assessing impacts of Landuse and Landcover changes on hydrology for the upper San Pedro watershed. *Journal of Hydrology, 407*(1–4), 105–114. http://doi.org/10.1016/j.jhydrol.2011.07.012

Niehoff, D., Fritsch, U., & Bronstert, A. (2002). Land-use impacts on storm-runoff generation: Scenarios of land-use change and simulation of hydrological response in a meso-scale catchment in SW-Germany. *Journal of Hydrology, 267*(1–2), 80–93. http://doi.org/10.1016/S0022-1694(02)00142-7

Nikolaidis, N. P., Karageorgis, A. P., Kapsimalis, V., Marconis, G., Drakopoulou, P., Kontoyiannis, H., & Pagou, K. (2006). Circulation and nutrient modeling of Thermaikos Gulf, Greece. *Journal of Marine Systems, 60*(1), 51–62.

Nobre, C. A., Sampaio, G., Borma, L. S., Castilla-Rubio, J. C., Silva, J. S., & Cardoso, M. (2016). Land-use and climate change risks in the Amazon and the need of a novel sustainable development paradigm. *Proceedings of the National Academy of Sciences*, 113(39): 10759-10768.

Nooka Ratnam, K., Srivastava, Y. K., Venkateswara Rao, V., Amminedu, E., & Murthy, K. S. R. (2005). Check dam positioning by prioritization of micro-watersheds using SYI model and morphometric analysis - Remote sensing and GIS perspective. Journal of the *Indian Society of Remote Sensing,* 33(1), 25–38. http://doi.org/10.1007/BF02989988

Noori, N., Kalin, L., Sen, S., Srivastava, P., Lebleu, C., & Hec-hms, F. Á. (2016). Identifying areas sensitive to land use / land cover change for downstream flooding in a coastal Alabama watershed. *Regional Environmental Change, 16*(6), 1833-1845. http://doi.org/10.1007/s10113-016-0931-5

Norzilah, A., Ahmad, M. F., Jusoh, A., Tofany, N., Yaacob, R., & Muslim, A. M. (2016). Hydrodynamics modelling at Setiu wetland, Terengganu. *Journal of Environmental Science and Technology, 9*(6), 437–445. http://doi.org/10.3923/jest.2016.437.445

Novotny, V. (2003). *Water quality: diffuse pollution and watershed management*. John Wiley & Sons.

NRCS (Natural Resource Conservation Service). (1986). Urban Hydrology for Small Watersheds TR-55. USDA Natural Resource Conservation Service Conservation Engineering Division Technical Release 55, 164. http://doi.org/Technical Release 55

NRCS (Natural Resource Conservation Service). (1997). Time of Concentration. *National Engineering Handbook*, 29.

NRCS (Natural Resource Conservation Service). (2004). National Engineering Handbook: In *Part 630 Hydrology*. (p. 79).

O'Donnell, T., Pearson, C. P., & Woods, R. A. (1988). Improved fitting for three-parameter Muskingum procedure. *Journal of Hydraulic Engineering, 114*(5), 516–528.

O'Geen, A. T., Budd, R., Gan, J., Maynard, J. J., Parikh, S. J., & Dahlgren, R. A. (2010). Mitigating nonpoint source pollution in agriculture with constructed and restored wetlands. In *Advances in Agronomy* (1st ed., Vol. 108, pp. 1–76). Elsevier Inc. http://doi.org/10.1016/S0065-2113(10)08001-6

Olang, L.O., Furst, J. (2011). Effects of land cover change on flood peak discharges and runoff volumes: model estimates for the Nyando River basin, Kenya. *Hydrological Processes, 25*, 80–89.

Olivera, F., & Maidment, D. (1999). Model for Runoff Routing. Water Resources Research, 35(4), 1155–1164. Retrieved from http://www.sciencedirect.com/science/article/pii/0022169464900253 2 February 2016.

Ongley, E. D., Xiaolan, Z., & Tao, Y. (2010). Current status of agricultural and rural non-point source pollution assessment in China. *Environmental Pollution, 158*(5), 1159–1168.

Ouyang, W., Song, K., Wang, X., & Hao, F. (2014). Non-point source pollution dynamics under long-term agricultural development and relationship with landscape dynamics. *Ecological Indicators, 45*, 579–589. http://doi.org/10.1016/j.ecolind.2014.05.025

Owuor, S. O., Butterbach-Bahl, K., Guzha, A. C., Rufino, M. C., Pelster, D. E., Díaz-Pinés, E., & Breuer, L. (2016). Groundwater recharge rates and surface runoff response to land use and land cover changes in semi-arid environments. *Ecological Processes, 5*(1), 16.

