UNIVERSITI PUTRA MALAYSIA

IMPACT OF CLIMATE CHANGE ON SOIL EROSION AND SEDIMENT YIELD AT HILLY FARMS OF CAMERON HIGHLANDS, MALAYSIA

NURADDEEN MUKHTAR NASIDI

IMPACT OF CLIMATE CHANGE ON SOIL EROSION AND SEDIMENT YIELD AT HILLY FARMS OF CAMERON HIGHLANDS, MALAYSIA

By

NURADDEEN MUKHTAR NASIDI

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

December 2020

DEDICATION

This PhD thesis is dedicated to my parents Malam Mukhtar Alhaji Nasidi and Maimuna Ahmad Baffa (Late), my wife Hadiza Mustapha Balarabe and my two children Ahmad and Ibrahim for their care, love, prayers, and support. Also, this Thesis is dedicated to my brothers and sisters – Karamat (gwaggo), Abulhameed (Baba karami), Nafisat, Aliyu, Imamu, Surayya, Ahmad and Hafsat.

Abstract of the thesis presented to the Senate of the Universiti Putra Malaysia in fulfillment of the requirement for the degree of Doctor of Philosophy

IMPACT OF CLIMATE CHANGE ON SOIL EROSION AND SEDIMENT YIELD AT HILLY FARMS OF CAMERON HIGHLANDS, MALAYSIA

By

NURADDEEN MUKHTAR NASIDI

December 2020

Chairman : Aimrun Wayayok, PhD
Faculty : Engineering

Soil erosion is one of the major environmental problems worldwide and is becoming serious limiting factor for crop production everywhere. It seriously impacts crop productivity by removing topmost soils and results into devastating almost irreversible damages. In Cameron Highlands, soil erosion has been a major environmental issue causing huge loss of agricultural soil and increasing rates of landslides. Recent studies and field surveys have reported that there is excessive soil erosion in Cameron Highlands with increasing risk of erosion-induced landslides and sedimentation of major water reservoirs. The purpose of this study was to project soil erosion and sediment yields to 2050s (2040-2069) and 2080s (2070-2099) under different climate change impact scenarios. The objective was also, to evaluate effectiveness of erosion control best management practices (BMPs) toward minimizing the potential soil erosion in Cameron Highlands using Global Circulation Models (GCMs) and four Representative Concentration Pathways (RCPs). To achieve this, precipitation datasets were obtained from World Data Center for Climate and downscaled using 30 years observed local precipitation data. intensity-frequency-duration (IDF) curves were constructed for current and future 2050s and 2080s scenarios. The rainfall trend was analyzed using Mann-Kendall and Sense' slope tests at 5% significance level. Soil erosion was assessed using Revised Universal Soil Loss Equation (RUSLE) model. Moreover, soil erodibility (K-factor) was developed through combination of field survey and existing soil series. Furthermore, crop management (C-factor) was established for current and future scenarios using Land Change Modeler (LCM) embedded in TerrSet software. Landsat 7 and 8 images were analyzed using IDRISI image processing software and simulated future land use scenarios by applying Markov Chain model. Furthermore, field experiments on erosion control BMPs were conducted at Cameron Highlands farm using three varieties of mustard crop (Green Apex 5502, Lucket 9116 and Little Princess 822) sown under both open and sheltered farms.

The study revealed that performance of precipitation model indicated by KGE, NSE, RMSE, SE, MAE, and MBE, are 0.64, 0.27, 1.25, 0.37, 1.63 and 0.15, respectively. The simulated precipitations were found to increase relative to baseline period by 6.8%, 12.9%, 20% and 37% for 2050s; 16.1%, 28.6%, 39.2% and 42.3% for 2080s under RCP2.6, RCP4.5, RCP6.0 and RCP8.5 scenarios, respectively. Projected IDF curves were found greater than the baseline condition under 2, 5, and 20 years return periods. The highest erosivity (R-factor) of 6,039 MJ mm $ha^{-1} hr^{-1} yr^{-1}$ was found at Tanah Rata sub-catchment by 2080s under RCP8.5 scenario, which indicated 83% increase relative to baseline. Moreover, spatial variation of K-factor was found ranged from 0.00113 to 0.01613. The erosion projection showed that severe to extreme forms of soil erosion (>50 t ha^{-1}) will occupy 12.44% of the study catchment, with highest annual soil loss of 1.71×10^6 ton by 2080s under RCP8.5 scenario. Similarly, the corresponding severe sediment yields will be 243,061 t $ha^{-1}year^{-1}$ which represents 57.6% of total soil loss by 2080s under RCP8.5 scenario. Sediment Delivery Ratio (SDR) was computed as 0.208 which signifies the fraction of soil loss deposited outside the study watershed. The field experiments revealed highly significant effect of three BMPs (terracing, sediment trap and waste management) on sediment yields generation in both open and sheltered farms. It has been presented that, largest sediment yields of 13.9 ton/ha, 14.2 ton/ha and 14.5 ton/ha are collected from open farm control plots sown with Green Apex 5502, Lucket 9116 and Little Princess 822, respectively. However, the application of the control BMPs achieved high sediment reductions of 53.8%, 54%, and 52.3%, under terracing, sediment trap and waste management, respectively. In the other hand, the sheltered farm BMPs achieved more sediment reductions of 65.4%, 59%, and 53.8% under terracing, sediment trap and waste management, respectively. Additionally, the crop yield performance shows a significant effect of the varieties of mustard, but not with the types of farms, on total sediment yields. It is noted that, nutrients loss in the runoff is a crucial factor of crop cultivation, however, this study did not evaluate it due to complexity of the work. In general, the study simulated the impact of climate change on erosion and sediment yields at Cameron Highlands and revealed the effects of control BMPs under both sheltered and open farms. This information is essential toward reducing large amount of predicted soil loss due to effect of climate change and will support the management and policies makers to design effective soil conservation measures.

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

KESAN PERUBAHAN IKLIM TERHADAP HAKISAN TANAH DAN HASIL ENDAPAN DI LADANG TANAH TINGGI CAMERON HIGHLANDS, MALAYSIA

Oleh

NURADDEEN MUKHTAR NASIDI

Disember 2020

Pengerusi : Aimrun Wayayok, PhD
Fakulti : Kejuruteraan

Hakisan tanah adalah salah satu masalah persekitaran utama di seluruh dunia dan menjadi faktor pembatas serius bagi pengeluaran tanaman di mana sahaja. Ini memberi kesan serius terhadap produktiviti tanaman dengan membuang tanah paling atas dan mengakibatkan kerosakan yang hampir tidak dapat dipulihkan. Di Tanah Tinggi Cameron Highlands, hakisan tanah telah menjadi isu utama persekitaran yang menyebabkan kehilangan tanah pertanian yang besar dan peningkatan kadar tanah runtuh. Kajian dan tinjauan lapangan baru-baru ini melaporkan bahawa terdapat hakisan tanah yang berlebihan di Tanah Tinggi Cameron Highlands dengan peningkatan risiko tanah runtuh yang disebabkan oleh hakisan. Tujuan kajian ini adalah untuk membuat unjuran hakisan tanah dan hasil endapan hingga 2050-an (2040-2069) dan 2080-an (2070-2099) di bawah senario kesan perubahan iklim yang berbeza. Juga, untuk menilai keberkesanan amalan pengurusan terbaik (BMP) bagi pengawalan hakisan ke arah meminimumkan potensi hakisan tanah di Cameron Highlands menggunakan Model Peredaran Global (GCM) dan empat laluan tumpuan perwakilan (RCP). Untuk mencapainya, set data hujan diperoleh dari Pusat Data Iklim Dunia, dan disahkan menggunakan data hujan tempatan yang diperhatikan selama 30 tahun. Kemudian, keluk intensiti-frekuensi-tempoh (IDF) dibina untuk senario 2050s dan 2080s semasa dan akan datang. Trend curah hujan dianalisis menggunakan ujian cerun Mann-Kendall dan Sense pada tahap signifikan 5%. Hakisan tanah dinilai menggunakan model semakan persamaan kehilangan tanah universal (RUSLE). Terutamanya, erodibiliti tanah (faktor K) dikembangkan melalui gabungan tinjauan lapangan dan siri tanah yang sediada. Selanjutnya, pengurusan tanaman (C-factor) dibuat untuk senario semasa dan masa depan menggunakan Land Change Modeler (LCM) yang tertanam dalam perisian TerrSet.

Gambar satelit Landsat 7 dan 8 dianalisis menggunakan perisian pemprosesan gambar IDRISI dan mensimulasikan senario penggunaan tanah masa depan dengan menggunakan model Markov Chain. Selanjutnya, eksperimen lapangan BMP untuk kawalan hakisan dilakukan di Cameron Highlands menggunakan tiga jenis tanaman sawi (Green Apex 5502, Lucket 9116 dan Little Princess 822) yang disemai di ladang terbuka dan terlindung. Kajian menunjukkan bahawa, prestasi model ensemble hujan menggunakan KGE, NSE, RMSE, SE, MBE, dan MAE masing-masing adalah 0.64, 0.27, 1.25, 0.37, 1.63, dan 0.15. Penetapan simulasi didapati meningkat berbanding tempoh awal sebanyak 6.8%, 12.9%, 20% dan 37% untuk 2050-an dan 16.1%, 28.6%, 39.2% dan 42.3% untuk 2080s di bawah senario RCP2.6, RCP4.5, RCP6.0 dan RCP8. 5 masing-masing. Lekuk IDF yang diunjurkan didapati lebih besar daripada keadaan asas di bawah 2, 5, dan 20 tahun tempoh ulangan. Erosiviti hujan tertinggi (faktor R) adalah 6,039 MJ mm ha^{-1} jam^{-1} tahun^{-1} dijumpai di tadahan Tanah Rata pada tahun 2080s di bawah senario RCP8.5 yang menunjukkan peningkatan 83% berbanding dengan garis dasar. Variasi spasial faktor K didapati antara 0.00113 hingga 0.01613. Unjuran menunjukkan hakisan tanah yang teruk hingga melampau (>50 t ha^{-1}) akan meliputi 12.44% kawasan tadahan kajian ini dengan kehilangan tanah tahunan yang tinggi sebanyak 1.71×10^6 tan menjelang tahun 2080-an di bawah senario RCP8.5. Begitu juga, hasil endapan yang teruk akan menjadi 243,061 t ha^{-1}year^{-1} yang meliputi 57.6% daripada jumlah kehilangan tanah pada tahun 2080-an di bawah senario RCP8.5. Nisbah penghantaran endapan (SDR) yang dikira adalah 0.,208 yang menandakan pecahan kehilangan tanah yang disimpan di luar kawasan kajian. Eksperimen lapangan menunjukkan kesan yang sangat signifikan dari tiga BMP (teras, perangkap endapan dan pengurusan sisa) terhadap penghasilan hasil endapan di ladang terbuka dan terlindung. Seperti maklumat diatas, hasil endapan terbesar ialah13.9, 14.2 dan 14.5 tan/ha dikumpulkan dari plot kawalan ladang terbuka yang ditaburkan masing-masing dengan Green Apex 5502, Lucket 9116 dan Little Princess 822. Walau bagaimanapun, penerapan BMP kawalan mencapai penurunan endapan tertinggi masing-masing sebanyak 53.8%, 54%, dan 52.3%, di bawah teras, perangkap sedimen dan pengurusan sisa. Sebaliknya, BMP ladang terlindung memperoleh pengurangan lebih banyak endapan sebanyak 61.8%, 55.4%, dan 46.5% di bawah teras, perangkap endapan dan pengurusan sisa. Selain itu, prestasi hasil tanaman menunjukkan kesan yang signifikan dari jenis mustard, tetapi tidak dengan jenis ladang, terhadap jumlah hasil endapan. Secara umum, kajian ini mensimulasikan kesan perubahan iklim terhadap hakisan dan hasil endapan di Cammeron Highlands dan mendedahkan kesan kawalan BMP di ladang terlindung dan terbuka. Maklumat ini penting untuk mengurangkan sejumlah besar kehilangan tanah yang diramalkan kerana kesan perubahan iklim dan akan membantu pihak pengurusan dan pembuat dasar untuk merancang langkah-langkah pemuliharaan tanah yang berkesan.

ACKNOWLEDGEMENTS

I would like to express my gratitude and praise to Almighty Allah who in his infinite mercy guided me all along the process of completing this thesis work. Secondly, I would extend my sincere appreciation to my parents, brothers and sisters for their care support and encouragement through my study processes.

My enormous appreciation is accredited to the supervisory committee led by Dr. Aimrun Wayayok who has given to me all sort of encouragement and support to ensure the successful conduct of this work. Contributions from the committee members; Associate Prof. Ahmad Fikri Abdullah and Dr. Muhamad Saufi Mohd Kassim are duly appreciated. Special thanks to the staff of the Department of Biological and Agricultural Engineering-Universiti Putra Malaysia, *Komplex Pertanian* Cameron Highlands, Department of Irrigation and Drainage (DID), Department of Agriculture Malaysia (DOA), Malaysian Meteorological Department (MMD) and Cameron Highlands Farmers' Association. I sincerely appreciate the support by Zukhairo B. Rippin (Chairman of farmer's association of Cameron Highlands) who assisted me enormously while conducting field experiment.

I would like to acknowledge the Federal Government of Nigeria for sponsoring my study through Tertiary Trust Fund (TETFUND) scholarship. I extent the appreciation to my employer Bayero University Kano for considering me worthy of the staff training fellowship. I appreciate the support from my lovely wife Hadiza Mustapha Balarabe and my two children Ahmad and Ibrahim for their care, endurance and accompany while staying in Malaysia.

Moreover, I appreciate the affable relationship with my friends from various countries which include Haidar (Iraq), Abdulahi, Yuhao Ang (China Malay), Abba Muhammad, Ahmad Hassan (Egypt), Katibi, Ali Al-Sarafi (Yemen), Abdussalam Haoma (Libya), Fa'iz (Malaysia), Fikri (Egypt), Moath (Yemen), to mention but few. Also, the relationships with lifetime friends are very much appreciated who remained in touched during my study tour, these include Murtala Sani, Nura J. Shanono, Mu'azu D. Zakari, Ibrahim Mahmud Mustafa M. Bello, Abba Ibrahim, Ibrahim Lawan and Habibu Isma'il. Furthermore, I acknowledged the entire staff of Department of Agricultural and Environmental Engineering, Bayero University Kano for their harmonious relationship and encouragement toward aching a greater success.

