DEVELOPING AN INTEGRATED CATCHMENT MANAGEMENT THROUGH WATER QUALITY ASSESSMENT, LANDUSE CHANGES ANALYSIS, SOIL EROSION STUDY & COMMUNITY ENGAGEMENT IN BERTAM RIVER CATCHMENT, CAMERON HIGHLANDS, MALAYSIA

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ABSTRAK

Perkembangan yang pesat di dalam pembinaan dan aktiviti agro-pelancongan telah mengancam kualiti air Sungai Bertam, Cameron Highlands (BRCC), Malaysia sepanjang dua dekad yang lalu. Senario ini telah menarik perhatian penyelidik untuk menyiasat hubungan di antara pengendalian tanah terhadap kualiti air bagi tujuan pemeliharaan SBC. Penilaian saintifik telah dijalankan bagi menentukan variasi kualiti air, mengkaji perubahan penggunaan tanah dan kesannya terhadap kualiti air serta menganggarkan pengagihan ruang hakisan tanah di bawah pengendalian tanah yang berlainan. Bagi menjalankan siasatan ini, sampel air telah dikumpulkan sebanyak enam kali dari Januari 2014 sehingga Februari 2015 daripada dua belas stesen yang dipilih. Sebanyak empat belas parameter kualiti air telah dianalisis. Peta guna tanah empat siri (1984, 1997, 2004 dan 2010) telah digunakan bagi menganalisis perubahan pola tanah dengan menggunakan teknik pengesanan perubahan melalui pendekatan GIS. Model persamaan umum kehilangan tanah (RUSLE) telah diguna pakai bagi menganggarkan kadar hakisan tanah. Kajian terhadap komuniti juga dijalankan melalui soalan kaji selidik yang telah dirangka dengan teliti. Hasil penilaian kualiti air menunjukkan terdapat perbezaan temporal dan spatial yang ketara (p <0.05) di dalam kebanyakan parameter kualiti air yang diperolehi. Kepekatan purata pepejal terampai, kekeruhan, keperluan oksigen biokimia serta tahap amonik-nitrogen dan fosfat-fosforus didapati melebihi Indeks Kualiti Air Negara (NWQS) Malaysia. Nutrien, bahan organik, dan hakisan tanah diklasifikasikan sebagai sumber pencemaran utama. Menurut DOE-WQI, status keseluruhan kualiti air SBC diklasifikasikan sebagai "Sedikit Tercemar" dan di bawah kategori kelas III. Kajian kepenggunaan tanah mendedahkan bahawa perubahan penggunaan tanah disebabkan perkembangan kawasan pertanian (16.37 km^2) dan pembangunan perbandaran (4.15 km^2) berkait rapat dengan kemerosotan kualiti air SBC. Perubahan yang ketara di dalam aktiviti pertanian dapat diperhatikan di sepanjang cerun yang lebih tinggi (>20^o). Manakala penggunaan tanah bagi aktiviti perhutanan (22.85 km^2) menjadikan kualiti air SBC lebih baik. Hasil penilaian hakisan tanah menunjukkan kadar purata tahunan hakisan tanah adalah sebanyak 123.23 tan/ha/tahun. Secara khususnya, kadar purata sub-tadahan atas, tengah dan bawah adalah sebanyak 27.60, 31.80 and 63.83 tan/ ha/ tahun. Kegiatan pertanian merupakan penyumbang utama kepada hakisan tanah yang lebih tinggi di sub-tadahan yang berbeza. Topografi lembangan juga memainkan peranan penting dalam mengawal pergerakan tanah. Hasil kaji-selidik terhadap komuniti menunjukkan bahawa rakyat mempunyai pengetahuan dan persepsi yang baik tentang kawasan persekitaran sungai dan tadahan. Oleh itu, dapat disimpulkan bahawa penemuan saintifik dan pemerhatian komuniti amat berkait rapat. Satu model bersepadu diwujudkan bagi pengurusan pemeliharaan BRCC agar pihak berkuasa dapat menyediakan maklumat saintifik melalui internet serta menganjurkan bengkel bagi mewujudkan kesedaran di kalangan masyarakat. Pendekatan ini boleh menjadi salah satu inisiatif inovatif ke arah pembangunan pengurusan lembangan yang mapan.

ABSTRACT

The rapid boost in construction and agro-tourism activities has significantly threatened the water quality within Bertam River Catchment, Cameron Highlands (BRCC) in Malaysia during the last two decades. The scenario has drawn the attention to investigate the relationship between land use and water quality for the sustainable development of BRCC. Hence, the current research aims at developing an effective model for the sustainable management of BRCC using integrated assessment of scientific findings with quantitative social information. Scientific assessment was carried out to determine the spatio-temporal variations of water quality, to assess the landuse changes and their impacts on water quality, as well as to estimate the spatial distribution of soil erosion under different landuses. To investigate water quality, samples were collected six times from January 2014 to February 2015 from twelve preselected stations. A total of fourteen water quality parameters were analyzed. For landuse study, four-time series landuse maps (1984, 1997, 2004 and 2010) were used to analyze the land pattern changes by change detection technique using GIS approach. The revised universal soil loss equation (RUSLE) model was applied to estimate the soil erosion rate. A community based survey was also conducted using a well-structured questionnaire. The results of water quality assessment showed significant temporal and spatial differences ($p<0.05$) in most of the water quality parameters across the catchment. The average concentrations of total suspended solids, turbidity, biochemical oxygen demand, ammonical-nitrogen, and phosphate-phosphorous exceeded the Malaysian National Water Quality Standards (NWQS) level for IIB. Nutrients, organic matter, and suspended sediments were determined as the major pollutants. The overall water quality status of the BRCC is classified as “Slightly Polluted” and falls under class III category according to the DOE-WQI. The landuse study revealed that landuse changes were mainly characterized by the expansion of agricultural (16.37km^2) and urban (4.15 km^2) land types, reducing the forest (22.85 km^2). A noticeable change in the agricultural activities was observed along the higher slope ranges (>20^o) with the passage of time. The urban and agricultural landuses are mainly related to water quality deterioration, where the forest is associated with better water quality within BRCC. The results of soil erosion assessment indicated that the annual average soil loss rate of the catchment was predicted to be 123.23 ton/ ha/ year. Individually, the average rate for Upper, Middle and Lower sub-catchment was 27.60, 31.80 and 63.83 ton/ ha/ year respectively. Agricultural activities were the main contributor to higher soil erosion in different sub-catchments. The topography of the catchment also played a major role in controlling soil movement. Community-based survey findings showed that the people have good knowledge and perception of the catchment environment. Therefore, significant associations were observed between the scientific findings and communities’ observations. Considering all the social and scientific findings, the proposed integrated model for BRCC management suggest that the authorities should provide the scientific information through internet and organizing workshops to motivate and create awareness. Similarly, whenever they take any initiative for management program within BRCC considering the scientific findings, they should focus more on the aged, higher educated and older residents for their higher level of awareness and positive willingness for participation. Overall, the findings of this study suggest that the effective implementation of socio-scientific integrated approach by the authorities can be an innovative initiative towards the development of sustainable catchment management.