Ozdemir, H., & Elbaşı, E. (2015). Benchmarking land use change impacts on direct runoff in ungauged urban watersheds. *Physics and Chemistry of the Earth, Parts A/B/C, 79–82*, 100–107.http://doi.org/10.1016/j.pce.2014.08.001

Öztürk, M., Copty, N. K., & Saysel, A. K. (2013). Modeling the impact of land use change on the hydrology of a rural watershed. *Journal of Hydrology, 497*, 97–109. http://doi.org/10.1016/j.jhydrol.2013.05.022

Pachauri, R. K., Allen, M. R., Barros, V. R., Broome, J., Cramer, W., Christ, R., & Dubash, N. K. (2014). *Climate change 2014: synthesis report. Contribution of Working Groups I, II and III to the fifth assessment report of the Intergovernmental Panel on Climate Change* (pp. 151). IPCC.

Pakoksung, K., & Takagi, M. (2016). Digital elevation models on accuracy validation and bias correction in vertical. *Modeling Earth Systems and Environment, 2*(1), 11. http://doi.org/10.1007/s40808-015-0069-3

Palviainen, M., Laurén, A., Launiainen, S., & Piirainen, S. (2016). Predicting the export and concentrations of organic carbon, nitrogen and phosphorus in boreal lakes by catchment characteristics and land use: A practical approach. *Ambio, 45*(8), 933–945. http://doi.org/10.1007/s13280-016-0789-2

Patel, D. P., Gajjar, C. A., & Srivastava, P. K. (2013). Prioritization of Malesari mini-watersheds through morphometric analysis: A remote sensing and GIS perspective. *Environmental Earth Sciences, 69*(8), 2643–2656. http://doi.org/10.1007/s12665-012-2086-0

Patil, J. P., Sarangi, A., Singh, A. K., & Ahmad, T. (2008). Evaluation of modified CN methods for watershed runoff estimation using a GIS-based interface. *Biosystems Engineering, 100*(1), 137–146. http://doi.org/10.1016/j.biosystemseng.2008.02.001

Patton, P. C. (1988). Drainage basin morphometry and floods. *Flood Geomorphology. John Wiley & Sons New York*. pp 51-64.

Perera, E. D. P., & Lahat, L. (2014). Fuzzy logic based flood forecasting model for the Kelantan River basin, Malaysia. *Journal of Hydro-environment Research, 9*(4), 542-553. http://doi.org/10.1016/j.jher.2014.12.001

Petersen, L., Heynen, M., & Pellicciotti, F. (2017). Freshwater Resources: Past, Present, Future. *The International Encyclopedia of Geography*.

Ponce, V. M., & Hawkins, R. H. (1996). Runoff Curve Number: Has It Reached Maturity? Journal of Hydrologic Engineering, 1(1), 11–19. http://doi.org/10.1061/(ASCE)1084-0699(1996)1:1(11)

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

Pradhan, B. (2010). Remote sensing and GIS-based landslide hazard analysis and cross-validation using multivariate logistic regression model on three test areas in Malaysia. *Advances in Space Research*, *45*(10), 1244–1256. http://doi.org/10.1016/j.asr.2010.01.006

Pradhan, B., Chaudhari, A., Adinarayana, J., & Buchroithner, M. F. (2011). Soil erosion assessment and its correlation with landslide events using remote sensing data and GIS: A case study at Penang Island, Malaysia. *Environmental Monitoring and Assessment*, *184*(2), 715–727. http://doi.org/10.1007/s10661-011-1996-8

Pradhan, B., & Youssef, A. M. (2011). A 100-year maximum flood susceptibility mapping using integrated hydrological and hydrodynamic models: Kelantan River Corridor, Malaysia. *Journal of Flood Risk Management*, *4*(3), 189–202. http://doi.org/10.1111/j.1753-318X.2011.01103.x

Pradhan, B., & Buchroithner, M. (Eds.). (2012). *Terrigenous Mass Movements: Detection, Modelling, Early Warning and Mitigation Using Geoinformation Technology*. Springer Science & Business Media.

Prasannakumar, V., Vijith, H., Abinod, S., & Geetha, N. (2012). Estimation of soil erosion risk within a small mountainous sub-watershed in Kerala, India, using Revised Universal Soil Loss Equation (RUSLE) and geo-information technology. *Geoscience Frontiers*, *3*(2), 209–215. http://doi.org/10.1016/j.gsf.2011.11.003

Press, W. H., Teukolsky, S. A., Vetterling, W. T., & Flannery, B. P. (1992). Numerical recipes in Fortran 77: the art of scientific computing. *Cambridge university press*, Cambridge.

Rakesh, K., Lohani, A. K., Sanjay, K., Chattered, C., & Nema, R. K. (2000). GIS based morphometric analysis of Ajay River basin up to Sararath gauging site of south Bihar. *Journal of Applied Hydrology*, *14*(4), 45–54.