This 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 the Supervisory Committee were as follows:

Aimrun Wayayok, PhD
Senior Lecturer
Faculty of Engineering
Universiti Putra Malaysia
(Chairperson)

Ahmad Fikri Abdullah, PhD
Associate Professor
Faculty of Engineering
Universiti Putra Malaysia
(Member)

Muhamad Saufi Mohd Kassim, PhD
Senior Lecturer
Faculty of Engineering
Universiti Putra Malaysia
(Member)

ZALILAH MOHD SHARIFF, PhD
Professor and Dean
School of Graduate Studies
Universiti Putra Malaysia

Date: 11 March 2021

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

ANN	Artificial Neural Network
AR5	Fifth Assessment Report
ASAE	American Society of Agricultural Engineers
BMPs	Best Management Practices
CDF	Cumulative Distribution Function
CMIP5	Coupled Model Intercomparison Project Phase 5
DEM	Digital Elevation Model
DID	Department of Irrigation and Drainage
ESCP	Erosion and Sediment Control Planning
ESDAC	European Soil Erosion Data Center
FAO	Food and Agriculture Organization
GCM	Global Circulation Model
GEV	Generalized Extreme Values
GHG	Greenhouse Gas
GIS	Geographic Information System
IDF	Intensity-Duration-Frequency
IPCC	Intergovernmental Panel for Climate Change
LCM	Land Change Modeler
LS	Slope Length and Steepness
LULC	Land Use and Land Cover
MAE	Mean Absolute Error
MBE	Mean Bias Error
NSE	Nash-Sutcliffe Efficiency
OM	Organic Matter
Pg	Petagram (=10^9 ton)
KGE	Kling-Gupta Efficiency
RCM	Regional Climate Model
RCP	Representative Concentration Pathway
RF	Radiative Forcing
RMSE	Root Mean Square Error

ROC	Relative Operating Characteristics
RUSLE	Revised Universal Soil Loss Equation
SDR	Sediment Delivery Ratio
SE	Standard Error
SEDD	Sediment Delivery Distributed
SPSS	Statistical Package for the Social Sciences
SRES	Special Report on Emission Scenarios
SWAT	Soil and Water Assessment Tools
SY	Sediment Yield
TSL	Tolerable Soil Loss
UNEP	United Nation Environment Program
USGS	United State Geological Survey
USLE	Universal Soil Loss Equation
WDCC	World Data Center for Climate
WEPP	Watershed Erosion Prediction Project
WMO	World Metrological Organization

CHAPTER 1

INTRODUCTION

1.1 Background of the Study

Approximately one third of global agricultural land (i.e. about 2 billion hectares of land) has been affected by soil degradation, in which water and wind erosion account for 56% and 28% damages, respectively (Oldeman et al., 1995). Whereas nearly 80% of the world's agricultural land is affected by moderate to extreme erosion, with only 10% estimated to be at a mild erosion rate (Lal, 1994). It is also reported that 10 million hectares of cropland globally have been lost every year due to soil erosion (Pimentel, 2006). In conjunction with increasing human population size, this figure is expected to be much higher at present (Lal, 1994; Pimentel, 2006). Across Africa, Asia and Latin America, where the majority of the population is dependent on agriculture, soil erosion could be serious threat for food production (Amundson et al., 2015; González-Morales et al., 2018; Oldeman et al., 1995; Hongfen Teng et al., 2018; L. Xu et al., 2012). This problem will continue to persist throughout 21st century (Hurni et al., 2005). Figure 1.1 presents global soil erosion map developed by Joint Research Centre of European Commission under European Soil Erosion Data Center (ESDAC) in 2012.

Soil erosion become one of the major environmental issues worldwide which seriously reduces potentials for crop production everywhere (Correa et al., 2016; Douglas, 1987; Gholami et al., 2018; González-Morales et al., 2018; Mondal et al., 2016; Nicu & Asăndulesei, 2018; D. P. Shrestha & Jetten, 2018; Smetanová et al., 2019; Zhou et al., 2019). Soil erosion phenomenon constitutes three main processes: the detachment of individual particle from soil mass, transportation of the detached particles by erosive agents such as wind or water and deposition of those particles as sediments when the erosive agent lost energy to sustain the movement (Royston Morgan & Philip, 2009). Thus, soil erosion affects ecology negatively and result into reduced available lands and other natural resources. This include: crop productivity reduction, water pollution, lower effective capacity of water reservoirs, increases the risk of flooding, landslides and habitat destruction (Prasannakumar et. al., 2012; Wang et al., 2016; Xu, et al., 2012). Therefore, erosion is a natural geological phenomenon which occur as a resulting of removal of soil particles by water or wind, transporting them elsewhere.

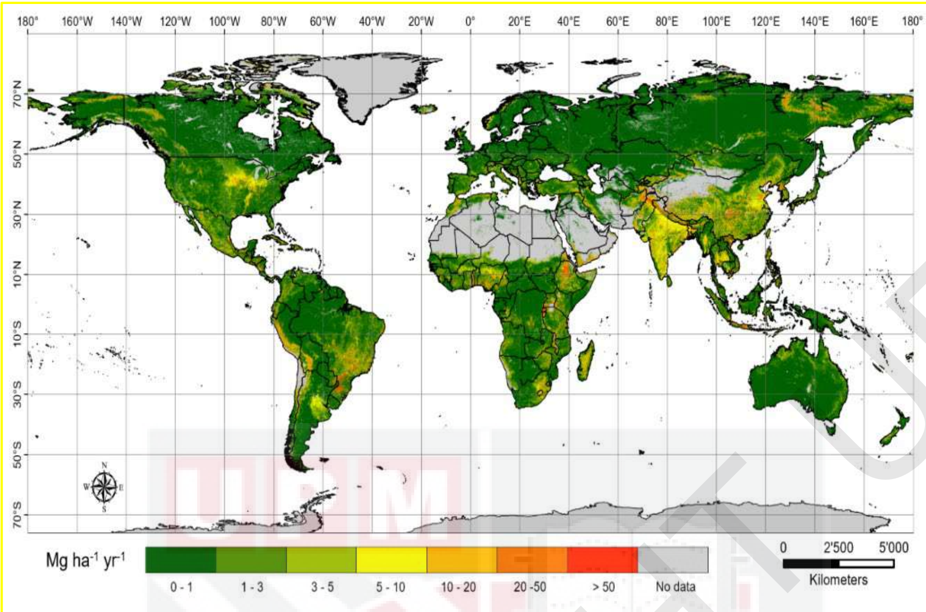

Figure 1.1 : Global Soil Erosion (ESDAC, 2012)

Human activities, on the other hand, such as agricultural practice, deforestation, and conversion of forest to agriculture exacerbate the process of erosion, particularly on steep slopes with minimum or no control measures in place (Fan et al., 2019; Williams et al., 1984). Erosion can equally be triggered or accelerated by climate change, tectonic activities, and other natural disasters (Abdullah et al., 2019; Azim et al., 2016; Várallyay, 2010). Soil erosion has become more severe in recent years especially in areas where there has been intensive land use for agricultural activities and developments for urbanization (Abdullah et al., 2019; Bosco et al., 2015; Panagos et al., 2017). Similarly, soil erosion affects quality of streams water, aquatic life, water conveyance systems and reservoirs (Mispan et al., 2015; Rickson, 2014). The chemical influx from pesticides, fungicide and fertilizers applications due to agricultural activities could be carried along with eroded soil and deposited downstream (Razali et al., 2018; Rickson, 2014). This will alter the chemical concentration such as sodium, potassium nitrogen, phosphorus, and heavy metals contents in the water available for irrigation, thus affect the crop physiological process (Mispan et al., 2015).

The process of soil erosion is influenced by biophysical factors of environment comprising of soil characteristics, climate, topography, soil cover and interactive effect between two or more (Douglas, 1987; Q. J. Liu et al., 2015; Rodrigo Comino et al., 2016). Terrain characteristics are particularly crucial factors affecting the mechanism and processes of soil erosion. This includes slope, length, aspect, and shape which play vital roles in runoff generation and transportation. There is a direct relationship between slope and runoff generation as such, the high the slope more the runoff and thus, the less infiltration (Ganasri & Ramesh, 2016). Climate factor is considered as one of the main influencing factors on rates and extent of erosion processes by both water and wind. Rainfall is one of the major factors influencing the river sediment yields (Basher et al., 2012). Therefore, any variation in climate characteristics has a consequential impact on soil erosion. However, erosion by water is the only category of erosion manifesting in Cameron Highlands and Malaysia which is profoundly become serious in last few decades (Abdullah et al., 2019; Barrow et al., 2005; Pradhan et al., 2012; Teh, 2011). The intensity of erosion is largely depend on rainfall erosivity, and crop cover which are often influenced by climate change (Gregersen et al., 2003; Mondal et al., 2016; Pheerawat & Udmale, 2017). Also, land use in relation to crop type, degree of soil disturbance and surface manipulations affect erosion rates (Mondal et al., 2016; Ouyang et al., 2018). To bring erosion down to a tolerable limit, control BMPs are necessary particularly during development or agricultural operations (Siong, 2013).

1.2 Global Land Use/Cover and Soil Erosion Conversions

The Joint Research Centre of European Commission has studied the dynamics of the world land use from 2001 through 2012 which revealed a decline in the forests by approximately 1.65 million km^2 (Borrelli et al., 2017). However, an expansion of the semi-natural vegetation (grassland, scrublands, savannah, transition forest) and cropland was reported as approximately 1.43 million km^2 and 0.22 million km^2, respectively. Over the study period, a total of 2.26 million km^2 of forests are projected to be lost, largely be replaced by semi-natural vegetation (2.17 million km^2) and to a lesser degree by cropland with 0.1 million km^2. The transitioning from forest to other land uses caused soil erosion to increase by 0.61 Pg $year^{-1}$ (ESDAC, 2012; Borrelli et al., 2017). Moreover, replacing forests with cropland (4.1% of the forest lost) is responsible for the increased soil loss of about 52%. At the same time, there was a gain for the forest area of about 0.61 million km^2 during the study period, which resulted into a net loss of forest to approximately 1.65 million km^2. The region that had experienced a conversion during the study period was approximately 3.3% of the study area (≈4 million km^2), of which 2.9 million km^2 showed a growth in soil erosion estimates of 1.74 Pg $year^{-1}$. Under this land use transition, the remaining 1.1 million km^2 (0.9%) reported a decrease in soil erosion of 0.88 Pg $year^{-1}$. This results in an average total soil erosion increase of approximately 0.86 Pg $year^{-1}$ for areas with a land use transition (Figure 1.2) in which, a Petagram, Pg = 10^9 ton; a, b, and c represent the net conversions of forest, vegetation, and croplands, respectively.

Furthermore, conservation of agriculture occupies about 15.3% of the estimated cropland (1.6 of 10.3 million km^2), resulting in an estimated decrease of about 7% overall soil erosion relative (from 10.93 to 10.15 Pg $year^{-1}$). The largest increase in soil erosion based on continental level are estimated in South America (16%), Oceania (15.4%), North America (12.5%), and in Europe (1.5%), Asia (1.2%) and to a lesser degree Africa (1.1%). In general, there is increase in soil erosion rates globally due to the conversions from one land use state to another.

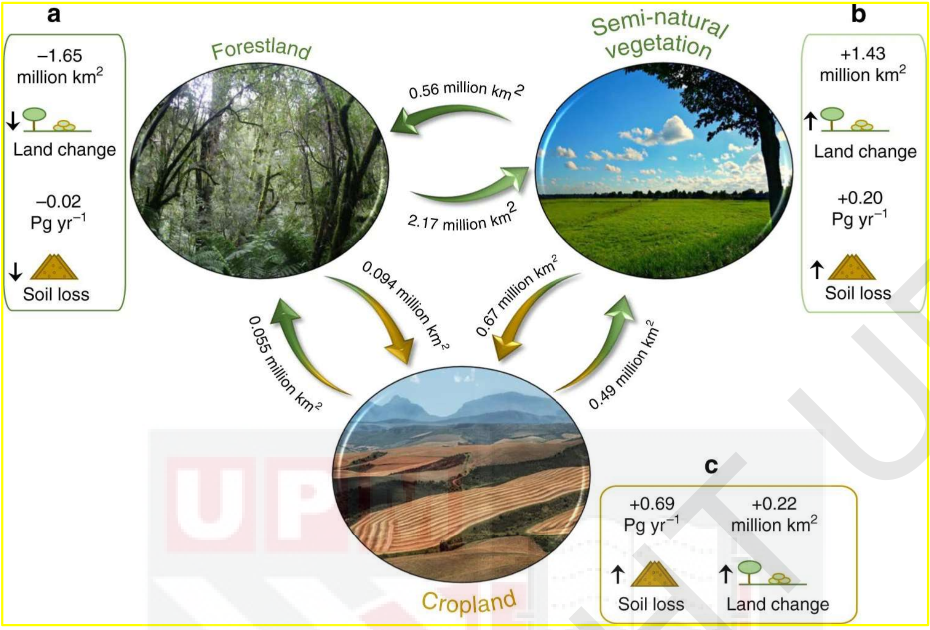

Figure 1.2 : Global erosion and land use conversions (Borrelli et al., 2017)

1.3 An Overview of Cameron Highlands

Malaysia is located in between Thailand from north and Indonesia from south, which is separated into two parts by the Southern China Sea. The two regions are referred to Peninsular Malaysia from the west and Malaysian Borneo in the east. The Cameron Highlands is situated in the Pahang State of Peninsular Malaysia which is considered as an important resort for the country (Gasim et al., 2012). The main towns of Cameron Highlands are Ringlet, Tanah Rata, Brinchang and Kampung Raja. The average elevation of the catchment is approximately 1,180 m while the highest peak is Mountain Brinchang at 2,032 m above means sea level (Tenaga National Berhad Research, 2009). Cameron Highlands is regarded as the "Green Bowl" for its potentials of growing wide variety of vegetables, flowers and other ornamental plants and supplying them to major cities in Malaysia, Singapore, and other neighboring countries.

Agriculture is an important sector in Malaysia and this sector has become the backbone of the county's economy for decades owing to high production of agricultural produce for domestic consumption and international exports (Amanina et al., 2018; Bivi et al., 2010; Paramananthan, 2015; Paterson, 2007; Robert et al., 2009). Cameron Highlands provides opportunity for agricultural activities and many tourist attractions such as tea plantations, tea factories, rose gardens, strawberry farms, natural waterfalls, golf courses and aging colonial-style homes offering a glimpse of the past (Kaffashi et al., 2015). According to Malaysian Department of Statistics, the agricultural sector contributes RM 94.1 billion to the country's GDP in 2015. Palm oil being the major contributor at 46.9%, followed by agriculture (17.7%), livestock (10.7%), fishing (10.7%), rubber (7.2%) as well as forestry and logging (6.9%).