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LIST OF SYMBOLS

%	Percentage
°C	Degree Centigrade
As	Arsenic
C	Cover Management
Cd	Cadmium
Cr	Chromium
ENE	East-North-East
ha	Hectare
Hg	Mercury
K	Soil Erodibility Factor
Km	Kilometer
L	Length
log	Logit
m	Meter
m/s	Meter/second
mg/L	Miligram/Liter
MJ	Megajoule
mm	Millimeter
NS	North-South
N-W	North-West
P	Conservation Factor
Q1	First quartile
Q3	Third quartile
R	Rainfall Erosivity Index
RM	Ringgit
S	Slope
t	Ton
TB	Tributaries
TCr	Total Chromium
yr	Year
Zn	Zinc

LIST OF ABBREVIATIONS

AN	Ammonical Nitrogen
ANN	Artificial Neural Network
ANOVA	Analysis of variance
APHA	American Public Health Association
BOD	Biochemical oxygen demand
CA	Cluster Analysis
CCA	Canonical Correspondence Analysis
COD	Chemical oxygen demand
DA	Discriminant Analysis
DEM	Digital Elevation Model
DID	Department of Irrigation and Drainage
DO	Dissolved oxygen
DOA	Department of Agriculture
DOE	Department of Environment
EQA	Environmental Quality Act
FA	Factor Analysis
GCS	Geographic Coordinate System
GIS	Geographical Information System
GLM	General Linear Model
HCA	Hierarchical Cluster Analysis
ICM	Integrated Catchment Management
IDW	Inverse Distance Weighted
KAP	Knowledge, Attitude, and Practices
KMO	Kaiser–Meyer–Olkin
LB	Lower Bertam
MJmm/ha/hr	Megajoule.milimeter/hectare-hour
MLD	Million Liters per Day
MOH	Ministry of Health
MSL	Mean Sea Level
NH_3-N	Ammonia nitrogen
NO_3-N	Nitrate nitrogen

NWQS	National Water Quality Standards
PCA	Principal Component Analysis
PO_4-P	Phosphorus phosphate
RMSE	Root Mean Square Error
RUSLE	Revised Universal Soil Loss Equation
SI	Sub-Index
SPSS	Statistical Package for the Social Sciences
SWAT	Soil and Water Assessment Tool
TDS	Total Dissolved Solids
TN	Total Nitrogen
TP	Total Phosphorus
TSS	Total Suspended Solids
UB	Upper Bertam
USLE	Universal Soil Loss Equation
UTM	Universal Transverse Mercator
WGS	World Geodetic System WGS84
WHO	World Health Organization
WQI	Water Quality Index
WQV	Water Quality Variable
WWAP	United Nations World Water Assessment Program

CHAPTER 1

INTRODUCTION

1.1 Background Study

Water is an indispensable natural resource on earth. It is a fundamental part of the environment, essential to sustain life, socio-economic development and healthy ecosystems (Chan, 2012; Othman et al., 2014). Although more than 70% of the earth's surface is covered by water, the available source of fresh water is only about 3%. Among the freshwater resources, surface water is the major source that represents 97% of total available water (Long and Pijanowski, 2017; WWAP, 2012). However, over the past few decades, anthropogenic activities coupled with global demand for freshwater have increased the risks of pollution and imposed severe stress on the water resources in many parts of the world (Connor et al., 2017; Fulazzaky, 2014). The rapid rate of deterioration of its quality also gives rise to a challenging issue on environmental concern throughout the world (Connor, 2015; Friesen et al., 2016). In terms of shortage and safety, the freshwater scarcity is, therefore, now a global crisis.

Worldwide deterioration of surface water quality is a combined effect of a number of factors; landuse being recognized as one of the most important ones. Any change in land use patterns by human activities affects the anthropogenic substances carried into hydrologic systems through changing its hydrological and chemical runoff processes (Lee et al., 2009; Pratt and Chang, 2012; Shen et al., 2014). Among the land use changes, deforestation, urbanization, and agricultural practices have significant effects on surface water quality and aquatic ecosystems within a watershed (Lee et al., 2009). Deforestation leads to increased soil erosion and delivers the sediments into river systems with increasing surface runoff. Agricultural intensification releases nutrients, agro-chemicals, salt and sediments from agricultural systems, concentrated in water bodies through the hydrologic cycle (Glavan et al., 2013; Kibena et al., 2014a; Mustard et al., 2012). Accelerated urban growth generates vast municipal wastewater that is ultimately discharged untreated directly into surface water bodies (Connor et al., 2017). Urban runoff negatively affect water quality by carrying nutrients, sediments and other pollutants into surface water (Ayivi, 2017; Wu and Chen, 2013). Therefore, understanding and exploring the relationships between landuse and water quality in any watershed or catchment is essential to improve the prediction of potential pollution and the assessment of pollutants significantly. Along with water quality, catchment environment protection is also a major concern in the sustainable development of Integrated Catchment Management.

In Malaysia, rivers are the main source of water supply contributing approximately 95% of total usage (Othman et al., 2012). Unfortunately, the water quality of Malaysian rivers is deteriorating every year, despite the enforcement of the Environmental Quality Act (EQA) in 1974 (Afroz and Rahman, 2017; Al-Mamun and Zainuddin, 2013). According to (DOE, 2015), 52% of the total 473 rivers were clean whereas 39% were slightly polluted and 9% were polluted. Compared to the condition of river in the year 2013, the percentages of polluted and slightly polluted rivers were increased by 4% and 3%, respectively in 2014. The untreated or partially treated wastewater discharged from domestic sewage, agro-based and manufacturing industries, animal husbandry, as well as surface runoff from earthworks, land clearing and agricultural activities had led to the problem of freshwater pollution in Malaysia (DOE, 2015; Hasan et al., 2015; Kozaki et al., 2016; Lee et al., 2017; Mostapa and Weston, 2016). All these sources of pollution are the ultimate result of different land patterns and landuse changes along with human activities that play the most significant role in the deterioration of water quality in Malaysia (Hua et al., 2016b).