Ramly, S., & Tahir, W. (2016). Application of HEC-GeoHMS and HEC-HMS as Rainfall–Runoff Model for Flood Simulation. In W. Tahir, P. I. D. S. H. Abu Bakar, M. A. Wahid, S. R. Mohd Nasir, & W. K. Lee (Eds.), *Proceedings of the International Symposium on Flood Research and Management (ISFRAM*) 2015 (pp. 181–192). Singapore: Springer Singapore. http://doi.org/10.1007/978-981-10-0500-8_15

Rawls, W. J., Shalaby, A., & McCuen, R. H. (1981). Evaluation of methods for determining urban runoff curve numbers. *Transactions of the ASABE*, *24*, 1562–1566.

Razmkhah, H. (2016). Comparing Performance of Different Loss Methods in Rainfall Runoff Modeling. *Water resources, 43*(1), 207-224. http://doi.org/10.1134/S0097807816120058

Refsgaard, J. C. (1996). *Distributed Hydrological Modelling.* (M. B. Abbott &J. C. Refsgaard, Eds.) Kluwer Academic Publishers (Vol. 22). http://doi.org/10.1007/978-94-009-0257-2

Refsgaard, J. C., & Storm, B. (1995). MIKE SHE. Computer Models of Watershed *Hydrology*, *1*, 809–846.

Renard, K. G., Foster, G. R., Weesies, G. A., Mccool, D. K., & Yoder, D. C. (2000). Predicting soil erosion by water : a guide to conservation planning with the Revised Universal Soil Loss Equation (RUSLE).

Ritter, A., & Muñoz-Carpena, R. (2013). Performance evaluation of hydrological models: Statistical significance for reducing subjectivity in goodness-of-fit assessments. *Journal of Hydrology*, *480*, 33–45.

Rizeei, H. M., Saharkhiz, M. A., Pradhan, B., & Ahmad, N. (2016). Soil erosion prediction based on land cover dynamics at the Semenyih watershed in Malaysia using LTM and USLE models. *Geocarto International, 31*(10), 1158-1177. http://doi.org/10.1080/10106049.2015.1120354

Robertson, D. M., Graczyk, D. J., Garrison, P. J., Lizhu, W., LaLiberte, G., & Bannerman, R. (2006). Nutrient concentrations and their relations to the biotic integrity of wadeable streams in Wisconsin. *US Geological Survey Professional Paper*, (1722), 1–139.

Rodríguez-Iturbe, I., & Valdes, J. B. (1979). The geomorphologic structure of hydrologic response. *Water Resources Research*, *15*(6), 1409–1420. http://doi.org/10.1029/WR015i006p01409

Rogers, W. F. (1980). A practical model for linear and nonlinear runoff. *Journal of Hydrology*, *46*(1–2), 51–78.

Romero, P., Castro, G., Gomez, J. A., & Fereres, E. (2007). Curve number values for olive orchards under different soil management. *Soil Science Society of America Journal*, *71*(6), 1758–1769.

Romshoo, S. A., Bhat, S. A., & Rashid, I. (2012). Geoinformatics for assessing the morphometric control on hydrological response at watershed scalein the upper Indus Basin. *Journal of Earth System Science*, *121*(3), 659–686. http://doi.org/10.1007/s12040-012-0192-8

Ros, F. C., Sidek, L. M., Ibrahim, N. N. N., & Abdul Razad, A. (2008). Probable Maximum Flood (PMF) for the Kenyir Catchment, Malaysia. In *International Conference on Construction and Building Technology.*

Rossi, L., Krejci, V., Rauch, W., Kreikenbaum, S., Fankhauser, R., & Gujer, W. (2005). Stochastic modeling of total suspended solids (TSS) in urban areas during rain events. *Water Research, 39*(17), 4188–4196. http://doi.org/10.1016/j.watres.2005.07.041

Saadatkhah, N., Tehrani, M. H., Mansor, S., Khuzaimah, Z., Kassim, A., & Saadatkhah, R. (2016). Impact assessment of land cover changes on the runoff changes on the extreme flood events in the Kelantan River basin. *Arabian Journal of Geosciences, 9*(17), 687. http://doi.org/10.1007/s12517-016-2716-z

Saghafian, B., Farazjoo, H., Bozorgy, B., & Yazdandoost, F. (2008). Flood intensification due to changes in land use. *Water Resources Management, 22*(8), 1051–1067. http://doi.org/10.1007/s11269-007-9210-z

Saghafian, B., & Khosroshahi, M. (2005). Unit Response Approach for Priority Determination of Flood Source Areas. *Journal of Hydrologic Engineering, 10*(4), 270–277. http://doi.org/10.1061/(ASCE)1084- 0699(2005)10:4(270)

Salerno, F., Viviano, G., Carraro, E., Manfredi, E. C., Lami, A., Musazzi, S., 94–105. http://doi.org/10.1016/j.jenvman.2014.06.011

Santhi, C., Arnold, J. G., Williams, J. R., Hauck, L. M., & Dugas, W. A. (2001). Application of a watershed model to evaluate management effects on point and nonpoint source pollution. *Transactions of the ASABE, 44*(6), 1559–1570.