In other hand, sedimentation of channels and storage reservoirs is another serious problem affecting the Cameron highlands (DID, 2012; Tenaga National Berhad Research, 2005). Sedimentation is a natural phenomenon which slows down the stream flow and thus causes sediment deposition in the impoundment thereby reduces carrying capacity (G. Zhao, Mu, et al., 2017). Nevertheless, the maximum effort is required to decelerate the process otherwise it will continue to further degrade the environment. According to report by erosion and sediment control guidelines (ESCP, 2018) in Cameron Highlands, largest proportion of sediments is related to unguided agricultural activities from hilly farms.

Similarly, Teh (2011) reported that the annual sediment yields from Cameron Highlands watershed in 1997 and 2006 were 282,465.5 m^3 $year^{-1}$ and 334,853.49 m^3 $year^{-1}$, respectively. This increment of 18.6% sediment rate was just within 9 years interval which certainly can pose a great danger in environmental sustainability. It will further affect agricultural lands and hydropower generation in near future except appropriate control measures are deployed. Moreover, land transformation had a great influence on susceptibility to soil erosion in the sense that forest area has less effect compared to developed areas (Suif et al., 2018).

Thus, land use developments in Cameron Highlands from forests to tea cultivation, estates and orchards up to market gardens and residential centers have had greater impacts on the soil surface, resulting in increasing rates of soil erosion (Mohd-Ariffin et al., 2014). The eroded sediments have been, and continue to be deposited along river channels and in diversion tunnels such as Ringlet reservoir (Raj, 2002). Moreover, since the early 1970's there have been changes in land use due to influx of tourism and an intensification of agricultural activities (Mansor et al., 2015). For example, large hotels, holiday homes and other recreational facilities has been greatly expanded in numbers and sizes. The development of agriculture to produce temperate type of vegetables and flowers has also been on increase since 1982, with many of the new farms situated on steep slopes (DID, 2012; Mansor et al., 2015; Teh, 2011; Tenaga National Berhad Research, 2009).

The history of agricultural development in Cameron highlands can be traced back to pre-independence era (Douglas, 1987). That was when British Colonist established a large-scale plantation and introduced different varieties of crops such as palm oil, rubber, and cocoa for the purpose of commercial production (Douglas, 1987; Mansor et al., 2015). Also, Malaysian government in earliest days of the post-independence era (1957 – 1970s) cleared large forest for extensive production of palm oil and rubber plantations which serves as a focus for economic growth in order to attract international markets. During those periods, domestic and commercial farmers dedicated their efforts toward producing more food and cash crops. Thereafter, the country experienced a rapid development and modernization of agricultural production throughout the year. The suitable lowlands for agricultural activities became scarce and left with no option than to cultivate the hilly areas (Douglas, 1987). Thus, farmers those that were mostly producing at commercial quantities began shifting their operations to hillside lands as a potential alternative. These activities had exacerbated soil erosion processes in Cameron highlands which is now facing serious challenges of soil erosion, sedimentation, floods and landslide incidences (Abdullah et al., 2019).

1.4 Research Problem

Climate change is undoubtedly a global issue which receives attention from national and international organizations. It has been predicted that, the trends in climate variables includes more hot-days heat waves, fewer cold-days, and cold waves. These changes could lead to increasing global precipitations, larger number of extremes events (flood and drought), and overall devastating ecosystem (Stocker et al., 2013, 2014). Moreover, global climate is already changing and that further changes are inevitable. For instance, during the last century from 1906 to 2005 the average global temperature rose by about 0.74ºC (IPCC, 2018). Similarly, several studies conducted at Cameron Highlands have reported considerable increase in both temperature and precipitation. Tan & Nying (2017) evaluated precipitation rates in Cameron Highlands under influence of changing climate and discovered that, about 30% higher precipitation will occur in the next 30 years. It has been correlated that high amount of precipitation lead to high tendency of soil erosion by splash and high transport capacity of sediments (Nearing et al., 1989; Nearing et al., 2015). In the future, the average rainfall under all RCP scenarios is expected to be higher than that from the historical period. The rainfall erosivity (R) and crop cover (C) factors will be changing too, thereby affecting the soil erosion rate and sediment yield. This issue has been ignored in the Camron Highlands despite its adverse effect on the environmental sustainability.

Similarly, soil erosion has been reported as a widespread environmental problem which directly affect of human lives and properties (Nigam et al., 2017; Hongfen Teng et al., 2018; Vergari, 2015). It reduces crop productivity potentials by adversely affecting soil quality parameters, physical characteristics, and resultant devastating environmental conditions. The problem of erosion is more pronounced at hilly areas with low vegetation cover due to rain splash and high energy of runoff (Alder et al., 2015; Les Basher et al., 2018; Douglas, 1987). This phenomenon leads to other forms of environmental disasters like landslides, floods and sedimentation of river networks and dams at downstream which often cause loss of lives and properties. Cameron Highlands have been facing severe soil erosion and sedimentation problems which seriously affect socio-economic activities of people and degrade environment (Mohd-Ariffin et al., 2014; Oliver et al., 2017; Pradhan et al., 2012; Sholagberu et al., 2016). This includes loss of agricultural lands, siltation of rivers and water reservoirs as well as frequent occurrences of floods and landslides (Gasim et al., 2012). Previous studies have shown the contribution of land use and land cover changes toward an accelarated soil erosion in Cameron highlands (Ganasri & Ramesh, 2016; Singh & Panda, 2017). For instance, the findings of earlier investigation by Douglas (1987) which attributed the source of soil erosion in Cameron highlands to human activities such as deforestation, tillage and other forms of soil disturbances.

According to ESCP guideline developed by Department of Agriculture (DOA, 2018), Cameron highlands has undergone rapid changes in temperature, precipitation, and water quality of rivers over the last few decades. These changes could equally influence soil erosion rates in the area by altering the magnitude of rainfall erosivity and intensity-duration-frequency relationship. Similar claims were reported by several studies in Cameron highlands. For example, Mohd-Ariffin et al., 2014 and Teh (2011) have reported huge sediment yields inflow from the watershed. This unexpected sediment load has reduced carrying capacity of major rivers and Sultan Abu Bakar Dam with consequences of drop in hydroelectric power generation. To maintain the power supply, Malaysian government has initiated a continuous daily sediment dredging operation which has a huge economic implication (Figure 1.3). in addition, the recent reports by Pradhan et al. (2012) and Teh (2012) indicated high soil erosion and huge sediment yields originating from agricultural farms where soil operations have been taking place with no proper control measures. Despite the incidence of soil erosion and sedimentation problems in the area, no research is conducted so far in the study watershed with respect to assessing climate change impacts on soil erosion, sediment yields and crop yield performance under control BMPs. Consequently, this research was meant to filling these study gaps.

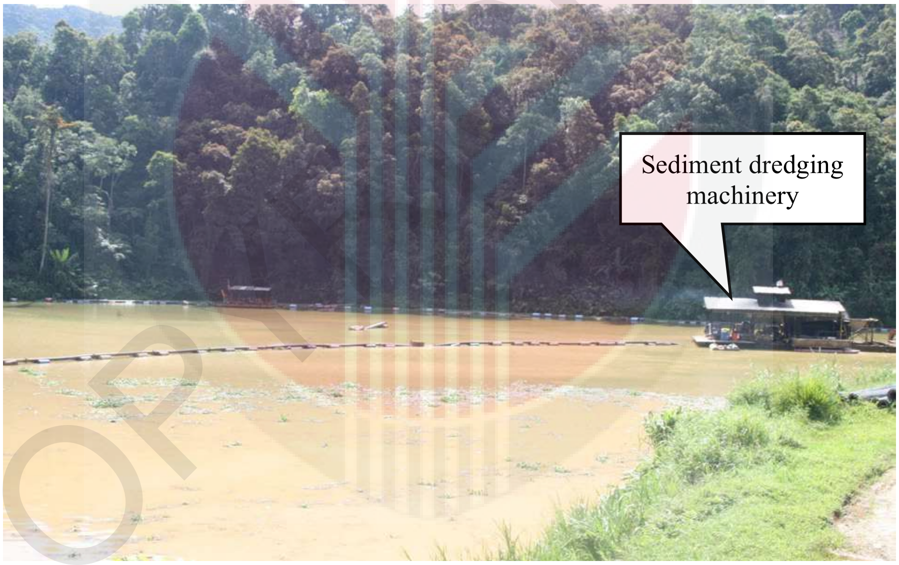

Figure 1.3 : Ringlet River in Cameron Highlands (Captured on 5th August 2018)

1.5 Research Hypothesis

Assessing the climate change inpact on environment is very crutial perticularly where the changes caused could be parmanent and irriversable. Soil erosion and sedimentation are among the phenomina that signifcantly affected by the impact of climate change. The higlands regions are chracterised with high slopes which lead to high energy of runoff which eventually cause significant soil erosion with slightest change in rainfall chracteristics. This study hypothesizes that:

- Multi-model ensemble of global circulation models (GCMs) will project future rainfall chraceristics with considerable degree of accuracy.

- Furure Intensity-Duration-Frquency curves will be higher than that of baseline condition which indicate higher tendancies of rainfall to cause more soil paticles detechments.

- There will be more soil erosion and sedimentation incidences at cameron Highlands by the 2050s and 2080s periods compared to the present scenario.

- Application of erosion control best management practices can profoundly reduce the maganitude of soil loss that might be caused by climate change in future.

- There will be a significant variation in projected soil loss scenarios between sheltered and open farming style.

1.6 Significance of the Study

Soil erosion has been an environmental degradation process that transforms the state of agricultural soil into non-productive or reduced productive potentials. Cameron Highlands is one of such areas that suffers soil degradation with many cases of erosion induced landslide incidences (Abdullah et al., 2019). The assessment of climate impact will help in knowing the extent of environmental input to the accelerating soil erosion and sedimentation in the study area. Also, prediction future incidents through projection of climate scenarios will help the policy and decision making more effective and to timely suggest environmental control measures. Furthermore, this will also help to address the possibility of reoccurrences of the problems and its consequential devastating effects of soil erosion and landslides.

1.7 Scope and Limitation of the Study

This research was aimed to conduct climate change impact assessment on soil erosion and sediment yields at Cameron Highlands watershed. It comprises the use of 20 ensemble GCMs, four emission scenarios and two projection periods only. The soil erosion assessment was conducted using revised universal soil loss equation (RUSLE) model. Rainfall erosivity (R), soil erodibility (K) and land use/cover (LULC) changes are the main focal points for making the erosion modelling. The current and future C-factor was based on literature and simulated future LULC states. Analysis of the LULC was achieved by using three past Landsat images while the projection was made by Land

Change Modeler in TerrSet software. Nevertheless, support management factor (P) has been assigned value of unity to inaccessible regions as suggested in the literature when it is difficult to distinguish the current practices due to illegal farming activities. Since the LS factor is not expected to change throughout the projection periods and therefore, the same value was maintained for all the projection scenarios. Three varieties of Mustard (Green Apex 5502, Lucket 9116 and Little Princess 822) were planted in both sheltered and open farms to study the effects of erosion control BMPs at Cameron Highlands (*Komplex Pertanian*), Department of Agriculture (DOA).

However, the study did not cover the crop evapotranspiration, and soil nutrients loss was not evaluated while quantifying the sediment loss, which is a vital component too. The Landsat images with 20 years records only were used in the analysis of land used changes and projections. Also, the K-factor did not cover all Cameron Highlands due to inaccessibility of remote forestlands, thus, existing soil series were used as compliment.

1.8 Research Objectives

1.8.1 Main Objective

The main objective of this study was to simulate the impact of climate change on soil erosion and sedimentation in future with application of Best Management Practices (BMPs) toward minimizing the projected effects at Cameron Highlands using Global Circulation Models.

1.8.2 Specific Objectives

1. To study the climate change effect on rainfall characteristics at Cameron Hihglands using 20 multi-model ensemble GCMs and two projection periods.
2. To determine the rainfall erosivity factor (R) under four RCP scenarios and crop management factor (R) for the Cameron Highlands watershed.
3. To determine the magnitude of soil erosion and sediment yields based on the four RCPs emission scenarios.
4. To suggest the suitable control BMPs by cultivating mustard crop at hilly farm of Cameron Highlands.

1.9 Thesis Structure and Outline

This thesis comprises of four main chapters – (1) Introduction (Background of the study, Introduction to Cameron Highlands, Research problem, Significance of the study, Scope, limitations and Objectives of the study), (2) Literature Review (Climate system, Introduction to climate change, Climate change drivers, Studies related to climate change in Malaysia, Hydrological processes, Soil erosion, Intensity-duration-frequency curves, Control BMPs, Description of models used, Downscaling, and Summary of the literature), (3) Material and Methods (Study location, Data source and types used, Land use prediction, Rainfall trend analysis, Runoff estimation, Development of IDF curves, Precipitation model validation, Soil erosion factors, Application of control BMPs, Experimental design, and Statistical analysis).

Lastly, chapter (4) Results and Discussion (Analysis of rainfall series, Temporal variability and precipitation concentration index, Spatial variability of precipitation, IDF curves projection, Peak runoff analysis, Current and future soil erosions, Analysis of land used and cover changes, Impact of climate change on projected soil erosion, Impact of climate change on sediment yields, Mustard crop yields performance, Analysis of sediment yields in opens and sheltered farms); and Summary and Conclusion (Research summary, Conclusion, Contribution of the current study, and Recommendation for future research).

REFERENCES

Abbaspour, K. C., Faramarzi, M., Ghasemi, S. S., & Yang, H. (2010). *Assessing the impact of climate change on water resources in Iran*. *45*(July 2009), 1–16. https://doi.org/10.1029/2008WR007615

Abdellah, M., Mohamed, H., & Farouk, D. (2018). The implication of climate change and precipitation variability on sedimentation deposits in Algerian dams. *Arabian Journal of Geosciences*, *11*(23). https://doi.org/10.1007/s12517-018-4100-7

Abdulkadir, T. S., Muhammad, R. U. M., Wan Yusof, K., Ahmad, M. H., Aremu, S. A., Gohari, A., & Abdurrasheed, A. S. (2019). Quantitative analysis of soil erosion causative factors for susceptibility assessment in a complex watershed. *Cogent Engineering*, *6*(1). https://doi.org/10.1080/23311916.2019.1594506

Abdulkareem, J. H., Pradhan, B., Sulaiman, W. N. A., & Jamil, N. R. (2019). Prediction of spatial soil loss impacted by long-term land-use/land-cover change in a tropical watershed. *Geoscience Frontiers*, *10*(2), 389–403. https://doi.org/10.1016/j.gsf.2017.10.010

Abdullah, A. F., Amiri, E., Daneshian, J., Teh, C. B. S., Wayayok, A., Massah Bavani, A., & Ahmadzadeh Araji, H. (2018). Impacts of climate change on soybean production under different treatments of field experiments considering the uncertainty of general circulation models. *Agricultural Water Management*, *205*(May), 63–71. https://doi.org/10.1016/j.agwat.2018.04.023

Abdullah, A. F., Wayayok, A., Nasidi, N. M., Hazari S. A. F, K., Sidek, L. M., & Selamat, Z. (2019). Modelling Erosion and Landslides Induced by Faming Activities at Hilly Farms. *Jurnal Teknologi*, *6*, 195–204.