Like other parts of Malaysia, the river systems of Cameron Highlands play a vital role as a source of freshwater supply, agricultural activities, hydroelectricity generation and recreational activities (Gasim et al., 2009a). Three main river systems namely Telom River, Bertam River, and Lemoi River along with many small tributaries mainly control the river networks in the Highlands. The Highlands is one of the extensive hill resorts well known for it’s agricultural and tourism activities. Unfortunately, the Highlands has experienced rapid development over the last two decades that lead to negative effects on the environment (Chan, 2006). Over the years, the sensitive forest cover has drastically reduced in the upper catchment of the river system from 95% in 1947 to 51% in 2003 and continued as a result of rapid development for agricultural and hill resort developments of the Highlands (Ismail et al., 2014; Kumaran and Ainuddin, 2006). With the rapid growth of urbanization and population, the solid waste generation in Cameron Highlands increased from 22 tons per day in 2000 to 46.05 tons per day in 2013. A huge amount of wastes is also dumped into open landfills due to the shortage of existing treatment process (Ramli, 2014). Moreover, wastewater discharge is released at random without the use of a proper sewerage system due to inadequate sewage treatment plants. In smaller settlement, latrine holes and direct releases into water courses are still practiced. Due to agricultural intensification, annual crops were planted on valley floors, slopes and hilltops. Agricultural wastes were usually disposed in the hillside or near the river due to no specific places for their disposal in the Highlands. Crops production is sustained mainly by high fertilizer and manure applications (Aminuddin et al., 2005). All these anthropogenic activities as a result of different landuse changes significantly influence the water quality of Highlands river systems.

Along with water quality, communities perceptions on catchment environment and their participation is very much imperative for sustainable development of local water resource management (Ayeni et al., 2014; Rolston et al., 2017). Furthermore, community-based indigenous knowledge on environmental changes is also very crucial to understand environmental impacts on local water resources (Aslin and Lockie, 2013). Now, the question arises whether the local community in the Highlands knows well the issues associated with environmental changes that are triggering water pollution. Hence, communities' knowledge, perceptions, and awareness on environmental changes can be corroborated with the assessment of scientific findings for the better development of water resource conservation and catchment management. This kind of interdisciplinary approach is crucial in the process of finding solutions to problems and sustainable management (Ayeni et al., 2016; Chicas et al., 2016; Deng et al., 2012).

1.2 Problem Statement

The Bertam River Catchment is the main socio-economic centre of the Highlands. It reflects the typical drainage pattern of a mountainous catchment. More importantly, the river system is the major source of potable water supply for the local residents as well as for the commercial utilization of the Highlands. The catchment covers the major urban and agricultural areas of the Highlands. Over the years, human activities significantly altered the land into an observable pattern in the Highlands. The sensitive forest areas are being cleared for resort and condominium construction as well as housing development as part of the urbanization processes while land clearing is done for agricultural activities as part of agro-tourism activities. Intensive agricultural practices as well as rapid development activities within the catchment have led to tremendous pressure on the existing river system and its quality within the catchment. Moreover, the river system in the catchment is very susceptible to soil erosion as the area is subjected to extensive rainfall, rugged mountainous topography and characterized by agricultural activities on steep slopes. All these anthropogenic activities as a result of landuse changes have significantly threatened the water quality of Bertam River and its tributaries, leading to adverse effects on the aquatic environment of the entire catchment.

In spite of being the socio-economic center of the Highlands, no detailed study has centered on the water quality as well as landuse change in the entire Bertam Catchment. Moreover, communities' knowledge, perceptions, and awareness on the issues associated with environmental changes that are triggering water pollution have yet to be documented. Considering the scenario, no study has yet been carried out on socio-scientific assessment for sustainable management of the Bertam River Catchment.

1.3 Research Aim and Objectives

The present study aims to develop an effective model for sustainable management of the Bertam River Catchment, Cameron Highlands in Malaysia using integrated assessment of scientific findings (water quality, landuse changes and soil erosion study) and quantitative social information (communities' knowledge, perception, and awareness).

Specifically, this thesis aims to accomplish the following objectives:

1. To determine the spatio-temporal variability of surface water quality and status; and to identify the potential sources of water pollution in the study area

2. To model the landuse pattern variations as well as land transformation and to assess their possible effects on seasonal surface water quality.

3. To evaluate the spatial variations of soil erosion loss at the catchment scale in relation to the potential role of different land use changes in the study area

4. To investigate the communities' knowledge and perceptions on water quality, landuse change and soil erosion to corroborate with scientific findings and to develop an integrated approach of scientific assessment with social information for sustainable catchment management.

1.4 The Scope of the Research

In achieving the objectives of the present study, the scopes of work can be outlined as follows:

i. Establishment of baseline data for water quality, land pattern change, soil erosion,

ii. Assessment of spatio-temporal variations of physico-chemical parameters of water quality.

iii. Application of multivariate statistical techniques for identifying pollution clusters and latent sources of water pollutions.

iv. Designation of water quality status as well as river condition using National Water Quality Standard (NWQS) and Water Quality Index (WQI) methods.

v. Application of Inverse distance weighted (IDW) interpolation technique for spatial modeling of water quality parameters and WQI mapping to prepare water contaminant maps using ArcGIS platform.

vi. Utilization of georeferencing, digitization, change detection and slope analysis techniques to analyze the changing status and trends of land usage over different time series maps using GIS approach.

vii. Delineation of catchment boundary and sub-catchment zones for area of interest and calculation of proportion of land types using ArcSWAT and GIS approach.

viii.Evaluation of the relationship among land use pattern and seasonal water quality, to assess the role of different land types responsible for water pollution.

ix. Simulation of R, LS and CP factor values to analyze the variation in the amount of annual soil loss in the study area.

x. Utilization of RUSLE model with GIS framework for estimation of soil erosion heterogeneity and potential vulnerable zones identification.

xi. Documentation of communities' knowledge, perceptions, and awareness towards environmental issues and their willingness to involve themselves in catchment manageme

xii. Assessment of correlation and association of communities' observation with scientific findings.

xiii. Application of logistic regression model to determine the factors influencing the communities' willingness to participate in catchment management program.

1.5 Organization of the Thesis

This thesis contains eight chapters. In chapter 1 (Introduction), a brief background of water, water quality, its pollution and sources, impacts of landuse and soil erosion on water quality worldwide and in Malaysia is described. The importance of public perception on environmental issues is also included. The problem statement has been given with some basis and rationale to find the directions and gaps in the study. Research objectives of the present study are elaborated in detail together with scopes and expected outcomes of the study to be covered. Additionally, the organization of the thesis is also given in this chapter.

Chapter 2 (Literature Review) provides a more detailed explanation of what was summarized in chapter 1. It also presents the reviews of published literature that are relevant to topics of the study and identifies the areas that have not been explored or have been inadequately examined.

Chapter 3 (Methodology) describes the materials and methods used in the present research to fulfill the objectives. The chapter introduces the overall information of the study area and then discusses on the measurements of surface water quality based on various parameters as well as data interpretation techniques. Different data acquisition, detection, analytical techniques are also discussed to assess the trend and status of landuse changes. The factors used in soil erosion modeling are also defined. Finally, the chapter provides details on the social survey including method, technique and statistical interpretation for sustainable catchment management.

Chapters 4 to 7 present the result and discussion of findings obtained from analytical and statistical interpretation as in chapter 3. Chapter 4 highlights on water quality assessment while chapter 5 presents landuse changes and their impact on water quality. Similarly, chapter 6 describes the soil erosion under different landuse changes and its impact on water quality. A detailed discussion on results of communities' knowledge, perception and awareness on catchment environment to correlate with scientific findings and model development is provided in chapter 7.