Sanyal, J., Densmore, A. L., & Carbonneau, P. (2014). Analysing the effect of land-use/cover changes at sub-catchment levels on downstream flood peaks: A semi-distributedmodelling approach with sparse data. *Catena*, *118*, 28–40. http://doi.org/10.1016/j.catena.2014.01.015

Schumm, S. A. (1956). Evolution of drainage systems and slopes in Badlands at Perth Amboy, New Jersey. (No. 67).

SCS (Soil Conservation Service). (1997). *National Engineering Handbook Section 4, Hydrology*.

Segura, C., Sun, G., McNulty, S., & Zhang, Y. (2014). Potential impacts of climate change on soil erosion vulnerability across the conterminous United States. *Journal of Soil and Water Conservation, 69*(2), 171–181. http://doi.org/10.2489/jswc.69.2.171

Sen, P. K. (1968). Estimates of the regression coefficient based on Kendall'stau. *Journal of American Statistical Association, 324*, 1379–1389.

Serpa, D., Nunes, J. P., Santos, J., Sampaio, E., Jacinto, R., Veiga, S., … & Abrantes, N. (2015). Impacts of climate and land use changes on the hydrological and erosion processes of two contrasting Mediterranean catchments. *Science of the Total Environment*, *538*, 64–77. http://doi.org/10.1016/j.scitotenv.2015.08.033

Shahid, M. A., Boccardo, P., Usman, M., Albanese, A., & Qamar, M. U. (2017). Predicting Peak Flows in Real Time through Event Based Hydrologic Modeling for a Trans-Boundary River Catchment. *Water Resources Management*, *31*(3), 793–810. http://doi.org/10.1007/s11269-016-1435-2

Shamshad, A., Azhari, M. N., Isa, M. H., Hussin, W. M. A. W., & Parida, B. P. (2008). Development of an appropriate procedure for estimation of RUSLE EI30 index and preparation of erosivity maps for Pulau Penang in Peninsular Malaysia. *Catena*, *72*(3), 423–432. http://doi.org/10.1016/j.catena.2007.08.002

Shamsudin, S., Dan, S., & Rahman, A. A. (2011). Uncertainty analysis of HEC-HMS model parameters using Monte Carlo simulation. *International Journal of Modelling and Simulation*, *31*(4), 279-286. http://doi.org/10.2316/Journal.20

Shen, Z., Hong, Q., Yu, H., & Niu, J. (2010). Parameter uncertainty analysis of non-point source pollution from different land use types. *Science of the Total Environment*, *408*(8), 1971–1978. http://doi.org/http://dx.doi.org/10.1016/j.scitotenv.2009.12.007

Shen, Z., Liao, Q., Hong, Q., & Gong, Y. (2012). An overview of research on agricultural non-point source pollution modelling in China. *Separation and Purification Technology*, *84*, 104–111. http://doi.org/10.1016/j.seppur.2011.01.018

Sherman, L. K. (1932). Streamflow from rainfall by the unit-graph method.*Eng. News Record*, *108*, 501–505.

Shi, Z. H., Ai, L., Fang, N. F., & Zhu, H. D. (2012). Modeling the impacts of integrated small watershed management on soil erosion and sediment delivery: A case study in the Three Gorges Area, China. *Journal of Hydrology*, *438*–439(Supplement C), 156–167. http://doi.org/https://doi.org/10.1016/j.jhydrol.2012.03.016

Shi, Z. H., Chen, L. D., Fang, N. F., Qin, D. F., & Cai, C. F. (2009). Research on the SCS-CN initial abstraction ratio using rainfall-runoff event analysis in the Three Gorges Area, China. *Catena*, *77*(1), 1–7. http://doi.org/10.1016/j.catena.2008.11.006

Singh S. (1972). Altimetric analysis: A morphometric technique of landform study. *National Geographic*, *7*, 59–68.

Singh, S. & Singh, M. C. (1997). Morphometric analysis of Kanhar river basin. *National Geographical Journal of India, 43*(1), 31–43.

Singh, P. K., Bhunya, P. K., Mishra, S. K., & Chaube, U. C. (2008). A sediment graph model based on SCS-CN method. *Journal of Hydrology, 349*(1–2), 244–255. http://doi.org/10.1016/j.jhydrol.2007.11.004

Singh, V. P. (1995). *Computer models of watershed hydrology*. *Rev.*

Singh, V. P. (1992). *Elementary hydrology*. Prentice Hall Englewood Cliffs.