Adhikari, S., & Southworth, J. (2012). Simulating forest cover changes of Bannerghatta National Park based on a CA-Markov model: a remote sensing approach. *Remote Sensing*, *4*(10), 3215–3243.

Al-sharif, A. A. A., & Pradhan, B. (2014). Monitoring and predicting land use change in Tripoli Metropolitan City using an integrated Markov chain and cellular automata models in GIS. *Arabian Journal of Geosciences*, *7*(10), 4291–4301. https://doi.org/10.1007/s12517-013-1119-7

Alder, S., Prasuhn, V., Liniger, H., Herweg, K., Hurni, H., Candinas, A., & Gujer, H. U. (2015). A high-resolution map of direct and indirect connectivity of erosion risk areas to surface waters in Switzerland-A risk assessment tool for planning and policy-making. *Land Use Policy*, *48*, 236–249. https://doi.org/10.1016/j.landusepol.2015.06.001

Alexakis, D., Hadjimitsis, D., & Agapiou, A. (2013). Integrated use of remote sensing, GIS and precipitation data for the assessment of soil erosion rate in the catchment area of "Yialias" in Cyprus. *Atmos. Res*, *131*, 108–124.

Almagro, A., Oliveira, P. T. S., Nearing, M. A., & Hagemann, S. (2017). Projected climate change impacts in rainfall erosivity over Brazil. *Scientific Reports*, *7*(1), 1–12. https://doi.org/10.1038/s41598-017-08298-y

Almazroui, M., Balkhair, K. S., Islam, M. N., & Şen, Z. (2017). Climate Change Impact on Monthly Precipitation Wet and Dry Spells in Arid Regions: Case Study over Wadi Al-Lith Basin. *Advances in Meteorology*, *2017*. https://doi.org/10.1155/2017/5132895

Amanambu, A. C., Li, L., Egbinola, C. N., Obarein, O. A.; Mupenzi, C.; Chen, D., Amanambu, A. C., Li, L., Egbinola, C. N., Obarein, O. A., Mupenzi, C., & Chen, D. (2019). Spatio-temporal variation in rainfall-runo ff erosivity due to climate change in the Lower Niger Basin, West Africa. *CATENA*, *172*(September 2018), 324–334. https://doi.org/10.1016/j.catena.2018.09.003

Amanina, N., Wahid, A., Wayayok, A., & Husain, M. C. (2018). *Water Management in Oil Palm Plantation for Control of G . Boninense : A Review on the Application of Nano-Porous Pipe*. *3*, 49–52.

Amin, I. M. Z. bin M., Ercan, A., Ishida, K., Kavvas, M. L., Chen, Z. Q., & Jang, S. H. (2019). Impacts of climate change on the hydro-climate of peninsular Malaysia. *Water (Switzerland)*, *11*(9), 1798. https://doi.org/10.3390/w11091798

Amin, M. Z. M., Shaaban, A. J., Ercan, A., Ishida, K., Kavvas, M. L., Chen, Z. Q., & Jang, S. (2017). Future climate change impact assessment of watershed scale hydrologic processes in Peninsular Malaysia by a regional climate model coupled with a physically-based hydrology modelo. *Science of the Total Environment*, *575*, 12–22. https://doi.org/10.1016/j.scitotenv.2016.10.009

Amirabadizadeh, M., Huang, Y. F., & Lee, T. S. (2015). Recent Trends in Temperature and Precipitation in the Langat River Basin, Malaysia. *Advances in Meteorology*, *2015*, 1–16. https://doi.org/10.1155/2015/579437

Amundson, R., Berhe, A. A., Hopmans, J. W., Olson, C., Sztein, A. E., & Sparks, D. L. (2015). Soil and human security in the 21st century. *Science*, *348*(6235), 1261071–1261071. https://doi.org/10.1126/science.1261071

Anand, J., Gosain, A. K., & Khosa, R. (2018). Prediction of land use changes based on Land Change Modeler and attribution of changes in the water balance of Ganga basin to land use change using the SWAT model. *Science of The Total Environment*, *644*, 503–519. https://doi.org/10.1016/j.scitotenv.2018.07.017

ASAE. (2011). *Standards for Engineering Practices and Data.* (S. Edition (ed.); Issue 565). Adopted and Published by American Society of Apicultural and Biological Engineers.

Azim, F., Shakir, A. S., Habib-ur-Rehman, & Kanwal, A. (2016). Impact of climate change on sediment yield for Naran watershed, Pakistan. *International Journal of Sediment Research*, *31*(3), 212–219. https://doi.org/10.1016/j.ijsrc.2015.08.002

Babel, M., & Plangoen, P. (2015). Projected Rainfall Erosivity Changes under Future Climate in the Upper Nan Watershed, Thailand. *Journal of Earth Science & Climatic Change*, *05*(10). https://doi.org/10.4172/2157-7617.1000242

Babur, M., Babel, M. S., Shrestha, S., Kawasaki, A., & Tripathi, N. K. (2016). Assessment of climate change impact on reservoir inflows using multi climate-models under RCPs-the case of Mangla Dam in Pakistan. *Water (Switzerland)*, *8*(9). https://doi.org/10.3390/w8090389

Barbosa, R. S., Marques Júnior, J., Barrón, V., Martins Filho, M. V., Siqueira, D. S., Peluco, R. G., Camargo, L. A., & Silva, L. S. (2019). Prediction and mapping of erodibility factors (USLE and WEPP) by magnetic susceptibility in basalt-derived soils in northeastern São Paulo state, Brazil. *Environmental Earth Sciences*, *78*(1), 1–12. https://doi.org/10.1007/s12665-018-8015-0

Barrow, C. J., CLifton, J., CHan, C. W., & TAn, Y. L. (2005). Sustainable Development in the Cameron Highlands, Malaysia. *Journal of Environmental Management*, *6*, 41–57.

Basher, L., Douglas, G., Elliott, S., Hughes, A., Jones, H., McIvor, I., Page, M., Rosser, B., & Tait, A. (2012). *Impacts of climate change on erosion and erosion control methods – A critical review* (Vol. 4, Issue November). https://www.mpi.govt.nz/document-vault/4074

Basher, Les, Betts, H., Lynn, I., Marden, M., McNeill, S., Page, M., & Rosser, B. (2018). A preliminary assessment of the impact of landslide, earthflow, and gully erosion on soil carbon stocks in New Zealand. *Geomorphology*, *307*, 93–106. https://doi.org/10.1016/j.geomorph.2017.10.006

Batista, P. V. G., Silva, M. L. N., Silva, B. P. C., Curi, N., Bueno, I. T., Júnior, F. W. A., Davies, J., & Quinton, J. (2017). Modelling spatially distributed soil losses and sediment yield in the upper Grande River Basin - Brazil. *CATENA*, *157*, 139–150. https://doi.org/https://doi.org/10.1016/j.catena.2017.05.025

Begou, B., Youngers, N., Adhikari, V., Yihun, Y., & Lankarani, H. (2016). Design and control of an active palm roll joint for the human prosthetic hand. *International Design Engineering Technical Conferences and Computers and Information in Engineering Conference*, *50138*, V003T11A013.

Begou, J. C., Jomaa, S., Benabdallah, S., Bazie, P., Afouda, A., & Rode, M. (2016). Multi-site validation of the SWAT model on the Bani catchment: Model performance and predictive uncertainty. *Water (Switzerland)*, *8*(5). https://doi.org/10.3390/w8050178

Bivi, M. R., Farhana, M. S. N., Khairulmazmi, A., & Idris, A. (2010). Control of Ganoderma boninense : A Causal Agent of Basal Stem Rot Disease in Oil Palm with Endophyte Bacteria In Vitro Control of Ganoderma boninense : A Causal Agent of Basal Stem Rot Disease in Oil Palm with Endophyte Bacteria In Vitro. *International Journa of Agriculture and BIology*, *12*(September 2015), 12:833-839.

Blanco H, L. R., Blanco-Canqui, H., & Lal, R. (2008). *Principles of soil conservation and management*. Springer Science+Business Media B.V, Berlin, p.

Boakye, E., Odai, S. N., Adjei, K. A., & Annor, F. O. (2008). Landsat images for assessment of the impact of land use and land cover changes on the Barekese catchment in Ghana. *European Journal of Scientific Research*, *22*(2), 269–278.

Bols, P. (1978). *The Iso-erodent Map of Java and Madura. Belgian Technical Assistance Project ATA 105, Soil Research Institute, Bogor. Choy, Indonesia*.

Borrelli, P., Robinson, D. A., Fleischer, L. R., Lugato, E., Ballabio, C., Alewell, C., Meusburger, K., Modugno, S., Schütt, B., Ferro, V., Bagarello, V., Oost, K. Van, Montanarella, L., & Panagos, P. (2017). An assessment of the global impact of 21st century land use change on soil erosion. *Nature Communications*, *8*(1). https://doi.org/10.1038/s41467-017-02142-7

Bosco, C., De Rigo, D., Dewitte, O., Poesen, J., & Panagos, P. (2015). Modelling soil erosion at European scale: Towards harmonization and reproducibility. *Natural Hazards and Earth System Sciences*, *15*(2), 225–245. https://doi.org/10.5194/nhess-15-225-2015

Bussi, G., Dadson, S. J., Prudhomme, C., & Whitehead, P. G. (2016). Modelling the future impacts of climate and land-use change on suspended sediment transport in the River Thames (UK). *Journal of Hydrology*, *542*, 357–372. https://doi.org/10.1016/j.jhydrol.2016.09.010

Buytaert, W., Vuille, M., Dewulf, A., Urrutia, R., Karmalkar, A., & Célleri, R. (2010). Uncertainties in climate change projections and regional downscaling in the tropical Andes: Implications for water resources management. *Hydrology and Earth System Sciences*, *14*(7), 1247–1258. https://doi.org/10.5194/hess-14-1247-2010

Caloiero, T., Coscarelli, R., Ferrari, E., & Sirangelo, B. (2015). Analysis of dry spells in southern Italy (Calabria). *Water (Switzerland)*, *7*(6), 3009–3023. https://doi.org/10.3390/w7063009

Choi, J., Lee, O., Jang, J., Jang, S., & Kim, S. (2019). Future intensity-depth-frequency curves estimation in Korea under representative concentration pathway scenarios of Fifth assessment report using scale-invariance method. *International Journal of Climatology*, *39*(2), 887–900. https://doi.org/10.1002/joc.5850

Choubin, B., Darabi, H., Rahmati, O., Sajedi-Hosseini, F., & Kløve, B. (2018). River suspended sediment modelling using the CART model: A comparative study of machine learning techniques. *Science of the Total Environment*, *615*, 272–281. https://doi.org/10.1016/j.scitotenv.2017.09.293

Chow, V. T., Maidment, D. R., Mays, L. W., Chow, Maidment, D. R., & Mays, L. W. (1988). *Applied Hydrology*. McGraw-Hill Book Company, New York, NY, USA.

Clark Labs. (2012). *Idrisi Selva help system in TerSet*. Clark University, USA.

Claudia, C. P. E. H., & Mark, L. P. E. (2011). Application of Inflow Design Flood Analysis to the Analysis and Design of High Hazard Dams in NRCS. *Watershed Management*, *60*, 431–442.

Congalton, R. G. (1991). A review of assessing the accuracy of classifications of remotely sensed data. *Remote Sensing of Environment*, *37*(1), 35–46. https://doi.org/10.1016/0034-4257(91)90048-B

Congalton, R. G. (2001). Accuracy assessment and validation of remotely sensed and other spatial information. *International Journal of Wildland Fire*, *10*(3–4), 321–328. https://doi.org/10.1071/wf01031

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. https://doi.org/10.1016/j.catena.2016.07.003

de Hipt, F. O., Diekkrüger, B., Steup, G., Yira, Y., Hoffmann, T., Rode, M., & Näschen, K. (2019). Modeling the effect of land use and climate change on water resources and soil erosion in a tropical West African catch-ment (Dano, Burkina Faso) using SHETRAN. *Science of The Total Environment*, *653*, 431–445. https://doi.org/https://doi.org/10.1016/j.scitotenv.2018.10.351

de Luis, M., González-Hidalgo, J. C., Brunetti, M., & Longares, L. A. (2011). Precipitation concentration changes in Spain 1946–2005. *Natural Hazards and Earth System Sciences*, *11*(5), 1259–1265. https://doi.org/10.5194/nhess-11-1259-2011

de Mello, C. R., Ávila, L. F., Viola, M. R., Curi, N., & Norton, L. D. (2015). Assessing the climate change impacts on the rainfall erosivity throughout the twenty-first century in the Grande River Basin (GRB) headwaters, Southeastern Brazil. *Environmental Earth Sciences*, *73*(12), 8683–8698. https://doi.org/10.1007/s12665-015-4033-3

DID. (2012). Urban Stormwater Management Manual for Malaysia. In Nor Azazi Zakaria, A. A. Ghani, & C. K. Chang (Eds.), *Manual* (2nd ed.). Department of Irrigation and Drainage (DID) Malaysia.

Douglas, I. (1987). *Natural and Man-Made Erosion in the Humid Tropics of Australia, Malaysia and Singapore*. Department of Geography University of Hull, U.K.

Duan, X., Gu, Z., Li, Y., & Xu, H. (2016). The spatiotemporal patterns of rainfall erosivity in Yunnan Province, southwest China: An analysis of empirical orthogonal functions. *Global and Planetary Change*, *144*, 82–93. https://doi.org/10.1016/j.gloplacha.2016.07.011

Ehmele, F., & Kunz, M. (2019). Flood-related extreme precipitation in southwestern Germany: Development of a two-dimensional stochastic precipitation model. *Hydrology and Earth System Sciences*, *23*(2), 1083–1102. https://doi.org/10.5194/hess-23-1083-2019

Eisakhani, M., Abdullah, M. P., Karim, O. A., & Malakahmad, A. (2015). Best management practices for water quality improvement of Bertam River, Malaysia. *International Journal of Applied Engineering Research*, *10*(2), 3923–3935.