Chapter 8 (Conclusions) concludes the findings from the present studies and gave recommendations for future studies in the related field made from the understanding and information generated in the current study. The recommendations are given due to their significance and importance to be further investigated by future research work in this area.

CHAPTER 2

LITERATURE REVIEWS

2.1 Introduction

The aim of the present research is mainly to study the integrated assessment of landuse-water quality relationships for sustainable management of Bertam River Catchment, Cameron Highlands with some specific objectives. To understand the overall objectives and to find out the knowledge gap of this research study, this chapter reviews the studies that are relevant to the relationship between water quality and landuse as well as its consequence, besides studies on soil erosion and their impact on water quality within a watershed or catchment. The review also includes public perception on such environmental issues. Firstly the chapter explores comprehensively the baseline knowledge, conceptual context, methodologies, techniques and analytical findings that currently exist within the domain of water quality, land use, soil erosion and social management related to natural resources and environmental issues. Secondly, it identifies the areas that have not been explored or have been inadequately examined.

This chapter is broadly composed of six sub-sections. The first part (section 2.2) summarizes the surface water quality with a focus on physicochemical and hydrological parameters, its sources of pollution and application of water quality assessment. The second part (section 2.3) focuses on the landuse change, changing factors, methods of change detection, and impact of specific landuse on water quality. Similarly, the third part reviews (section 2.4) the relevant literature on soil erosion process and factors, application of soil erosion assessment and its impact on water quality. The fourth part (section 2.5) investigates the social survey approach for understanding public knowledge, perceptions and awareness as well as their importance on sustainable management. Further in section 2.6, the area of knowledge gap for the present study is identified. Finally, in six-part (section 2.7) the chapter concludes with a summary of the literature review.

2.2 Water Quality Assessment

Surface water quality is very important and a sensitive issue as it plays a vital role in aquatic ecosystems, human health, and socio-economic development. A healthy environment of surface water is defined as one in which the water quality supports a rich and varied community of organisms and protects public health. Being a part of the regional hydrological assessment, water quality evaluation is an overall process of assessing its physical, chemical and biological characteristics in relation to natural water quality, human effects, and intended uses. Another important issue when considering water quality assessment is water quality monitoring. Hence, water quality assessment includes the monitoring program to define the status of water, to detect the spatial and seasonal variations and trends as well as to provide the information enabling the establishment of cause-effect relationships (Mei et al., 2014; Othman et al., 2012). Hydrological variables assessment is also important as it plays a major role in determining the quality of water in any watershed (Perrin et al., 2014). Characteristically, the quality of water is determined by comparing its physical, chemical, biological and aesthetic characteristics with water quality guidelines or standards.

2.2.1 Physical Parameters

Physical characteristics of surface water quality are usually constitutes the on-site field parameters and generally consists of measuring water temperature, pH, conductivity, dissolved oxygen (DO), and total dissolved solids (TDS). Though total suspended solids (TSS) is an important physical parameter, it is usually measured in the laboratory. The physical characteristics of water quality are often related to chemical parameters. Five physical water quality parameters that were analyzed and assessed in this study are reviewed in detail. The dissolved oxygen (DO) is measured on-site, but its review is included in the chemical parameters section.

2.2.1.1 Temperature

The most common physical assessment of water quality is the measurement of temperature. It is a measure of how much heat is present in the water. The important source of freshwater temperature is generally the sun. It can also be affected by the temperature of water inputs (such as precipitation, surface runoff, groundwater, and water from up-stream tributaries), heat exchanges with the air, and heat lost or gained by evaporation or condensation (Selvanayagam and Abril, 2015). The temperature of surface water usually ranges between 0 ºC and 30 ºC (RAMP, 2016b). It fluctuates over periods of 24 hours (diurnal temperature changes) and over longer periods of time (seasonally). It varies along the length of a river with latitude and elevation, even between small sections only meters apart, depending on local conditions (Selvanayagam, 2016) .

Water temperature is one of the most important factors of an aquatic system which influences several other parameters and can alter the physical and chemical properties of water. It directly influences the amount of dissolved oxygen that is available to aquatic organisms. The solubility of oxygen decreases as water temperature increases and vice versa. Therefore, in temperate climates, levels are oxygen typically higher in the winter and lower in the summer (Perlman, 2013). Temperature also affects the solubility and reaction rates of compounds chemicals. In general, the rate of chemical reactions increases with increasing water temperature. Higher temperature (more than 26 °C) can make the toxic chemical more soluble and influence the tolerance limit of aquatic organisms (Bhadja and Vaghela, 2013). More importantly, water temperature affects the metabolic rates of aquatic organisms and photosynthesis of aquatic plants. Higher water temperature increases respiration rates and digestive responses of aquatic organisms that lead to increased oxygen consumption (Di Santo and Bennett, 2011). Higher surface water temperature can affect the biological productivity and can accelerate the growth of bacteria and fungi in the water besides encouraging algal blooms (Jiménez Cisneros et al., 2014). This may create toxic contaminants that cause serious threats to human and aquatic ecosystem health. Water temperature is, therefore, an imperative parameter for effective management of aquatic ecosystem as well as water resources management (Danladi Bello et al., 2017)

2.2.1.2 pH

The pH is one of the important water quality parameters for all forms of water in the environment. It plays a critical role in the chemistry of river water quality. The pH, or the "potential of hydrogen", is a measure of the hydrogen ions (H^+) concentration in water and is commonly used to describe the acid-base balance of water. On the pH scale (0-14), a pH of 7 represents neutral conditions, while pH value greater than 7 indicate basic (alkaline) conditions and pH values less than 7 indicate acidic conditions. Natural fresh waters have a pH range in between 6 to 8. This pH range is favoured by the largest species of aquatic species (FEM, 2015).

The pH affects the solubility and toxicity of chemicals and heavy metals in the water. A slight fluctuation in the pH of water can increase the solubility of phosphorus and other nutrients making them more accessible for plant growth. A low pH can also allow toxic elements and compounds to become mobile and available for uptake by organisms (USGS, 2015). Level of pH is influenced by several conditions, such as sources of water, acid rain, surrounding rock formations, and certain wastewater discharges. Presence of higher organic matter leads to higher decomposition, which can affect the pH level. Similarly, soil pH also affects water pH level (FEM, 2015). The level of pH recorded from Malaysian river has a range between 3.8 to 9.1. The NWQS Malaysia recommended threshold range of pH is 6.5 to 8.5 (DOE, 2010).

2.2.1.3 Conductivity

The conductivity of water is a measure of the ability of water to pass an electrical current. This ability is directly related to the concentrations of ions in the water. These conductive ions come from inorganic dissolved salts, such as the anions of chloride, nitrate, sulfate, and phosphate or the cations of sodium, magnesium, calcium, iron, and aluminum (EPA, 2012b). It is actually the total measurement of the ions in the water.