Singh, V. P., & Woolhiser, D. A. (2002). Mathematical Modeling of Watershed Hydrology. *Journal of hydrologic engineering, 7*(4), 270-292.

Sinnakaudan, S. K., Ab Ghani, A., Ahmad, M. S. S., & Zakaria, N. A. (2003). Flood risk mapping for Pari River incorporating sediment transport. *Environmental Modelling and Software, 18*(2), 119–130. http://doi.org/10.1016/S1364-8152(02)00068-3

Smith, K. (1996). *Environmental Hazards: Assessing Risk and Reducing Disaster* (2nd edition). London: Routledge.

Soulis, K., & Dercas, N. (2007). Development of a GIS-based spatially distributed continuous hydrological model and its first application. *Water International, 32*(1), 177–192. http://doi.org/10.1080/02508060708691974

Soulis, K. X., & Valiantzas, J. D. (2012). SCS-CN parameter determination using rainfall-runoff data in heterogeneous watersheds – the two-CN system approach. *Hydrology and Earth System Sciences, 16*(3), 1001–1015. http://doi.org/10.5194/hess-16-1001-2012

Soulis, K. X., Valiantzas, J. D., Dercas, N., & Londra, P. A. (2009). Investigation of the direct runoff generation mechanism for the analysis of the SCS-CN method applicability to a partial area experimental watershed. *Hydrology and Earth System Sciences*, 605–615.

Sreedevi, P. D., Owais, S., Khan, H. H., & Ahmed, S. (2009). Morphometric analysis of a watershed of South India using SRTM data and GIS. *Journal of the Geological Society of India, 73*(4), 543–552. http://doi.org/10.1007/s12594-009-0038-4

Srinivasan, M. S., Gerard-Marchant, P., Veith, T. L., Gburek, W. J., & Steenhuis, T. S. (2005). Watershed scale modeling of critical source areas of runoff generation and phosphorus transport. *Journal of the American Water Resources Association, 41*(2), 361–375. http://doi.org/DOI 10.1111/j.1752-1688.2005.tb03741.x

Srivastava, P. K., Mukherjee, S., & Gupta, M. (2008). Groundwater quality assessment and its relation to land use/land cover using remote sensing and GIS. In *Proceedings of international groundwater conference on groundwater use—efficiency and sustainability: groundwater and drinking water issues, Jaipur, India* (pp. 19-22).

Steffen, W., Crutzen, J., & McNeill, J. R. (2007). The Anthropocene: are humans now overwhelming the great forces of Nature? *Ambio, 36*(8), 614–621. http://doi.org/10.1579/0044-7447(2007)36[614:TAAHNO]2.0.CO;2

Strahler, A. N. (1957). Quantitative analysis of watershed geomorphology. *Transaction of American Geophysics Union, 38*(6), 913–920.

Strahler, A. N. (1964). Quantitative geomorphology of drainage basin and channel networks. *Handbook of Applied Hydrology*. Retrieved from http://ci.nii.ac.jp/naid/10021229789/en/

Sukhanovskii, Y. P. (2010). Rainfall Erosion Model. *Eurasian Soil Science, 43*(9), 1036–1046. http://doi.org/10.1134/S1064229310090115

Sulaiman, W. N. A., Heshmatpoor, A., & Rosli, M. H. (2010). Identification of flood source areas in Pahang river basin, Peninsular Malaysia. *EnvironmentAsia, 3*, 73–78.

Suliman, A. H. A., Katimon, A., Darus, I. Z. M., & Shahid, S. (2016). TOPMODEL for streamflow simulation of a tropical catchment using different resolutions of ASTER DEM: optimization through response surface methodology. *Water Resources Management, 30*(9), 3159–3173. http://doi.org/10.1007/s11269-016-1338-2

Suresh, R. (2007). *Soil and Water Conservation Engineering*. Standard Publishers Distributors.

Suriya, S., & Mudgal, B. V. (2012). Impact of urbanization on flooding: The Thirusoolam sub watershed - A case study. *Journal of Hydrology, 412*–413, 210–219.
http://doi.org/10.1016/j.jhydrol.2011.05.008

Suwandana, E., Kawamura, K., Sakuno, Y., Kustiyanto, E., & Raharjo, B. (2012). Evaluation of ASTER GDEM2 in comparison with GDEM1, SRTM DEM and topographic-map- derived DEM using inundation area analysis and RTK-dGPS data. *Remote Sensing, 4*(8), 2419–2431.