Elagib, N. A. (2011). Changing rainfall, seasonality and erosivity in the hyper-arid zone of Sudan. *Land Degradation & Development*, *22*(6), 505–512. https://doi.org/10.1002/ldr.1023

Elangovan, A., & Seetharaman, R. (2011). Estimating Rainfall Erosivity of the Revised Universal Soil Loss Equation from daily rainfall depth in Krishanagiri Watershed region of Tamil Nadu, India. *International Conference on …*, *19*, 48–52. http://www.ipcbee.com/vol19/10-ICECS2011R00018.pdf

Fagbohun, B. J., Anifowose, A. Y. B., Odeyemi, C., Aladejana, O. O., & Aladeboyeje, A. I. (2016). GIS-based estimation of soil erosion rates and identification of critical areas in Anambra sub-basin, Nigeria. *Modeling Earth Systems and Environment*, *2*(3), 159. https://doi.org/10.1007/s40808-016-0218-3

Fan, J., Yan, L., Wu, L., Zhang, P., & Zhang, G. (2019). Estimation and prediction of the soil erosion risk influenced by the urbanization process within a county in hilly area of southeast China, using rusle and clues model. *Applied Ecology and Environmental Research*, *17*(1), 855–878. https://doi.org/10.15666/aeer/1701_855878

Fenta, A. A., Yasuda, H., Shimizu, K., Haregeweyn, N., Kawai, T., Sultan, D., Ebabu, K., & Belay, A. S. (2017). Spatial distribution and temporal trends of rainfall and erosivity in the Eastern Africa region. *Hydrological Processes*, *31*(25), 4555–4567. https://doi.org/10.1002/hyp.11378

Ferreira, V., & Panagopoulos, T. (2014). Seasonality of soil erosion under Mediterranean conditions at the Alqueva dam watershed. *Environmental Management*, *54*(1), 67–83. https://doi.org/10.1007/s00267-014-0281-3

Fischer, B. M. C., Mul, M. L., & Savenije, H. H. G. (2013). Determining spatial variability of dry spells: A Markov-based method, applied to the Makanya catchment, Tanzania. *Hydrology and Earth System Sciences*, *17*(6), 2161–2170. https://doi.org/10.5194/hess-17-2161-2013

Foody, G. M. (2002). Status of land cover classification accuracy assessment. *Remote Sensing of Environment*, *80*(1), 185–201. https://doi.org/10.1016/S0034-4257(01)00295-4

Foster, G. R., McCool, D. K., Renard, K. G., & Moldenhauer, W. C. (1981). Conversion of the universal soil loss equation to SI metric units. *Journal of Soil and Water Conservation*, *36*(6), 355–359.

Fu, L., Zhang, L., & He, C. (2014). Analysis of agricultural land use change in the middle reach of the Heihe River Basin, Northwest China. *International Journal of Environmental Research and Public Health*, *11*(3), 2698–2712. https://doi.org/10.3390/ijerph110302698

Fujibe, F., Yamazaki, N., Katsuyama, M., & Kobayashi, K. (2005). The Increasing Trend of Intense Precipitation in Japan Based on Four-hourly Data for a Hundred Years. *SOLA*, *1*, 41–44. https://doi.org/10.2151/sola.2005-012

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. https://doi.org/10.1016/j.gsf.2015.10.007

Gao, J.-Z., Long, Y., Zhang, X.-B., Collins, A. L., He, X.-B., Zhang, Y.-Q., & Shi, Z.-L. (2016). Interpreting sedimentation dynamics at Longxi catchment in the Three Gorges Area, China, using Cs-137 activity, particle size and rainfall erosivity. *Journal of Mountain Science*, *13*(5), 857–869. https://doi.org/10.1007/s11629-015-3637-0

Gashaw, T., Tulu, T., Argaw, M., & Worqlul, A. W. (2017). Evaluation and prediction of land use/land cover changes in the Andassa watershed, Blue Nile Basin, Ethiopia. *Environmental Systems Research*, *6*(1). https://doi.org/10.1186/s40068-017-0094-5

Gashaw, T., Tulu, T., Argaw, M., & Worqlul, A. W. (2019). Modeling the impacts of land use–land cover changes on soil erosion and sediment yield in the Andassa watershed, upper Blue Nile basin, Ethiopia. *Environmental Earth Sciences*, *78*(24). https://doi.org/10.1007/s12665-019-8726-x

Gasim, M. B., Mokhtar, M., Surif, S., Toriman, M. E., Rahim, S. A., & Lun, P. I. (2012). Analysis of thirty years recurrent floods of the Pahang River, Malaysia. *Asian Journal of Earth Sciences*, *5*(1), 25–35. https://doi.org/10.3923/ajes.2012.25.35

Gebrehiwot, S. G., Bewket, W., Gärdenäs, A. I., & Bishop, K. (2014). Forest cover change over four decades in the Blue Nile Basin, Ethiopia: Comparison of three watersheds. *Regional Environmental Change*, *14*(1), 253–266. https://doi.org/10.1007/s10113-013-0483-x

Gericke, A., Kiesel, J., Deumlich, D., & Venohr, M. (2019). Recent and future changes in rainfall erosivity and implications for the soil erosion risk in Brandenburg, NE Germany. *Water (Switzerland)*, *11*(5). https://doi.org/10.3390/w11050904

Ghani, A. A., Lo, C. H., & Chung, S. L. (2013). Basaltic dykes of the Eastern Belt of Peninsular Malaysia: The effects of the difference in crustal thickness of Sibumasu and Indochina. *Journal of Asian Earth Sciences*, *77*, 127–139. https://doi.org/10.1016/j.jseaes.2013.08.004

Ghani, A. H. A., Lihan, T., Rahim, S. A., Musthapha, M. A., Idris, W. M. R., & Rahman, Z. A. (2013). Prediction of sedimentation using integration of RS, RUSLE model and GIS in Cameron Highlands, Pahang, Malaysia. *AIP Conference Proceedings*, *1571*(December 2013), 543–548. https://doi.org/10.1063/1.4858711

Gholami, V., Booij, M. J., Tehrani, E. N., & Hadian, M. A. (2018). Spatial soil erosion estimation using an artificial neural network (ANN) and field plot data. *CATENA*, *163*, 210–218. https://doi.org/https://doi.org/10.1016/j.catena.2017.12.027

Giang, P., Giang, L., & Toshiki, K. (2017). Spatial and Temporal Responses of Soil Erosion to Climate Change Impacts in a Transnational Watershed in Southeast Asia. *Climate*, *5*(1), 22. https://doi.org/10.3390/cli5010022

González-Morales, S. B., Mayer, A., & Ramírez-Marcial, N. (2018). Assessment of soil erosion vulnerability in the heavily populated and ecologically fragile communities in Motozintla de Mendoza, Chiapas, Mexico. *Solid Earth*, *9*(3), 745–757. https://doi.org/10.5194/se-9-745-2018

Gregersen, B., Lauridsen, P. E., Kaas, M., Lopdrup, U., & Keur, P. Van Der. (2003). Land Use and Soil Erosion in Tikolod ,. *ASEAN Review of Biodiversity and Environmental Conservation*, *17*(March), 1–11. https://doi.org/10.1179/009346990791548628

Hailegeorgis, T. T., & Alfredsen, K. (2017). Analyses of extreme precipitation and runoff events including uncertainties and reliability in design and management of urban water infrastructure. *Journal of Hydrology*, *544*, 290–305. https://doi.org/10.1016/j.jhydrol.2016.11.037

Haiyan, F., & Liying, S. (2017). Modelling soil erosion and its response to the soil conservation measures in the black soil catchment, Northeastern China. *Soil and Tillage Research*, *165*, 23–33. https://doi.org/https://doi.org/10.1016/j.still.2016.07.015

Hanaish, I. S., Ibrahim, K., & Jemain, A. A. (2011). Daily rainfall disaggregation using HYETOS model for Peninsular Malaysia. *International Conference on Applied Mathematics, Simulation, Modelling - Proceedings*, *January*, 146–150.

Herrero, A., Buendía, C., Bussi, G., Sabater, S., Vericat, D., Palau, A., & Batalla, R. J. (2017). Modeling the sedimentary response of a large Pyrenean basin to global change. *Journal of Soils and Sediments*, *17*(11), 2677–2690. https://doi.org/10.1007/s11368-017-1684-6

Holz, D. J., Williard, K. W. J., Edwards, P. J., & Schoonover, J. E. (2015). Soil erosion in humid regions: a review. *Journal of Contemporary Water Research & Education*, *154*(1), 48–59.

Hosking, J. R. M. (1990). L-moments: Analysis and estimation of distributions using linear combinations of order statistics. *J. R. Stat. Soc. B*, *52*, 105–124.

Hosking, J. R. M., & Wallis, J. R. (1997). *Regional Frequency Analysis: An Approach Based on L-Moments*. Cambridge University Press: New York, NY, USA.

Hosseinpour, A., Dolcine, L., & Fuamba, M. (2014). Natural flow reconstruction Using Kalman filter and water balance-based methods II: Case studies, results, and discussion. *Journal of Hydrologic Engineering*, *19*(12), 1040–1049. https://doi.org/10.1061/(ASCE)HE.1943-5584

Hurni, H., Tato., K., & Gete, Z. (2005). The implications of changes in population, land use, and land management for surface runoff in the Upper Nile basin area of

Ethiopia. *Mt Res Dev.*, *25*(2), 147–154.

Hurni, Hans. (1988). Degradation and conservation of the resources in the Ethiopian highlands. *Mountain Research and Development*, 123–130.

IPCC. (2013). *IPCC (2013) Summary for Policymakers. In: Climate Change 2013: The Physical Science Basis, Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University*. https://selectra.co.uk/sites/selectra.co.uk/files/pdf/Climate change 2013.pdf

IPCC. (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*.

Ismail, M., Che, K., Othman, C., Abd Malek, I., & Abdullah, S. (2012). Land use trends analysis using SPOT-5 images and its effect on the landscape of Cameron Highlands, Malaysi. *Asian J Geoinformatics*, *12*(1), 1–8.

Jain, M., & Kothyari, U. C. (2000). Estimation of soil erosion and sediment yield using GIS. *Hydrol Sci*, *45*, 771–786.

Javelle, P., Ouarda, T. B. M. J., Lang, M., Bobée, B., Galéa, G., & Grésillon, J. M. (2002). Development of regional flood-duration-frequency curves based on the index-flood method. *Journal of Hydrology*, *258*(1–4), 249–259. https://doi.org/10.1016/S0022-1694(01)00577-7

Kaffashi, S., Radam, A., Shamsudin, M. N., Yacob, M. R., & Nordin, N. H. (2015). Ecological conservation, ecotourism, and sustainable management: The case of Penang National Park. *Forests*, *6*(7), 2345–2370. https://doi.org/10.3390/f6072345

Kang, Y., Khan, S., & Ma, X. (2009). Climate change impacts on crop yield, crop water productivity and food security - A review. *Progress in Natural Science*, *19*(12), 1665–1674. https://doi.org/10.1016/j.pnsc.2009.08.001

Khambhammettu, P. (2005). Mann-Kendall test analysis for the Fort Ord Site, Ohio. *Annual Groundwater Monitoring Report, Former Fort Ord, California, USA*.

Khassaf, S., & Al Rammahi, A. (2018). Estimation of Slope Length Factor (L) and Slope Steepness Factor (S) of Rusle Equation in the Euphrates River Watershed By Gis Modeling. *Kufa Journal of Engineering*, *9*(3), 81–91. https://doi.org/10.30572/2018/kje/090307

Kim, J., & Ivanov, V. Y. (2015). A holistic, multi-scale dynamic downscaling framework for climate impact assessments and challenges of addressing finer-scale watershed dynamics. *Journal of Hydrology*, *522*, 645–660. https://doi.org/10.1016/j.jhydrol.2015.01.025

Klik, A., Haas, K., Dvorackova, A., & Fuller, I. C. (2015). Spatial and temporal distribution of rainfall erosivity in New Zealand. *Soil Research*, *53*(7), 815–825. https://doi.org/10.1071/SR14363

Knijff, J. M., Jones, R. J. A., & Montanarella, L. (2000). Soil Erosion Risk Assessment in Europe. *EUR 19044 EN. Luxembourg: Office for Official Publications of the European Communities*, *EUR 19044*(EN), 32 pp. https://doi.org/citeulike-article-id:13481385

Knoben, W. J. M., Freer, J. E., & Woods, R. A. (2019). Technical note: Inherent benchmark or not? Comparing Nash-Sutcliffe and Kling-Gupta efficiency scores. *Hydrology and Earth System Sciences*, *23*(10), 4323–4331. https://doi.org/10.5194/hess-23-4323-2019

Koutsoyiannis, D., & Onof, C. (2001). Rainfall disaggregation using adjusting procedures on a Poisson cluster model. *Journal of Hydrology*, *246*(1–4), 109–122. https://doi.org/10.1016/S0022-1694(01)00363-8

Kristvik, E., Johannessen, B., & Muthanna, T. (2019). Temporal Downscaling of IDF Curves Applied to Future Performance of Local Stormwater Measures. *Sustainability*, *11*(5), 1231. https://doi.org/10.3390/su11051231

Kwan, M. S., Tanggang, F. T., & Juneng, L. (2011). Projected changes of future climate extremes in Malaysia. National Symposium on Climate Change Adaptation. *Sains Malaysiana*, *42*(8), 1051–1058.

Lal, R. (1994). Water management in various crop production systems related to soil tillage. *Soil Tillage Res.*, *30*, 169-185.

Lana, X., Casas-Castillo, M. C., Serra, C., Rodríguez-Solà, R., Redaño, A., Burgueño, A., & Martínez, M. D. (2019). Return period curves for extreme 5-min rainfall amounts at the Barcelona urban network. *Theoretical and Applied Climatology*, *135*(3–4), 1243–1257. https://doi.org/10.1007/s00704-018-2434-4

Lee, J. P. (2007). Estimation of Rainfall-runoff Erosivity for Individual Storm Events. *Journal of Hydrology*, *160*(537), 2007.

Leow, C. S., Engineering, R., & Drainage, U. (2011). *Development of rainfall erosivity isohyet map for Peninsular Malaysia*. *December*, 748–756.