The natural factor that affects the conductivity of streams and rivers is mainly the geology i.e., the geologic colloid systems of the area through which the water flows. It varies depending upon the type of rock or soil that the water has come in contact with. The streams that run through granite bedrock tend to have lower conductivity and those that flow through limestone and clay tends to have higher conductivity (FEM, 2015). Other variations can also be caused by the type or amount of biological activity in surface water. Degradation of plant matter increases the dissolved solids as well as the conductivity of the water. On the other hand, anthropogenic activities that are responsible to raise or lower the conductivity are industrial and urban land uses. High conductance readings can come from industrial pollution or urban runoff, such as water flowing from streets, buildings and parking lots. A failing septic system near water body could raise the conductivity of that water due to the presence of chloride, phosphate, and nitrate. Temperature also affects conductivity; warm water has a higher conductivity (Appelo and Postma, 2004; Barron and Ashton, 2005). Conductivity is measured in micro Siemens per centimeter (µS/cm).

2.2.1.4 Turbidity

Turbidity is a measure of water clarity, which is caused by the presence of suspended matter in a water body such as clays, mud, algae, silica, and bacteria. These substances enter the water body through non-point source pollution, such as soil erosion and urban runoff, and through processes within the water body, such as algal growth (EPA, 2012a). It indicates the deficiency of water clearness and the degree to which light is entering a column of water. Turbidity lessens the entering amount of light in water a column resulting in a decrease of photosynthesis of aquatic plants (Wilson, 2010).

High turbidity from anthropogenic sources has significant negative impacts on aquatic fauna. High turbidity elevate nutrient inputs that stimulate algal blooms, waste discharge, and an abundance of bottom feeders that stir up sediments and limits light availability for photosynthesis (Baoligao et al., 2016; González-Ortegón et al., 2010; Kimbell and Morrell, 2015). As water becomes more turbid, less sunlight is able to penetrate its surface, resulting in a decrease of photosynthesis of aquatic plants (Wilson, 2010). As a result, the amount of oxygen produced by the aquatic plants decrease. In addition, suspended materials absorb heat from sunlight and raise the water temperature. This also limits the amount of dissolved oxygen that water can hold.

Anthropogenic activities increase turbidity and may lead to concerns about the impact on various fishery species (Allen-Ankins et al., 2012) Urbanization and residential areas contribute a lot to turbidity to the nearby water bodies through stormwater pollution from paved surfaces such as roads, bridges and parking lots. Forestry activities including timber harvesting, deforestation for land use development and management cause huge soil erosions and runoffs that contribute to increased stream sediment followed by turbidity (Ling et al., 2016). However, all of the studies were consistent in finding higher turbidity levels is surface water during periods with higher stream flow or precipitation levels. Turbid water is unfit for industrial as well as the homestead or recreational uses.

2.2.1.5 Total Dissolved Solids (TDS)

Total dissolved solids (TDS) is the measure of all organic and inorganic substances that are dissolved in water. The inorganic sources of TDS include dissolved anion of carbonates, chlorides, sulfates and nitrates, and cations of sodium, potassium, calcium, and magnesium. On the other hand, organic sources include leaves, silt, and plankton, and industrial, domestic as well as sewage wastes.

TDS can also increase due to runoff from agricultural areas where fertilizers and pesticides are used on lawns and farms. Atmospheric deposition also contributes to the TDS concentration in water. Soil and rocks may release ion when water moves over them to cause increased TDS level in surface water (Lawson, 2011; Wilson, 2010). Freshwater usually has TDS levels between 0 and 1,000 mg/L, depending on the geology of the region, climate and weathering, and other geographical features that affect sources of dissolved material and its transport to a water system. Some dissolved inorganic elements such as nitrogen, phosphorus, and sulfur are nutrients essential for life.

2.2.1.6 Total Suspended Solids (TSS)

Total suspended solids (TSS) is a measure of the suspended solids in water that can be trapped in a water filter. TSS is universal in aquatic ecosystems and contributes to bottom material composition, water-column turbidity, and chemical constituent transport. They include silt, clay, plankton, organic wastes, and inorganic precipitates. They are also capable of settling out of the water column onto the stream bottom when stream velocities are low. Excessive amounts of sediment can degrade water quality and harm aquatic ecosystems through physical, biological, and chemical processes (Duan et al., 2013).

Anthropogenic activities can significantly contribute to the higher concentration of suspended solids in water including soil particles, phytoplankton, and zooplankton, and small fragments of dead plants contribute a lot to the suspended solids. Moreover, discharge of industrial wastes, urban and domestic wastes, runoff from agricultural sites, and riverbank erosion along with soil erosion from new construction sites or upland are the potential sources of suspended solids in water.

Low concentrations of total solids can result in a limited growth of aquatic organisms due to nutrient deficiencies while high concentrations can lead to eutrophication of the stream or increased turbidity (Akan et al., 2012; Lawson, 2011). Both eutrophication and increased turbidity result in a decrease in stream water quality. High level of TSS results in an increase in water temperature by absorbing heat from sunlight, which consequently decreases the DO level in the water. Moreover, a water body loses its capability to support a diversified aquatic life when TSS level increases in that water (Akan et al., 2012).

2.2.2 Chemical Parameters

Chemical water quality parameters are important indicators of water quality. These parameters may be used to indicate sources of pollution or be linked to other physical or biological water quality parameters. Commonly measured chemical parameters include nitrates, nitrites, ammonia, ortho- and total phosphates, dissolved oxygen and biochemical oxygen demand. Chemical assessment in this study consisted of measuring biochemical oxygen demand (BOD_5), chemical oxygen demand (COD) and nutrients such as nitrate nitrogen (NO_3-N), ammonia nitrogen (NH_3-N), total nitrogen (TN), phosphorus phosphate (PO_4-P) and total phosphorus (TP).

2.2.2.1 Dissolved Oxygen (DO)

Dissolved oxygen (DO) is one of the most vital components of water quality in surface water bodies. It is the amount of oxygen dissolved in water, measured in milligrams per litre (mg/l). The principal sources of DO in surface water are mostly natural. The DO enters surface water through diffusion from the atmosphere at the stream surface exchange (atmospheric reaeration) and from photosynthesis by aquatic plants living in the water. On the other hand, its concentration decreases due to algal uptake for respiration, sediment oxygen demand, organic matter consumption (BOD), nitrification of ammonium (NH_4), and oxidation of NO_2 (Bailey and Ahmadi, 2014). Temperature can affect DO concentrations physically with a higher solubility of DO observed for colder waters, or indirectly via the significant role of temperature in ecosystem metabolism (Yvon-Durocher et al., 2010). In conjunction with natural drivers of DO dynamics, stream DO concentrations can also be affected by forest management activities. Clearfelling may introduce brash material into receiving aquatic systems, potentially increasing organic matter supply and thus biological oxygen demand (BOD). It can stimulate eutrophication via increased nutrient export to receiving waters and increased light availability as well as temperature following canopy removal. Eutrophication generally promotes excessive plant growth and decay, eventually causing a severe reduction in DO (O'Driscoll et al., 2016).