Tahir, W., & Che Hamid, H. A. (2013). Flood Forecasting Using Tank Model and Weather Surveillance Radar (WSR) Input for Sg Gombak. *International Journal of Civil & Environmental Engineering, 13*(2), 42–46. Retrieved from http://www.ijens.org/Vol_13_I_02/133202-5757-IJCEE-IJENS.pdf

Tan, M. L., Ibrahim, A. L., Yusop, Z., Duan, Z., & Ling, L. (2014). Impacts of land-use and climate variability on hydrological components in the Johor River basin, Malaysia. *Hydrological Sciences Journal*, *6667*(January 2016), 141217125340005. http://doi.org/10.1080/02626667.2014.967246

Tang, Z., Engel, B. a., Pijanowski, B. C., & Lim, K. J. (2005). Forecasting land use change and its environmental impact at a watershed scale. *Journal of Environmental Management*, *76*(1), 35–45. http://doi.org/10.1016/j.jenvman.2005.01.006

Tangang, F. T., & Juneng, L. (2011). Climate projection downscaling for Peninsular Malaysia and Sabah-Sarawak using Hadley Centre PRECIS model. *Technical Consultation Report for National Hydraulic Research Institute of Malaysia* (NAHRIM).

Tarboton, D. G. (1989). *The Analysis of River Basins and Channel Networks Using Digital Terrain Data.*

Teegavarapu, R. S. V, & Chandramouli, V. (2005). Improved weighting methods, deterministic and stochastic data-driven models for estimation of missing precipitation records. *Journal of Hydrology*, *312*(1-4), 191-206. http://doi.org/10.1016/j.jhydrol.2005.02.015

Teh, S. H. (2011). Soil erosion modeling using RUSLE and GIS on Cameron highlands, Malaysia for hydropower development (*Masters dissertation*).

Tehrany, M. S., Pradhan, B., & Jebur, M. N. (2014). Flood susceptibility mapping using a novel ensemble weights-of-evidence and support vector machine models in GIS. *Journal of Hydrology*, *512*, 332–343. http://doi.org/10.1016/j.jhydrol.2014.03.008

Terranova, O., Antronico, L., Coscarelli, R., & Iaquinta, P. (2009). Soil erosion risk scenarios in the Mediterranean environment using RUSLE and GIS: An application model for Calabria (southern Italy). *Geomorphology*, *112*(3–4), 228–245. http://doi.org/10.1016/j.geomorph.2009.06.009

Thanapakpawin, P., Richey, J., Thomas, D., Rodda, S., Campbell, B., & Logsdon, M. (2006). Effects of landuse change on the hydrologic regime of the Mae Chaem River basin, NW. *Journal of Hydrology*, *334*, 215–230.

Thanapakpawin, P., Richey, J., Thomas, D., Rodda, S., Campbell, B., & Logsdon, M. (2007). Effects of landuse change on the hydrologic regime of the Mae Chaem river basin, {NW} Thailand. *Journal of Hydrology*, *334*(1–2), 215–230. http://doi.org/http://dx.doi.org/10.1016/j.jhydrol.2006.10.012

Todini, E., & Wallis, J. R. (1977). Using CLS for daily or longer period rainfall-runoff modelling. *Mathematical Models for Surface Water Hydrology*, *100*, 149–168.

Tong, S. T. Y., & Chen, W. (2002). Modeling the relationship between land use and surface water quality. *Journal of Environmental Management*, *66*(4), 377–393. http://doi.org/10.1006/jema.2002.0593

Tucker, G. E., & Bras, R. L. (1998). Hillslope processes, drainage density, and landscape morphology. *Water Resources Research*, *34*(10), 2751-2764.

Turpin, N., Bontems, P., Rotillon, G., Bärlund, I., Kaljonen, M., Tattari, S., & Zahm, F. (2005). AgriBMPWater: Systems approach to environmentally acceptable farming. *Environmental Modelling and Software, 20*(2), 187–196. http://doi.org/10.1016/j.envsoft.2003.09.004

UNESCO. (United Nations Educational, Scientific and Cultural Organization). (1985). *Teaching aids in Hydrology, technical papers in hydrology* (2nd ed.).

USEPA. (United States Environmental Protection Agency). (2009). National Water Quality Inventory: Report to Congress. Water, (January), 43. http://doi.org/http://www.epa.gov/owow/305b/2004report/

USACE-HEC. (United States Army Corps of Engineers–Hydrologic Engineering Center). (2000). *Hydrologic Modeling System HEC–HMS: technical reference manual*.California, USA.

USACE-HEC. (United States Army Corps of Engineers–Hydrologic Engineering Center). (2010). *Hydrologic Modeling System, HEC- HMS User's Manual.* California, USA.

Vaidya, N., Kuniyal, J. C., & Chauhan, R. (2013). Morphometric analysis using Geographic Information System (GIS) for sustainable development of hydropower projects in the lower Satluj river catchment in Himachal Pradesh, India. *International Journal of Geomatics and Geosciences, 3*(3), 464.