Li, S. H., Jin, B. X., Wei, X. Y., Jiang, Y. Y., & Wang, J. L. (2015). Using CA-Markov Model to Model the Spatiotemporal Change of Land Use/Cover in Fuxian Lake for Decision Support. In *ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences* (Vol. 2, Issue 4W2). https://doi.org/10.5194/isprsannals-II-4-W2-163-2015

Li, X., & Ye, X. (2018). Variability of rainfall erosivity and erosivity density in the Ganjiang River Catchment, China: Characteristics and influences of climate change. *Atmosphere*, *9*(2). https://doi.org/10.3390/atmos9020048

Li, Zhiying, & Fang, H. (2016). Impacts of climate change on water erosion: A review. *Earth-Science Reviews*, *163*, 94–117. https://doi.org/https://doi.org/10.1016/j.earscirev.2016.10.004

Li, Zhongwu, Huang, J., Zeng, G., Nie, X., Ma, W., Yu, W., Guo, W., & Zhang, J. (2013). Effect of Erosion on Productivity in Subtropical Red Soil Hilly Region: A Multi-Scale Spatio-Temporal Study by Simulated Rainfall. *PLoS ONE*, *8*(10), 1–10. https://doi.org/10.1371/journal.pone.0077838

Liew, S. C., Raghavan, S. V., & Liong, S. Y. (2014). How to construct future IDF curves, under changing climate, for sites with scarce rainfall records? *Hydrological Processes*, *28*(8), 3276–3287. https://doi.org/10.1002/hyp.9839

Litschert, S. E., Theobald, D. M., & Brown, T. C. (2014). Effects of climate change and wildfire on soil loss in the Southern Rockies Ecoregion. *Catena*, *118*, 206–219. https://doi.org/10.1016/j.catena.2014.01.007

Liu, Q. J., An, J., Wang, L. Z., Wu, Y. Z., & Zhang, H. Y. (2015). Influence of ridge height, row grade, and field slope on soil erosion in contour ridging systems under seepage conditions. *Soil and Tillage Research*, *147*, 50–59. https://doi.org/https://doi.org/10.1016/j.still.2014.11.008

Liu, Y. H., Li, D. H., Chen, W., Lin, B. S., Seeboonruang, U., & Tsai, F. (2018). Soil erosion modeling and comparison using slope units and grid cells in Shihmen reservoir watershed in Northern Taiwan. *Water (Switzerland)*, *10*(10). https://doi.org/10.3390/w10101387

Lujan, D., & Gabriels, D. (2005). Assessing the rain erosivity and rain distribution in different agro-climatological zones in Venezuela. *Sociedade Natureza*, *Special Issue*, 16–29.

Madsen, H., Mikkelsen, P. S., Rosbjerg, D., & Harremoës, P. (2002). Regional estimation of rainfall intensity-duration-frequency curves using generalized least squares regression of partial duration series statistics. *Water Resources Research*, *38*(11), 21-1-21–11. https://doi.org/10.1029/2001wr001125

Malarvizhi, K., Kumar, S. V., & Porchelvan, P. (2016). Use of High Resolution Google Earth Satellite Imagery in Landuse Map Preparation for Urban Related Applications. *Procedia Technology*, *24*(December 2016), 1835–1842. https://doi.org/10.1016/j.protcy.2016.05.231

Mansor, N., Rashid, K. M., Mohamad, Z., & Abdullah, Z. (2015). Agro Tourism Potential in Malaysia. *International Academic Research Journal of Business and Technology*, *1*(2), 37–44. http://www.iarjournal.com/wp-content/uploads/IBTC2015-p37-44.pdf

Markus, M., Angel, J., Wang, K., Byard, G., Mcconkey, S., & Zaloudek, Z. (2017). *Impacts of potential future climate change on the expected frequency of extreme rainfall events in Cook, DuPage, Lake, and Will Counties in Northeastern Illinois*. *December*.

Marziali, L., Tartari, G., Salerno, F., Valsecchi, L., Bravi, C., Lorenzi, E., Genoni, P., & Guzzella, L. (2017). Climate change impacts on sediment quality of Subalpine reservoirs: Implications on management. *Water (Switzerland)*, *9*(9), 1–18.

https://doi.org/10.3390/w9090680

Matonse, A. H., Anandhi, A., Frei, A., Pierson, D. C., Schneiderman, E. M., Zion, M. S., & Lounsbury, D. (2011). Examination of change factor methodologies for climate change impact assessment. *Water Resources Research*, *47*(3). https://doi.org/10.1029/2010WR009104

McGehee, R., & Srivastava, P. (2018). Benchmarking reliable erosion indices from quarter-hour station data for climate studies in the southeastern United States. *Journal of Soil and Water Conservation*, *73*(4), 363–376. https://doi.org/10.2489/jswc.73.4.363

Mehlum, H., Torvik, R., & Moene, K. (2006). Insitutions and the Resource Curse. *Economic Journal*, *116*, 1–20. https://doi.org/10.1111/j.1468-0297.2006.01045.x

Miller, K., Miller, K. A., & Yates, D. (2014). Climate Change and Water Resources : A Primer for Water Utilities CLIMATE CHANGE AND WATER RESOURCES : A Primer for Water Utilities Preliminary Draft Not for citation or reproduction – all figure permissions are pending National Center for Atmospheric Res. *The National Center for Atmospheric Research*, *January 2005*.

Minasny, B., Mcbratney, A. B., Mckenzie, N. J., & Grundy, M. J. (2008). Predicting soil properties using pedotransfer functions and environmental correlation. *Guidelines for Surveying Soil and Land Resources*, *1983*, 349–367.

Mispan, M. R., Haron, S. H., Ismail, B. S., Abd Rahman, N. F., Khalid, K., & Abdul Rasid, M. Z. (2015). The Use of Pesticides in Agriculture Area , Cameron Highlands. *International Journal of Scientific Progress and Research (Ijspr)*, *15*(1), 19–22. www.ijspr.com

Mohd-Ariffin, A. R., Md Ali, Z., Zainol, R., Rahman, S., Ang, K. H., & Sabran, N. (2014). Sustainable Highland Development through Stakeholders' Perceptions on Agro EcoTourism in Cameron Highlands: A Preliminary Finding. *SHS Web of Conferences*, *12*(December 2014), 01086. https://doi.org/10.1051/shsconf/20141201086

Mondal, A., Khare, D., & Kundu, S. (2016). Change in rainfall erosivity in the past and future due to climate change in the central part of India. *International Soil and Water Conservation Research*, *4*(3), 186–194. https://doi.org/10.1016/j.iswcr.2016.08.004

Moore, I. D., & Burch, G. J. (1986). Physical Basis of the Length-slope Factor in the Universal Soil Loss Equation. *Soil Science Society of America Journal*, *50*(5), 1294–1298. https://doi.org/10.2136/sssaj1986.03615995005000050042x

Morgan, R. (2005). *Soil erosion and conservation* (Third). Blackwell Science, Oxford.

Morgan, Royston, & Philip, C. (2009). *Soil erosion and conservation*. John Wiley & Sons.

Mosammam, H. M., Nia, J. T., Khani, H., Teymouri, A., & Kazemi, M. (2016). Monitoring land use change and measuring urban sprawl based on its spatial forms: The case of Qom city. *Egyptian Journal of Remote Sensing and Space Science*, *20*(1), 103–116. https://doi.org/10.1016/j.ejrs.2016.08.002

Najibi, N., Devineni, N., & Lu, M. (2017). Hydroclimate drivers and atmospheric teleconnections of long duration floods: An application to large reservoirs in the Missouri River Basin. *Advances in Water Resources*, *100*, 153–167. https://doi.org/10.1016/j.advwatres.2016.12.004

Neal, M. R., Nearing, M. A., Vining, R. C., Southworth, J., & Pfeifer, R. A. (2005). Climate change impacts on soil erosion in Midwest United States with changes in crop management. *Catena*, *61*(2-3 SPEC. ISS.), 165–184. https://doi.org/10.1016/j.catena.2005.03.003

Nearing, M. A., Unkrich, C. L., Goodrich, D. C., Nichols, M. H., & Keefer, T. O. (2015). Temporal and elevation trends in rainfall erosivity on a 149 km2 watershed in a semi-arid region of the American Southwest. *International Soil and Water Conservation Research*, *3*(2), 77–85. https://doi.org/10.1016/j.iswcr.2015.06.008

Nearing, M., Foster, G., Lane, L., & Flinkener, S. (1989). A process based soil erosion model for USDA water erosion prediction project technology. *ASCE*, *32*, 1587–1593.

Neelin, J. D. (2011). *Climate Change and Climate Modeling* (L. A. University of California (ed.)). Cambridge University Press 978-0-521-84157-3 -.

Nickel, P. M., & Eikenberry, A. M. (2019). The Impact of Natural Disasters can Affect Economic Sustainability and Development. *Journal of Southwest Jiaotong University*, *54*(October), 1–12. https://doi.org/10.35741/0258-2724.54.5.17

Nicu, I. C., & Asăndulesei, A. (2018). GIS-based evaluation of diagnostic areas in landslide susceptibility analysis of Bahluieț River Basin (Moldavian Plateau, NE Romania). Are Neolithic sites in danger? *Geomorphology*, *314*, 27–41. https://doi.org/10.1016/j.geomorph.2018.04.010

Nigam, G. K., Sahu, R. K., Sinha, M. K., Deng, X., Singh, R. B., & Kumar, P. (2017). Field assessment of surface runoff, sediment yield and soil erosion in the opencast mines in Chirimiri area, Chhattisgarh, India. *Physics and Chemistry of the Earth, Parts A/B/C*, *101*, 137–148. https://doi.org/https://doi.org/10.1016/j.pce.2017.07.001

Nkunzimana, A., Bi, S., Jiang, T., Wu, W., & Abro, M. I. (2019). Spatiotemporal variation of rainfall and occurrence of extreme events over Burundi during 1960 to 2010. *Arabian Journal of Geosciences*, *12*(5). https://doi.org/10.1007/s12517-019-4335-y

Noh, N. S. M., Sidek, L. M., Wayayok, A., Abdullah, A. F., Basri, H., & Farhan, S. A. (2019). Erosion and Sediment Control Best Management Practices in Agricultural Farms for Effective Reservoir Sedimentation Management at Cameron Highlands.

International Journal of Recent Technology and Engineering, *8*(4), 6198–6205. https://doi.org/10.35940/ijrte.d5138.118419

Nunes, A. N., Lourenço, L., Vieira, A., & Bento-Gonçalves, A. (2016). Precipitation and Erosivity in Southern Portugal: Seasonal Variability and Trends (1950-2008). *Land Degradation and Development*, *27*(2), 211–222. https://doi.org/10.1002/ldr.2265

Oldeman, L., Van Lynden, G., & Van Engelen, V. (1995). An international methodology for soil degradation assessment and for a soils and terrain digital database (SOTER). *Paper Presented at the Regional Workshop on Assessment and Monitoring of Land Degradation Cairo, May 13-15, 1995.*

Oliver, J. (1980). *Monthly precipitation distribution: a comparative index.* (Vol. 32). Prof Geogr.

Oliver, T. H., Gillings, S., Pearce-Higgins, J. W., Brereton, T., Crick, H. Q. P., Duffield, S. J., Morecroft, M. D., & Roy, D. B. (2017). Large extents of intensive land use limit community reorganization during climate warming. *Global Change Biology*, *23*(6), 2272–2283. https://doi.org/10.1111/gcb.13587

Olmedo, C., María, T., Pontius, R. G., Paegelow, M., & Mas, J.-F. (2015). Comparison of simulation models in terms of quantity and allocation of land change. *Environmental Modelling & Software*, *69*, 214–221. https://doi.org/10.1016/j.envsoft.2015.03.003

Oloruntade, A., Mohammed, T. a., & Aimrun, W. (2017). *Rainfall Trends in the Niger-South Basin , Nigeria, SCIENCE & TECHNOLOGY 1948-2008*. *25*(2), 479–496.

Op de Hipt, F., Diekkrüger, B., Steup, G., Yira, Y., Hoffmann, T., & Rode, M. (2018). Modeling the impact of climate change on water resources and soil erosion in a tropical catchment in Burkina Faso, West Africa. *CATENA*, *163*(August 2017), 63–77. https://doi.org/10.1016/j.catena.2017.11.023

Ostovari, Y., Ghorbani-Dashtaki, S., Bahrami, H. A., Naderi, M., Dematte, J. A. M., & Kerry, R. (2016). Modification of the USLE K factor for soil erodibility assessment on calcareous soils in Iran. *Geomorphology*, *273*, 385–395. https://doi.org/10.1016/j.geomorph.2016.08.003

Ouyang, W., Wu, Y., Hao, Z., Zhang, Q., Bu, Q., & Gao, X. (2018). Combined impacts of land use and soil property changes on soil erosion in a mollisol area under long-term agricultural development. *Science of The Total Environment*, *613–614*, 798–809. https://doi.org/https://doi.org/10.1016/j.scitotenv.2017.09.173

Panagos, P., Ballabio, C., Borrelli, P., Meusburger, K., Klik, A., Rousseva, S., Tadić, M. P., Michaelides, S., Hrabalíková, M., Olsen, P., Aalto, J., Lakatos, M., Rymszewicz, A., Dumitrescu, A., Beguería, S., & Alewell, C. (2015). Rainfall erosivity in Europe. *Science of The Total Environment*, *511*, 801–814. https://doi.org/10.1016/j.scitotenv.2015.01.008

Panagos, P., Ballabio, C., Meusburger, K., Spinoni, J., Alewell, C., & Borrelli, P. (2017). Towards estimates of future rainfall erosivity in Europe based on REDES and WorldClim datasets. *Journal of Hydrology*, *548*. https://doi.org/10.1016/j.jhydrol.2017.03.006

Panagos, P., Borrelli, P., Poesen, J., Ballabio, C., Lugato, E., Meusburger, K., Montanarella, L., & Alewell, C. (2015). The new assessment of soil loss by water erosion in Europe. *Environmental Science & Policy*, *54*, 438–447. https://doi.org/10.1016/j.envsci.2015.08.012

Pandey, A., Himanshu, S. K., Mishra, S. K., & Singh, V. P. (2016). Physically based soil erosion and sediment yield models revisited. *CATENA*, *147*, 595–620. https://doi.org/https://doi.org/10.1016/j.catena.2016.08.002

Parajuli, P. B., Jayakody, P., Sassenrath, G. F., & Ouyang, Y. (2016). Assessing the impacts of climate change and tillage practices on stream flow, crop and sediment yields from the Mississippi River Basin. *Agricultural Water Management*, *168*, 112–124. https://doi.org/https://doi.org/10.1016/j.agwat.2016.02.005

Paramananthan, S. (2015). Soil Properties and Their Influence on Oil Palm Management and yield. *Proceedings of a Workshop Held in Medan*, 72.

Parry, M. L., Canziani, O., Palutikof, J. P., van der Linden, P., & Hanson, C. E. (2007). Climate Change 2007: Impacts, Adaptation and Vulnerability. In *Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*.