Dissolved oxygen is essential for a healthy aquatic ecosystem. It is essential for aerobic respiration at all trophic levels for fish and aquatic animals. The need for oxygen depends on the species and life stage; some organisms are adapted to lower oxygen conditions, while others require higher concentrations for their metabolic demands (FEM, 2015). Low DO affects to aquatic organisms. It can either harm or support use for aquatic life depending on its concentration. Thus, it is like a barometer for the river ecosystem and a key factor for survival of various aquatic lives (Kannel et al., 2007). In Malaysia, oxygen solubility is limited by the equatorial climate; cool climate countries, on the other hand, tend to have higher oxygen solubility (Zainudin, 2010).

2.2.2.2 Biochemical Oxygen Demand (BOD)

The biochemical oxygen demand (BOD) is one of the most widely used parameters for water quality assessment. It provides information about the ready biodegradable fraction of organic compounds in water and wastewater (Jouanneau et al., 2014). BOD is the amount of dissolved oxygen taken up through the respiratory activity of microorganisms to break down organic material present in a given water sample at a certain temperature over a specific time period (Connor et al., 2017). This measurement is obtained over a period of five days at a certain temperature and is expressed in mg/L.

The BOD is the aerobic biodegradation that consists of oxidizing organic matter biologically. During this process, the organic matter is converted by microorganisms into microbial biomass, eventual transformation products of biodegradation reaction (compounds derived from the initial organic matter), CO_2 and H_2O, according to Equation 2.1 (Jouanneau et al., 2014).

$$X_0 + S + O_2 \xrightarrow{N,P,MN} X_f + T_p + CO_2 + H_2O \qquad 2.1$$

where, X_0: Initial biomass, S: Organic carbon sources, O_2: Oxygen, N: Nitrogen source P: Phosphorus source, MN: mineral nutrients, X_f: Final biomass, T_p: Transformation products of biodegradation, CO_2: Carbon dioxide, H_2O: Water.

In surface water, BOD level usually increases due to the enrichment of organic matter, decay of plant and animal matter into lakes, reservoirs, and streams (Annalakshmi and Amsath, 2012). Hence, the higher the number of organic materials, the more usage of oxygen for aerobic oxidation, and the higher the measure of BOD. Higher BOD leads to the decrease of oxygen that may cause the reduction of metabolism in aquatic organisms and lead to low productivity of fish and other organisms (Pörtner, 2010). Moreover, an excess of organic matter depletes oxygen from the water bodies and increases the risk of eutrophication and algal blooms (Connor et al., 2017). The discharge of industrial effluents that contain a considerable amount of organic materials and nutrients significantly contribute to the BOD level (Gadhia et al., 2013; Islam et al., 2013). In addition, effluents or wastewater from agricultural farms, urban and domestic wastewater are also responsible for high levels of BOD in surface water ((Al-Badaii et al., 2013). Various factors affect BOD levels, including 1) delayed oxygen consumption from biodegradation of organic matter, 2) oxygen consumption by nitrification, 3) oxygen consumption by reduction of inorganic substances, and 4) oxygen consumption by a reduced amount of microbes. The first three factors raise BOD values, and latter factor decreases BOD (Mouri et al., 2011).

2.2.2.3 Chemical Oxygen Demand (COD)

Chemical oxygen demand (COD) is the measurement of the amount of pollution that cannot be oxidized biologically in a sample of water. COD mostly caused by reaction. The higher the chemical oxygen demand, the higher the amount of pollution (mostly inorganic) in the test sample (Connor et al., 2017).

COD is an indicator of organics in the water, usually used in conjunction with BOD. The COD is a measurement of the amount of material that can be oxidized in the presence of a strong chemical oxidizing agent. It is usually used to determine the number of organic pollutants found in surface water. High COD levels may cause a reduction in DO level due to the decomposition by microbes and consequently hamper the aquatic life (Annalakshmi and Amsath, 2012). The causes of higher COD values are primarily industrial, domestic and urban wastewater. Industries that produce and discharge their effluents containing a significant amount of inorganic compound may be the major sources of COD in adjacent water bodies (Naddeo et al., 2013; Zhao et al., 2011). Besides industrial and urban wastewater, agricultural runoff also contributes to the higher amount of COD (Zhao et al., 2011). In seasonal variation it was also noticed that during the wet season due to increased water flow, COD was recorded comparatively lower than the dry season (Varol et al., 2012).

2.2.2.4 Nutrients Parameters

Nitrogen and phosphorus are the most important parameters in water quality assessment, as they are most often in short supply relative to the needs of plants, algae, and microbes. In aquatic ecosystems, nitrogen and phosphorus are found in both particulate and dissolved phases and in varying chemical forms, as organic particulate, inorganic particulate, dissolved organic and dissolved inorganic form. The availability of nutrients for uptake and use by living organisms depend on the chemical form of the nutrients and the biochemical processes to the organism (Bernhard, 2010; RAMP, 2016a). Before describing the details of nutrients, it is necessary to briefly review the nutrient cycle for understanding the sources of nutrients (Figure 2.1 and Figure 2.2).

The main sources of nitrogen and phosphorus in river systems are mainly derived from atmospheric deposition (mainly nitrogen), erosive runoff, agricultural fertilizer, animal manure from livestock production, and point sources from domestic and industrial waste-water (Duan et al., 2013; Zhang et al., 2010a). As there is no nitrogen in native rock, the major sources of nitrogen are atmospheric and human-induced inputs. Together with nitrogen gas, atmospheric NOx is formed by lightning, combustion (as an inadvertent by-product), and emissions from biological systems. Nitrogen fixation by leguminous plants also contributes to atmospheric nitrogen. The input of atmospheric nitrogen to terrestrial and aquatic environments depends on biological assimilation through nitrogen fixation and the dissolution of nitrogen gases in atmospheric moisture (Markov, 2012). Human-induced inputs disturb the natural cycle of nitrogen. Sources include sewage discharge, septic tanks, landfill sites, fertilizer application, livestock wastes, and fossil fuel burning. Nitrogen fixed by crops may be lost to water bodies as a component of watershed runoff (Figure 2.1). Nitrogen can also be released from newly plowed soils if the land is under-drained or has clear-felled forest areas (Bernhard, 2010; Markov, 2012). The primary source of phosphorus comes from phosphate minerals in sediments. Atmospheric phosphorus sources are relatively insignificant compared to nitrogen sources. Phosphorus inputs mostly rely on the degree of erosion and weathering of rocks containing phosphorus. The phosphorus cycle is more closed and has a longer time span than that of nitrogen, but human interventions such as releases of phosphorus effluents of high concentrations from various industrial and agricultural activities accelerate the phosphorus cycling (Filippelli, 2009) explain more on Figure 2.2.