Vazquez-Amabile, G., Engel, B. A., & Flanagan, D. C. (2006). Modeling and risk analysis of nonpoint-source pollution caused by atrazine using SWAT. *Transactions of the ASABE, 49*(3), 667-678.

Velleux, M. L., England, J. F., & Julien, P. Y. (2008). TREX: Spatially distributed model to assess watershed contaminant transport and fate. *Science of the Total Environment*, *404*(1), 113–128. http://doi.org/https://doi.org/10.1016/j.scitotenv.2008.05.053

Verma, A. K., Jha, M. K., & Mahana, R. K. (2010). Evaluation of HEC-HMS and WEPP for simulating watershed runoff using remote sensing and geographical information system. *Paddy and Water Environment, 8*(2), 131-144.

Vieux, B. E. (2001). Distributed hydrologic modeling using GIS. In *Distributed Hydrologic Modeling Using GIS* (pp. 1-17). Springer, Dordrecht.

Vittala, S. S., Govindaiah, S., & Gowda, H. H. (2004). (2004). Morphometric analysis of sub-watersheds in the pavagada area of Tumkur district, South India using remote sensing and GIS techniques. *Journal of the Indian Society of Remote Sensing, 32*(4), 351–362. http://doi.org/10.1007/BF03030860

Vitousek, P. M., Mooney, H. A., Lubchenco, J., & Melillo, J. M. (1997). Human domination of Earth's ecosystems. *Science*, *277*(5325), 494-499.

Vorosmarty, C. J., Green, P., Salisbury, J., Lammers, R. (2000). Global water resources: vulnerability from climate change and population growth. *Science*, *289*, 284–288.

Wan, I. (1996). Urban growth determinants for the state of Kelantano of the state's policy makers. Penerbitan Akademik Fakulti Kejuruteraan dan Sains Geoinformasi. *Buletin Ukur, 7,* 176-189.

Wang, G. X., Liu, J. Q., Kubota, J. P., & Chen, L. (2007). Effects of land use changes on hydrological processes in the middle basin of the Heihe River, northeast China. *Hydrological Processes*, *21*(1370–1382).

Wang, G., Hapuarachchi, P., Ishidaira, H., Kiem, A. S., & Takeuchi, K. (2009). Estimation of soil erosion and sediment yield during individual rainstorms at catchment scale. *Water Resources Management*, *23*(8), 1447–1465. http://doi.org/10.1007/s11269-008-9335-8

Wang, J., Shao, J., Wang, D., Ni, J., & Xie, D. (2015). Simulation of the dissolved nitrogen and phosphorus loads in different land uses in the Three Gorges Reservoir Region - Based on the improved export coefficient model. *Environmental Sciences: Processes and Impacts*, *17*(11), 1976–1989. http://doi.org/10.1039/c5em00380f

Wang, S., Kang, S., Zhang, L., & Li, F. (2008). Modelling hydrological response to different land-use and climate change scenarios in the Zamu River basin of northwest China. *Hydrological Processes, 22*(14), 2502–2510. http://doi.org/10.1002/hyp.6846

Wang, S., & Wang, S. (2013). Land use/land cover change and their effects on landscape patterns in the Yanqi Basin, Xinjiang (China). *Environmental Monitoring and Assessment*, *185*(12), 9729–9742. http://doi.org/10.1007/s10661-013-3286-0

Watt, E. W., & Chow, A. K. C. (1985). A general expression for basin lag time. *Canadian Journal of Civil Engineering, 12*(2), 294–300.

Weifeng, Z. H. O. U., & Bingfang, W. U. (2008). Assessment of soil erosion and sediment delivery ratio using remote sensing and GIS: a case study of upstream Chaobaihe River catchment, north China. *International Journal of Sediment Research, 23*(2), 167-173.

Weng, Q. (2001). Modeling urban growth effects on surface runoff with the integration of remote sensing and GIS. *Environmental Management*, *28*(6), 737–748.

Willmott, C. J. (1981). On the validation of models. *Physical Geography, 2*(2), 184–194. http://doi.org/10.1080/02723646.1981.10642213

Willmott, C. J. (1982). Some comments on the evaluation of model performance. *Bulletin of the American Meteorological Society, 63*(11), 1309–1313.

Wischmeier, W. H., & Smith, D. D. (1978). Predicting rainfall erosion losses-A guide to conservation planning. *Predicting rainfall erosion losses-a guide to conservation planning.*

Wong, C. L., Venneker, R., & Uhlenbrook, S. (2010). Analysis and modelling of runoff from two distinct river basins in Peninsular Malaysia. In *Conference Proceedings of the HydroPredict Conference* (p. 11).