Paterson, R. R.M. (2007). Ganoderma disease of oil palm-A white rot perspective necessary for integrated control. *Crop Protection*, *26*(9), 1369–1376. https://doi.org/10.1016/j.cropro.2006.11.009

Paterson, Robert R.M., Moen, S., & Lima, N. (2009). The feasibility of producing oil palm with altered lignin content to control ganoderma disease. *Journal of Phytopathology*, *157*(11–12), 649–656. https://doi.org/10.1111/j.1439-0434.2009.01553.x

Peleg, N., Molnar, P., Burlando, P., & Fatichi, S. (2019). Exploring stochastic climate uncertainty in space and time using a gridded hourly weather generator. *Journal of Hydrology*, *571*(February), 627–641. https://doi.org/10.1016/j.jhydrol.2019.02.010

Pérez-Vega, A., Mas, J.-F., & Ligmann-Zielinska, A. (2012). Comparing two approaches to land use/cover change modeling and their implications for the assessment of biodiversity loss in a deciduous tropical forest. *Environmental Modelling & Software*, *29*(1), 11–23. https://doi.org/10.1016/j.envsoft.2011.09.011

Perkins, S. E., Alexander, L. V., & Nairn, J. R. (2012). Increasing frequency, intensity and duration of observed global heatwaves and warm spells. *Geophysical Research Letters*, *39*(20), 2012GL053361. https://doi.org/10.1029/2012GL053361

Petkovšek, G., & Mikoš, M. (2004). Estimating the R factor from daily rainfall data in the sub-Mediterranean climate of southwest Slovenia / Estimation du facteur R à partir de données journalières de pluie dans le climat sub-méditerranéen du Sud-Ouest de la Slovénie . *Hydrological Sciences Journal*, *49*(5). https://doi.org/10.1623/hysj.49.5.869.55134

Pheerawat, P., & Udmale, P. (2017). Impacts of climate change on rainfall erosivity in the Huai Luang watershed, Thailand. *Atmosphere*, *8*(8). https://doi.org/10.3390/atmos8080143

Pimentel, D. (2006). Soil erosion: a food and environmental threat. *Environment, Development and Sustainability*, *8*(1), 119–137.

Pradhan, B., Chaudhari, A., Adinarayana, J., & Buchroithner, M. F. (2012). 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. https://doi.org/10.1007/s10661-011-1996-8

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. https://doi.org/10.1016/j.gsf.2011.11.003

Qi, Z., Kang, G., Chu, C., Qiu, Y., Xu, Z., & Wang, Y. (2017). Comparison of SWAT and GWLF model simulation performance in humid south and semi-arid north of China. *Water (Switzerland)*, *9*(8). https://doi.org/10.3390/w9080567

Qiu, J., Shen, Z., Leng, G., Xie, H., Hou, X., & Wei, G. (2019). Impacts of climate change on watershed systems and potential adaptation through BMPs in a drinking water source area. *Journal of Hydrology*, *573*, 123–135. https://doi.org/https://doi.org/10.1016/j.jhydrol.2019.03.074

Rahman, M. R., Shi, Z. H., & Chongfa, C. (2009). Soil erosion hazard evaluation-An integrated use of remote sensing, GIS and statistical approaches with biophysical parameters towards management strategies. *Ecological Modelling*, *220*(13–14), 1724–1734. https://doi.org/10.1016/j.ecolmodel.2009.04.004

Raj, J. K. (2002). Land use changes, soil erosion and decreased base flow of rivers at Cameron Highlands, Peninsular Malaysia. *Bulletin of the Geological Society of Malaysia, Annual Geological Conference 2002 Issue*, *45*, 3–10.

Razali, A., Syed Ismail, S. N., Awang, S., Praveena, S. M., & Zainal Abidin, E. (2018). Land use change in highland area and its impact on river water quality: a review of case studies in Malaysia. *Ecological Processes*, *7*(1), 19. https://doi.org/10.1186/s13717-018-0126-8

Renard, K. ., Foster, G. R., Weeises, G. A., McCool, D. K., & Yoder, D. C. (1997). *Predicting Soil Reosion by Water: A Guide to conservation Planning with Revised Universal Soil Loss Equation (RUSLE)* (Agricultur). United Stated deparment of Agriculture, Agriculture Handbbooh 703.

Renard, K. G., & Freimund, J. R. (1994). Using monthly precipitation data to estimate the Rfactor in the revised USLE. *J. Hydrol.*, *157*(1–4), 287–306.

Rickson, R. J. (2014). Can control of soil erosion mitigate water pollution by sediments? *Science of the Total Environment*, *468–469*, 1187–1197. https://doi.org/10.1016/j.scitotenv.2013.05.057

Rodrigo Comino, J., Quiquerez, A., Follain, S., Raclot, D., Le Bissonnais, Y., Casalí, J., Giménez, R., Cerdà, A., Keesstra, S. D., Brevik, E. C., Pereira, P., Senciales, J. M., Seeger, M., Ruiz Sinoga, J. D., & Ries, J. B. (2016). Soil erosion in sloping vineyards assessed by using botanical indicators and sediment collectors in the Ruwer-Mosel valley. *Agriculture, Ecosystems & Environment*, *233*, 158–170. https://doi.org/10.1016/j.agee.2016.09.009

Sadeghi, S. H. R., & Hazbavi, Z. (2015). Trend analysis of the rainfall erosivity index at different time scales in Iran. *Natural Hazards*, *77*(1), 383–404. https://doi.org/10.1007/s11069-015-1607-z

Sadeghi, S. H., & Tavangar, S. (2015). Development of stational models for estimation of rainfall erosivity factor in different timescales. *Natural Hazards*, *77*(1), 429–443. https://doi.org/10.1007/s11069-015-1608-y

Sardari, M. R. A., Bazrafshan, O., Panagopoulos, T., & Sardooi, E. R. (2019). Modeling the impact of climate change and land use change scenarios on soil erosion at the minab dam watershed. *Sustainability (Switzerland)*, *11*(12). https://doi.org/10.3390/su10023353

Schleiss, A. J., Franca, M. J., Juez, C., & De Cesare, G. (2016). Reservoir sedimentation. *Journal of Hydraulic Research*, *54*(6), 595–614. https://doi.org/10.1080/00221686.2016.1225320

Schmidli, J., & Frei, C. (2005). Trends of heavy precipitation and wet and dry spells in Switzerland during the 20th century. *International Journal of Climatology*, *25*(6), 753–771. https://doi.org/10.1002/joc.1179

Searchinger, T., Heimlich, R., Houghton, R. A., Dong, F., Elobeid, A., Fabiosa, J., Tokgoz, S., Hayes, D., & Yu, T. (2008). *Emissions from Land-Use Change*. *423*(February), 1238–1241.

Semenov, M. A., & Stratonovitch, P. (2010). Use of multi-model ensembles from global climate models for assessment of climate change impacts. *Climate Research*, *41*(1), 1–14. https://doi.org/10.3354/cr00836

Shafaei, M., Fakheri-Fard, A., Dinpashoh, Y., Mirabbasi, R., & De Michele, C. (2017). Modeling flood event characteristics using D-vine structures. *Theoretical and Applied Climatology*, *130*(3–4), 713–724. https://doi.org/10.1007/s00704-016-1911-x

Shen, D., Bao, W., & Ni, P. (2018). A method for detecting abrupt change of sediment discharge in the Loess Plateau, China. *Water (Switzerland)*, *10*(9).

https://doi.org/10.3390/w10091183

Sholagberu, A. T., Ul Mustafa, M. R., Wan Yusof, K., & Ahmad, M. H. (2016). Evaluation of rainfall-runoff erosivity factor for cameron highlands, Pahang, Malaysia. *Journal of Ecological Engineering*, *17*(3), 1–8. https://doi.org/10.12911/22998993/63338

Shrestha, A., Babel, M. S., Weesakul, S., & Vojinovic, Z. (2017). Developing Intensity-Duration-Frequency (IDF) curves under climate change uncertainty: The case of Bangkok, Thailand. *Water (Switzerland)*, *9*(2). https://doi.org/10.3390/w9020145

Shrestha, D. P., & Jetten, V. G. (2018). Modelling erosion on a daily basis, an adaptation of the MMF approach. *International Journal of Applied Earth Observation and Geoinformation*, *64*, 117–131. https://doi.org/10.1016/j.jag.2017.09.003

Singh, G., & Panda, R. K. (2017). Grid-cell based assessment of soil erosion potential for identification of critical erosion prone areas using USLE, GIS and remote sensing: A case study in the Kapgari watershed, India. *International Soil and Water Conservation Research*, *5*(3), 202–211. https://doi.org/10.1016/j.iswcr.2017.05.006

Siong, T. H. (2013). A Case Study on Soil Erosion Rate and Sediment Yield of a Proposed Infratructural Development Project. In *Faculty of Resource Science and Technology Universiti Malaysia Sarawak*. Universiti Malaysia Sarawak, Malaysia.

Smetanová, A., Follain, S., David, M., Ciampalini, R., Raclot, D., Crabit, A., & Bissonnais, Y. Le. (2019). Landscaping compromises for land degradation neutrality: The case of soil erosion in a Mediterranean agricultural landscape. *Journal of Environmental Management*, *235*, 282–292. https://doi.org/https://doi.org/10.1016/j.jenvman.2019.01.063

Solomon, S., Manning, M., Marquis, M., Qin, D., & others. (2007). *Climate change 2007-the physical science basis: Working group I contribution to the fourth assessment report of the IPCC* (Vol. 4). Cambridge university press.

Stocker, T. F., Qin, D., Plattner, G. K., Tignor, M. M. B., Allen, S. K., Boschung, J., Nauels, A., Xia, Y., Bex, V., & Midgley, P. M. (2013). Climate change 2013 the physical science basis: Working Group I contribution to the fifth assessment report of the intergovernmental panel on climate change. In Intergovernmental Panel on Climate Change (Ed.), *Climate Change 2013 the Physical Science Basis: Working Group I Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* (Vol. 9781107057). Cambridge University Press. https://doi.org/10.1017/CBO9781107415324

Stocker, T. F., Qin, D., Plattner, G. K., Tignor, M. M. B., Allen, S. K., Boschung, J., Nauels, A., Xia, Y., Bex, V., & Midgley, P. M. (2014). Climate Change 2013 - The Physical Science Basis. In Intergovernmental Panel on Climate Change (Ed.), *Climate Change 2013 the Physical Science Basis: Working Group I Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* (Vol. 9781107057). Cambridge University Press.

https://doi.org/10.1017/CBO9781107415324

Suif, Z., Yoshimura, C., Ahmad, N., & Hul, S. (2018). Distributed model of hydrological and sediment transport process in Mekong River Basin. *International Journal of GEOMATE*, *14*(42), 134–139. https://doi.org/10.21660/2018.42.3515

Sun, W., Mu, X., Song, X., Wu, D., Cheng, A., & Qiu, B. (2016). Changes in extreme temperature and precipitation events in the Loess Plateau (China) during 1960-2013 under global warming. *Atmospheric Research*, *168*, 33–48. https://doi.org/10.1016/j.atmosres.2015.09.001

Suresh, R. (2017). *Soil and Water Conservation Engineering*. Standard Publisher Distributors.

Switzman, H., Razavi, T., Traore, S., Coulibaly, P., Burn, D. H., Henderson, J., Fausto, E., & Ness, R. (2017). Variability of Future Extreme Rainfall Statistics: Comparison of Multiple IDF Projections. *Journal of Hydrologic Engineering*, *22*(10), 04017046. https://doi.org/10.1061/(ASCE)HE.1943-5584.0001561

Tan, K. W., & Nying, L. P. (2017). Climate Change Asessment on Rainfall and Tempreture in Cameron Highlands, Malaysia using Reginal Climate. *Carpathian Journal of Earth and Environmental Sciences*, *12*(2), 413–421.

Teferi, E., Uhlenbrook, S., Bewket, W., Wenninger, J., & Simane, B. (2010). The use of remote sensing to quantify wetland loss in the Choke Mountain range, Upper Blue Nile basin, Ethiopia. *Hydrology and Earth System Sciences*, *14*(12), 2415–2428. https://doi.org/10.5194/hess-14-2415-2010

Teh, S. H. (2011). Soil Erosion Modeling Using RUSLE and GIS on Cameron Highlands, Malaysia for Hydropower Development [Solborg at Nordurslod]. In *RES | The School for Renewable Energy Science*. https://www.engr.colostate.edu/~pierre/ce_old/Projects/linkfiles/Thesis Soo Huey Teh.pdf

Tenaga National Berhad Research. (2005). *Progress Report 4: An Impact Study of Different Land Use Type to Hydro Power Generation in Cameron Highlands*.

Tenaga National Berhad Research. (2009). *Progress Report 5: An Impact Study of Different Land Use Type to Hydro Power Generation in Cameron Highlands*.

Teng, Hong-fen, Hu, J., Zhou, Y., Zhou, L., & Shi, Z. (2019). Modelling and mapping soil erosion potential in China. *Journal of Integrative Agriculture*, *18*(2), 251–264. https://doi.org/https://doi.org/10.1016/S2095-3119(18)62045-3

Teng, Hongfen, Liang, Z., Chen, S., Liu, Y., Viscarra Rossel, R. A., Chappell, A., Yu, W., & Shi, Z. (2018). Current and future assessments of soil erosion by water on the Tibetan Plateau based on RUSLE and CMIP5 climate models. *Science of the Total Environment*, *635*, 673–686. https://doi.org/10.1016/j.scitotenv.2018.04.146

Tew, K. H. (1999). *Production of Malaysian soil erodibility monograph in relation to* *soil erosion issues*.

Thellmann, K., Golbon, R., Cotter, M., Cadisch, G., & Asch, F. (2019). Assessing Hydrological Ecosystem Services in a Rubber-Dominated Watershed under Scenarios of Land Use and Climate Change. *Forests*, *10*(2), 176. https://doi.org/10.3390/f10020176

Thomas, J., Joseph, S., & Thrivikramji, K. P. (2018). Assessment of soil erosion in a tropical mountain river basin of the southern Western Ghats, India using RUSLE and GIS. *Geoscience Frontiers*, *9*(3), 893–906. https://doi.org/https://doi.org/10.1016/j.gsf.2017.05.011

Timothy, S., Heimlich, R., Houghton, R. A., Dong, F., Elobeid, A., Fabiosa, J., Tokgoz, S., Hayes, D., & Yu, T.-H. (2017). Predicting land-use change. *American Association for the Advancement of Science, 1200 New York Avenue NW, Washington, DC 20005.*, *85*, 1–6.