There are several important pathways that nutrients can transit from the soil surface to water bodies. First, surface runoff or overland flow transports sediment-associated nutrient species such as solid-phase nitrogen and phosphorus (particulate P, dissolved inorganic P or insoluble P in the soil). The relative importance of the overland pathway is determined by soil surface permeability and surface roughness. Second, infiltration and subsurface through-flow is the dominant pathway for soluble nutrient species such as dissolved nitrogen and phosphorus. Together with through-flow, groundwater flow is an important pathway for the movement of soluble nutrient species (Connor et al., 2017).

Nutrients assessment in this study consisted of measuring of nitrate-nitrogen (NO_3-N), ammoniacal-nitrogen (NH_3-N), total nitrogen (TN), phosphorus phosphate (PO_4-P) and total phosphorus (TP). The above-mentioned nutrients variables were reviewed in detailed.

Ammonical-nitrogen (NH_3-N)

In a water body, ammonia exists in two forms, such as ionized ammonium (NH_4^+) and un-ionized ammonia (NH_3). The sum of these two forms of ammonia is referred to ammoniacal nitrogen.

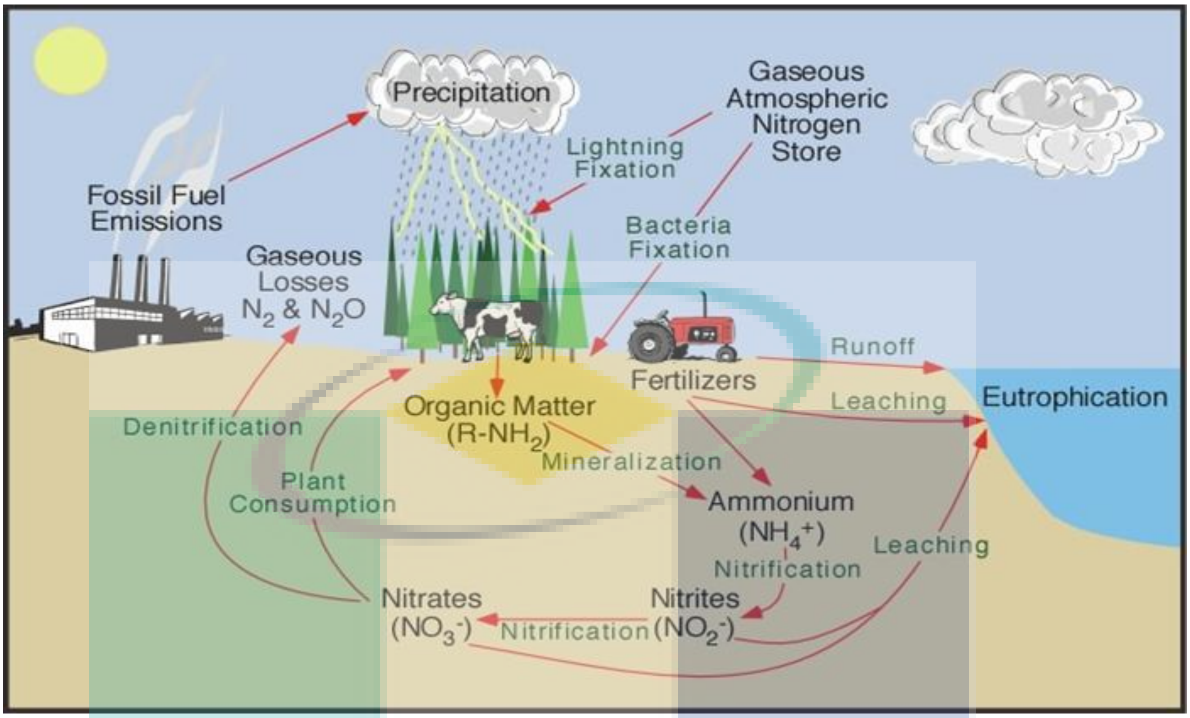

Figure 2.1 The nitrogen cycle.

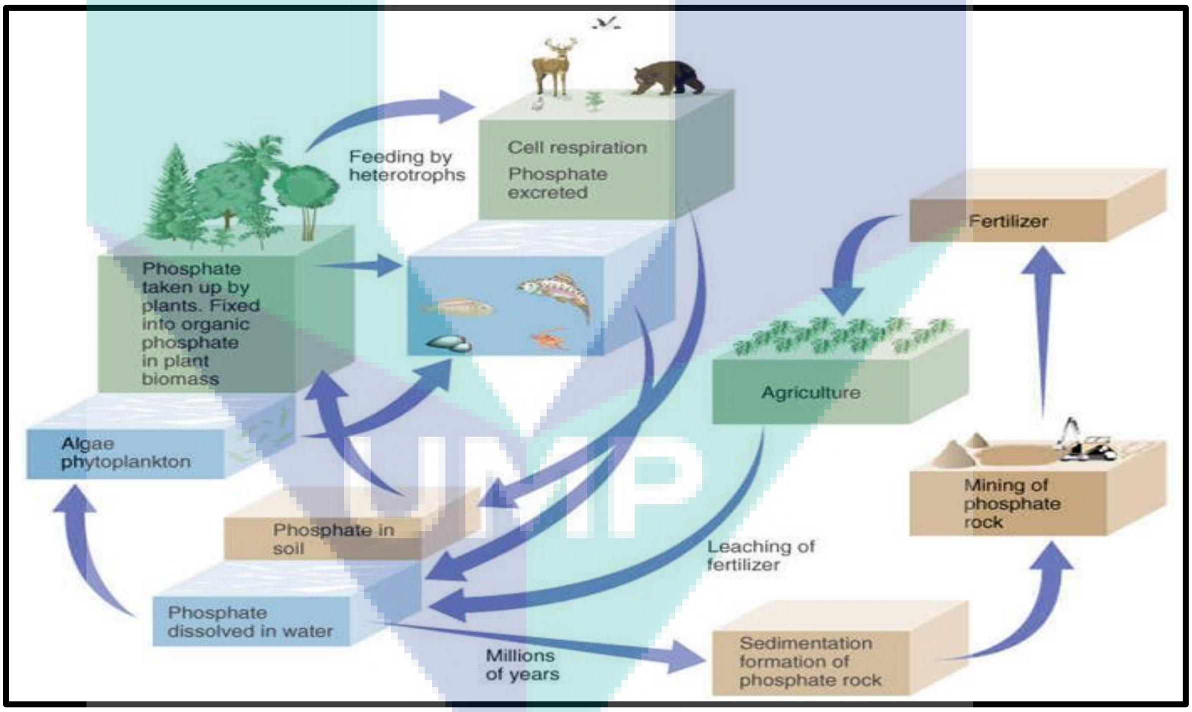

Figure 2.2 The phosphorus cycle.