Woodward, D. E., Hawkins, R. H., Jiang, R., Hjelmfelt, Jr, A. T., Van Mullem, J. A., & Quan, Q. D. (2003). Runoff curve number method: examination of the initial abstraction ratio. In *World Water & Environmental Resources Congress 2003* (pp. 1-10).

Woolhiser, D. A. (1973). Hydrologic and watershed modeling–state of the art. *Transactions of the ASAE, 16*(3), 553–559.

World Bank (2008). World Development Indicators Online. The World Bank, Development Data Group

Wu, Y. E., & Hung, M. (2016). Comparison of Spatial Interpolation Techniques Using Comparison of Spatial Interpolation Techniques Using Visualization and Quantitative Assessment Visualization and Quantitative Assessment.

Wurbs, R. A. (1998). Dissemination of generalized water resources models in the United States. *Water International*, *23*(3), 190–198.

Xia, J. (2002). *Theory and Method on Nonlinear Hydrology System.* Wuhan: Wuhan University Press.

Xiao, B., Wang, Q. H., Fan, J., Han, F. P., & Dai, Q. H. (2011). Application of the SCS-CN model to runoff estimation in a small watershed with high spatial heterogeneity. *Pedosphere, 21*(6), 738–749. http://doi.org/10.1016/S1002-0160(11)60177-X

Yaseen, Z. M., El-Shafie, A., Afan, H. A., Hameed, M., Mohtar, W. H. M. W., & Hussain, A. (2016). RBFNN versus FFNN for daily river flow forecasting at Johor River, Malaysia. *Neural Computing and Applications*, *27*(6), 1533–1542. http://doi.org/10.1007/s00521-015- 1952-6

Yuan, Y., Nie, W., McCutcheon, S. C., & Taguas, E. V. (2014). Initial abstraction and curve numbers for semiarid watersheds in Southeastern Arizona. *Hydrological Processes, 28*(3), 774-783. http://doi.org/10.1002/hyp

Yusof, M. F., Azamathulla, H. M., & Abdullah, R. (2014). Prediction of soil erodibility factor for Peninsular Malaysia soil series using ANN. *Neural Computing and Applications*, *24*(2), 383–389. http://doi.org/10.1007/s00521-012-1236-3

Yusop, Z., Chan, C. H., & Katimon, A. (2007). Runoff characteristics and application of HEC-HMS for modelling stormflow hydrograph in an oil palm catchment. *Water Science & Technology*, *56*(8), 41. http://doi.org/10.2166/wst.2007.690

Zaimes, G. N., Schultz, R. C., & Isenhart, T. M. (2008). Total phosphorus concentrations and compaction in riparian areas under different riparian land-uses of Iowa. *Agriculture, Ecosystems & Environment*, *127*(1–2), 22–30. http://doi.org/http://dx.doi.org/10.1016/j.agee.2008.02.008

Zhan, X., & Huang, M. L. (2004). ArcCN-Runoff: An ArcGIS tool for generating curve number and runoff maps. *Environmental Modelling and Software, 19*(10), 875–879. http://doi.org/10.1016/j.envsoft.2004.03.001

Zhang, B.-L., Yin, L., Zhang, S.-M., Engel, B., & Theller, L. (2016). GIS and L-THIA based analysis on variations of non-point pollution in in Nansi Lake basin, China. *Journal of Donghua University (English Edition)*, *33*(6), 851–858.

Zhang, J., Shen, T., Liu, M., Wan, Y., Liu, J., & Li, J. (2010). Research on non-point source pollution spatial distribution of Qingdao based on L-THIA model. *Mathematical and Computer Modelling*, *54*(3–4), 1151–1159. http://doi.org/10.1016/j.mcm.2010.11.048

Zhang, S., Liu, C., Yao, Z., & Guo, L. (2007). Experimental study on lag time for a small watershed. *Hydrological Processes*, *21*(8), 1045–1054.

Zhang, X., Yu, X., Wu, S., Zhang, M., Li, J., & Xiaoming Z, Xinxiao Y, Manliang Z, J. L. (2007). Response of land use/coverage change to hydrological dynamics at watershed scale in the Loess Plateau of China. *Acta Ecologica Sinica, 27*(2), 414–421. http://doi.org/10.1016/S1872-2032(07)60013-4

Zhang, Y., Degroote, J., Wolter, C., & Sugumaran, R. (2009). Integration of modified universal soil loss equation (MUSLE) into a GIS framework to assess soil erosion risk. *Land Degradation & Development*, *20*(1), 84–91. http://doi.org/10.1002/ldr.893

Zope, P. E., Eldho, T. I., & Jothiprakash, V. (2015). Impacts of urbanization on flooding of a coastal urban catchment : a case study of Mumbai City, India. *Natural Hazards*, *75*(1), 887-908. http://doi.org/10.1007/s11069-014-1356-4