Tingem, M., Rivington, M., Bellocchi, G., Azam-Ali, S., & Colls, J. (2008). Effects of climate change on crop production in Cameroon. *Climate Research*, *36*(1), 65–77. https://doi.org/10.3354/cr00733

Troeh, F. ., Hoobs, J. ., & Donahue, R. . (1999). *Soil and Water Conservation: Productivity and Environmental Protection* (Vol. 27, Issue Sep 2003). New Jersey, Prentice-Hall.

Trzaska, S., & Schnarr, E. (2014). A review of downscaling methods for climate change projections. *United States Agency for International Development by Tetra Tech ARD*, *September*, 1–42.

UNESCO. (2013). *Soil Erosion and sediment production on watershed landscapes: Processes and control.*

Vanoni, V. (1975). *Sedimentation Engineering* (Vito A. Vanoni (ed.)). American Society of Civil Engineers. http://ascelibrary.org/doi/book/10.1061/9780784408230

Vanoni, V. A. (1975). *Sedimentation engineering, manual and reports on engineering* (P. N. 54 (ed.)). American Society of Civil Engineers.

Várallyay, G. (2010). The impact of climate change on soils and on their water management. *Agronomy Research*, *8*(Ii), 385–396. http://agronomy.emu.ee/vol08Spec2/p08s214.pdf

Vergari, F. (2015). Assessing soil erosion hazard in a key badland area of Central Italy. *Natural Hazards*, *79*, 71–95. https://doi.org/10.1007/s11069-015-1976-3

Vijith, H., Seling, L. W., & Dodge-Wan, D. (2018). Estimation of soil loss and identification of erosion risk zones in a forested region in Sarawak, Malaysia, Northern Borneo. *Environment, Development and Sustainability*, *20*(3), 1365–1384. https://doi.org/10.1007/s10668-017-9946-4

Viola, M. R., Mello, C. R. De, Chou, S. C., Yanagi, S. N., & Gomes, J. L. (2015). *Assessing climate change impacts on Upper Grande River Basin hydrology , Southeast Brazil*. *1068*(May 2014), 1054–1068. https://doi.org/10.1002/joc.4038

Vu, T. M., & Mishra, A. K. (2019). Nonstationary frequency analysis of the recent extreme precipitation events in the United States. *Journal of Hydrology*, *575*(May), 999–1010. https://doi.org/10.1016/j.jhydrol.2019.05.090

Wang, C., Zhang, Y., Yang, Y., Yang, Q., Kush, J., Xu, Y., & Xu, L. (2016). Assessment of sustainable livelihoods of different farmers in hilly red soil erosion areas of southern China. *Ecological Indicators*, *64*, 123–131. https://doi.org/10.1016/j.ecolind.2015.12.036

Wang, Y. (2005). Observed trends in extreme precipitation events in China during 1961–2001 and the associated changes in large-scale circulation. *Geophysical Research Letters*, *32*(9), L09707. https://doi.org/10.1029/2005GL022574

Warrick, J. A., Melack, J. M., & Goodridge, B. M. (2015). Sediment yields from small, steep coastal watersheds of California. *Journal of Hydrology: Regional Studies*, *4*, 516–534. https://doi.org/https://doi.org/10.1016/j.ejrh.2015.08.004

Wayayok, A., Nasidi, N. M., & Abdullahi, A. F. (2018). *Erosion and Sediment Control guidelines for Agricultural Activities in Hilly Areas: Case Study of Cameron Highlands, Malaysia*.

Weebers, R. C. M., & Idris, H. (2016). *Decisions made on the Development of the Hill Station of Cameron Highlands from 1884 till present day*. *7*(1), 1–11.

Weil, R., & Brady, N. (2016). The Nature and Properties of Soils. In *Tribology Series* (Fifteenth, Vol. 9, Issue C, pp. 59–101). Pearson Education, Columbus, Ohio, USA. https://linkinghub.elsevier.com/retrieve/pii/S0167892208708435

Whischmeier, W. H., & Smith, D. D. (1978). Predicting rainfall erosion losses. *Agricutural Handbook 537 Prepaered by Science and Education Administration*, *537*(1), 57. https://doi.org/10.1017/CBO9781107415324.004

Wilby, R. L., & Harris, I. (2006). A framework for assessing uncertainties in climate change impacts: Low-flow scenarios for the River Thames, UK. *Water Resources Research*, *42*(2). https://doi.org/10.1029/2005WR004065

Wilby, Robert L, Charles, S. P., Zorita, E., Timbal, B., Whetton, P., & Mearns, L. O. (2004). Guidelines for use of climate scenarios developed from statistical downscaling methods. *Supporting Material of the Intergovernmental Panel on Climate Change, Available from the DDC of IPCC TGCIA*, *27*.

Williams, J. R., Jones, C. A., & Dyke, P. T. (1984). A modelling approach to determining the relationship between erosion and soil productivity. *Transactions - American Society of Agricultural Engineers*, *27*(1), 129–144. https://doi.org/10.13031/2013.32748

Winkler, R. D., Moore, R. D. D., Redding, T. E., Spittlehouse, D. L., Smerdon, B. D., & Carlyle-Moses, D. E. (2010). The effects of forest disturbance on hydrologic processes and watershed. *Compendium of Forest Hydrology and Geomorphology in British Columbia. BC Min. For. Range*, *66*, 179.

Wischmeier, W., & Smith, D. (1978). *Predicting Rainfall Erosion Losses- A Guide to Consrvation Planning. U.S. Department of Agriculture Handbook*. U S. Department of Agriculture.

Wright, D. B., Smith, J. A., Villarini, G., & Baeck, M. L. (2013). Estimating the frequency of extreme rainfall using weather radar and stochastic storm transposition. *Journal of Hydrology*, *488*, 150–165. https://doi.org/10.1016/j.jhydrol.2013.03.003

Xu, L., Xu, X., & Meng, X. (2012). Risk assessment of soil erosion in different rainfall scenarios by RUSLE model coupled with Information Diffusion Model : A case study of Bohai Rim , China. *Catena*, *100*, 74–82. https://doi.org/10.1016/j.catena.2012.08.012

Xu, M., Dong, X., Yang, X., Chen, X., Zhang, Q., Liu, Q., Wang, R., Yao, M., Davidson, T. A., & Jeppesen, E. (2017). Recent sedimentation rates of shallow lakes in the middle and lower reaches of the Yangtze River: Patterns, controlling factors and implications for lake management. *Water (Switzerland)*, *9*(8). https://doi.org/10.3390/w9080617

Yang, F., & Lu, C. (2015). Spatiotemporal variation and trends in rainfall erosivity in China's dryland region during 1961-2012. *Catena*, *133*, 362–372. https://doi.org/10.1016/j.catena.2015.06.005

Yang, X., Sun, W., Li, P., Mu, X., Gao, P., & Zhao, G. (2018). Reduced sediment transport in the Chinese Loess Plateau due to climate change and human activities. *Science of The Total Environment*, *642*, 591–600. https://doi.org/https://doi.org/10.1016/j.scitotenv.2018.06.061

Yao, X., Yu, J., Jiang, H., Sun, W., & Li, Z. (2016). Roles of soil erodibility, rainfall erosivity and land use in affecting soil erosion at the basin scale. *Agricultural Water Management*, *174*, 82–92. https://doi.org/https://doi.org/10.1016/j.agwat.2016.04.001

Yira, Y., Diekkrüger, B., Steup, G., & Yaovi Bossa, A. (2017). Impact of climate change on hydrological conditions in a tropical West African catchment using an ensemble of climate simulations. *Hydrology and Earth System Sciences*, *21*(4), 2143–2161. https://doi.org/10.5194/hess-21-2143-2017

Zakaria, N.A., Ghani, A. A., Abdullah, R., Sidek, L. M., Kassim, A. H., Ainan, A., & ABSTRACT. (2004). Msma- a New Urban Stormwater Management Manual for Malaysia. *Advances in Hydro-Science - Engineering*, *VI*(September 2015), 1–10.

Zhang, L. T., Li, Z. Bin, & Wang, S. S. (2016). Spatial scale effect on sediment dynamics in basin-wide floods within a typical agro-watershed: A case study in the hilly loess region of the Chinese Loess Plateau. *Science of the Total Environment*, *572*, 476–486. https://doi.org/10.1016/j.scitotenv.2016.08.082

Zhao, G., Kondolf, G. M., Mu, X., Han, M., He, Z., Rubin, Z., Wang, F., Gao, P., & Sun, W. (2017). Sediment yield reduction associated with land use changes and check dams in a catchment of the Loess Plateau, China. *Catena*, *148*, 126–137. https://doi.org/10.1016/j.catena.2016.05.010

Zhao, G., Mu, X., Han, M., An, Z., Gao, P., Sun, W., & Xu, W. (2017). Sediment yield and sources in dam-controlled watersheds on the northern Loess Plateau. *CATENA*, *149*, 110–119. https://doi.org/10.1016/j.catena.2016.09.010

Zhao, L., & Hou, R. (2018). Effects of collection time intervals of surface runoff and sediment on soil erosion analysis during rainfall. *CATENA*, *165*, 201–206. https://doi.org/https://doi.org/10.1016/j.catena.2018.02.003

Zhao, Q., Liu, Q., Ma, L., Ding, S., Xu, S., Wu, C., & Liu, P. (2017). Spatiotemporal variations in rainfall erosivity during the period of 1960–2011 in Guangdong Province, southern China. *Theoretical and Applied Climatology*, *128*(1–2), 113–128. https://doi.org/10.1007/s00704-015-1694-5

Zhou, J., Fu, B., Yan, D., Lü, Y., Wang, S., & Gao, G. (2019). Assessing the integrity of soil erosion in different patch covers in semi-arid environment. *Journal of Hydrology*, *571*, 71–86. https://doi.org/https://doi.org/10.1016/j.jhydrol.2019.01.056

Zhu, G., Tang, Z., Shangguan, Z., Peng, C., & Deng, L. (2019). Factors Affecting the Spatial and Temporal Variations in Soil Erodibility of China. *Journal of Geophysical Research: Earth Surface*, *124*(3), 737–749. https://doi.org/10.1029/2018JF004918

BIODATA OF STUDENT

Nuraddeen Mukhtar Nasidi is currently a staff of Bayero University Kano, Department of Agricultural and Environmental Engineering. He was born at Hausawa Quarters, Gwale Local Government Area, Kano State of Nigeria. He received his secondary school education from Rumfa College Kano in July 2000. He proceeds to Bayero University Kano to study bachelor's degree at the department of Agricultural and Environmental Engineering, where he graduated with B. Eng. Agricultural Engineering degree in February 2008. He continued to pursue his Master' degree at Ahmadu Bello University, Zaria, Nigeria and graduated with M.Sc. Soil and Water Engineering degree in June 2015. Then, He enrolled into PhD program in field of Soil and Water Engineering in February 2018 at the Department of Biological and Agricultural Engineering, University Putra Malaysia.

LIST OF PUBLICATIONS

Nasidi N. M., A. Wayayok, A. F. Abdullah. M. S. M. Kassim (2020). Current and Future Intensity-Duration-Frequency Curves based on Weighted Ensemble GCMs and Temporal Disaggregation. Sains Malaysiana http://dx.doi.org/10.17576/jsm-2020-4910-03 (Published) (**Q3. Scopus**).

Nasidi N. M., A. Wayayok, A. F. Abdullah. M. S. M. Kassim (2020). Spatio-temporal dynamics of Rainfall erosivity due to Climate Change in Cameron Highlands, Malaysia. Modelling Earth Systems and Environment, DOI 10.1007/s40808-020-00917-4 (Published) (**Q2. Scopus**).

Nasidi N. M., A. Wayayok, A. F. Abdullah, and M. S. M. Kassim (2020). Susceptibility to Soil Erosion and Risk Assessment at Hilly Farms using Geospatial Techniques. Journal of Engineering Technology and Applied Physics. e-ISSN: 2682-8383. https://doi.org/10.33093/jetap.2020.x1.2 (Published) (**Scopus**)

Abdullah, A. F**.,** Wayayok, A., **Nasidi, N. M**., Hazari S. A. F, K., Sidek, L. M., & Selamat, Z. (2019). Modelling Erosion and Landslides Induced by Faming Activities at Hilly Farms. Jurnal Teknologi, 6, 195–204. EISSN 2180 – 3722 (Published) **(Scopus)**.

Nasidi, N. M., A. Wayayok, A. F. Abdullah, and M. S. M. Kassim (2020). Vulnerability of Potential Soil Erosion and Risk Assessment at Hilly Farms using InSAR Technology. Algerian Journal of Engineering and Technology, http://dx.doi.org/10.5281/zenodo.3841100 (Published) (**Scopus**).

Nasidi N. M., A. Wayayok, A. F. Abdullah. M. S. M. Kassim (2021). Spatial variability of soil erodibility in response to various agricultural land use at highland farms. Basrah Journal of Agriculture Sciences. ISSN: 2520-0860 (To publish in March 2021) (**Scopus**).

Nasidi N. M., A. Wayayok, A. F. Abdullah. M. S. M. Kassim (2021). Spatial and Temporal Variability of Potential Precipitation affected by Climate Change in Cameron Highlands Watershed, Malaysia. Journal of Hydrology: Regional Studies (under Review) (ISI Q1).

Nasidi N. M., A. Wayayok, A. F. Abdullah. M. S. M. Kassim (2021). Prediction of Land Use and Cover Changes using Hybrid System of Satellite Image Classification for Highlands Area, Malaysia. Journal of the Indian Society of Remote Sensing. Springer Nature (Accepted) (Q3. Scopus)

Nasidi N. M., A. Wayayok, A. F. Abdullah. M. S. M. Kassim (2021). Dynamics of Potential Precipitation under Climate Change Scenarios at Cameron Highlands, Malaysia. SN Applied Sciences. Springer Nature. (Published) (Scopus).

Nasidi N. M., A. Wayayok, A. F. Abdullah. M. S. M. Kassim (2021). Mustard Crop Performance under Climate change and Control Management Practices for soil Conservation. Agricultural Water management (under Review) (ISI, Q1)

Irfan A. S, A. Wayayok, Z. Khan, **N. M. Nasidi** (2021). Optimizing Water Allocation Model at Diversion Uptake for Irrigation During Reduced Flow Scenarios. Journal of Irrigation and Drainage Engineering. ASCE (under second revision) (ISI, Scopus).

Ismail H., M. K. Rowshon, L. S. Hin, A. F.B. Abdullah and **N. M. Nasidi** (2020). Assessment of climate change impact on future streamflow at Bernam river basin Malaysia. IOP Conf. Series: Earth and Environmental Science 540 (2020) 012040. IOP Publishing. doi:10.1088/1755-1315/540/1/012040 (Published) (Scopus).