The un-ionized form of ammonia is usually toxic to aquatic organisms even in low concentration that can be stable at water column below the water-air interface (Francis-Floyd et al., 2009). The toxicity of unionized ammonia is critically dependent on pH and temperature. At a given concentration of total ammonia, pH has a greater influence compared to the temperature (FEM, 2015) Free toxic ammonia may rapidly convert to non-toxic ammonium (NH_4^+) ion [2 NH_3 (aq) ≈ NH_4^+ (aq) + NH_2^- (aq)] in acidic condition. Unpolluted freshwater generally contains a small amount of ammonia and ammonia compound, normally < 0.1 mg/L and rarely contains >0.05 mg/L(Bartram et al., 1996; Chapman, 1996)

The aerobic oxidation of organic nitrogen and phosphorus compounds are facilitated under oxygenated conditions. The microorganisms and nitrification caused by nitrifying bacteria are mainly responsible for such oxidation. As a result, organic nitrogen compounds were decomposed to NH_3, to dissolve in the form NH_4^+ in the water phase. Furthermore, it is oxidized to NO_3 by nitrification (Francis-Floyd et al., 2009; Kozaki et al., 2017). High DO concentration can facilitate the nitrification processes by converting NH_4-N concentration into NO_3-N and vice versa (Glibert et al., 2014).

Nitrate- nitrogen (NO_3-N)

In-stream, concentrations of NO_3 is of paramount importance due to their effects on aquatic life and the overall environmental health of a river system. The nitrate ion (NO_3^-) is the common form of combined nitrogen found in natural water. Nitrite (NO_2^-) ion rapidly oxidizes to nitrate (WHO, 2011). This conversion process is Ammonia + Oxygen + Alkalinity + Nitrosomonas = Nitrite and Nitrite + Oxygen + Alkalinity + Nitrobacter = Nitrate. It is an essential element for aquatic plant and its fluctuation can cause a limiting effect on plant growth (Piwpuan et al., 2013). It is the stable form of combined nitrogen for oxygenated systems (WHO, 2011).

NO_3 increases due to oxidation of NO_2 and decreases due to algal uptake, which depends on the local growth rate of algae, and denitrification. NO_3- was reduced to N_2 gas through denitrification (Bailey and Ahmadi, 2014). A higher level of nitrate in surface water can affect phytoplankton growth. An excessive amount of nitrate can cause the extreme growth of algae. Algae can rob the water of dissolved oxygen and eventually kill fish and other aquatic life. The major source of nitrate concentration in surface water is the agricultural runoff. Problems associated with high concentration of NO3 include eutrophication, which induces DO depletion (i.e., hypoxia) due to increased biologic activity, and contamination of drinking water which can have serious negative health effects for infants due to methemoglobinemia (Bailey and Ahmadi, 2014). The concentration of nitrate in surface water may exceed more than 5 mg/L if it is induced by the human activities. The expected level of nitrate concentration is less than 1.0 mg/L (Chapman, 1996).

Total Nitrogen (TN)

Nitrogen is an essential nutrient for the formation of amino acids for the growth of all living organisms. However, it cannot be used directly by most aquatic plants due to its molecular form. It must be converted to another form, such as ammonia (NH_3). Ammonia may be taken up by plants or oxidized by bacteria into nitrate (NO_3^-) or nitrite (NO_2^-). Excessive concentrations of nitrogen can lead to eutrophication and subsequent degradation of stream water quality. Sewage and agricultural runoff are the most common sources of excessive nitrogen (RAMP, 2016a)

Phosphate-phosphorous

Alike nitrogen, phosphate (PO_4^{3-}) is one of the limiting factors of aquatic environment that controls the productivity of aquatic organisms. It is an essential element for plants and aquatic organisms. In an aquatic environment, it exists in both dissolved and particulate phases. The higher level of phosphate greatly stimulates the growth and production of algae that can cause eutrophication in water bodies. The potential effect of eutrophication to river water may be the incremental rate of biomass, shifting of the bloom-forming algae to toxic or inedible species, reduce fish productivity, reduction in aquatic species, development of scum and odours as well as reducing the DO concentration (Filippelli, 2009; RAMP, 2016a).

In surface water, phosphorus initiates from a variety of sources; with anthropogenic activities as the major sources of phosphorus. Anthropogenic sources include soil erosion due to human activities and runoff from farmland or lawns, runoff from urban areas and construction sites, use of detergents and septic systems, municipal sewage treatment plants and human and animal wastes (Al-Badaii et al., 2013; Barakat et al., 2016; Carter and Dzialowski, 2012; Dodd and Sharpley, 2015; Mouri et al., 2011). Phosphate is a common water quality parameter in agricultural areas because a substantial amount of phosphate fertilizers is usually used in agriculture and the animal waste contains a high amount of excess phosphorus, which may seep into the adjacent water bodies through spills, leaks, and runoff during storms. A significant amount of phosphate in water comes from various natural sources, which include the weathering of phosphorus-bearing rocks, decomposition of organic matter that contain phosphate compounds, atmospheric deposition, the soluble nonreactive P pool in water or soil and sediment flux into the water bodies (Dodd and Sharpley, 2015).

Total Phosphorous (TP)

Phosphorus is an essential nutrient for living organisms and exists in water bodies as both dissolved and particulate species. In natural waters, phosphorus occurs mostly as dissolved orthophosphates (PO_4^{3-}) and polyphosphates, and organically bound phosphates (Chapman, 1996).When an excess of phosphorus enters a river or lake, algae and aquatic plants grows uncontrollably, choke up the waterway and use up large amounts of oxygen in respiration causing eutrophication. Due to the decrease in dissolved oxygen levels, the aquatic life cannot survive (RAMP, 2016a).

2.2.3 Hydrological Variables

Rainfall and streamflow are major hydrological variables that have potential spatial and seasonal impacts on water quality. Non-treated domestic and industrial effluents are discharged continuously to the river causes variations in pollutants due to variations in flows (Perrin et al., 2014). Since flow discharges vary with the hydrological conditions, dilution may or may not occur. High pollutant concentrations are measured during base flow conditions which, in arid and semi-arid regions, can last for several months. It is worth noting that sedimentation of particulate pollutants in the river bed can also occur due to the low velocity of the flow during low flow conditions (Magbanua et al., 2015)

2.2.3.1 Rainfall

Rainfall has a significant effect on streanflow and thus play important role in in controlling the water quality from year to year (Zhou et al., 2012). During the wet period, the rainfall usually at its maximum, thereby increase stremflow high. As a result, the water quality has the chance to have better or become worse, depending on input from point and non-point source pollutions. On the other hand, the streamflow remain fairly constant in dry season that contribute less pollutants to river water. The elevated levels of ammonium, nitrate, and phosphate, may expect in water quality as the non-point sources is significant. originating from the agro-fertilizer and chemicals used in wet season (Zainudin, 2010).

2.2.3.2 Streamflow/Discharge

River discharge has been used extensively as a covariate in water quality assessment and in the development of water quality criteria for rivers being evaluated for disposal of wastewater, based on low discharge conditions. However, there is variation in constituent concentration and stream discharge among parameters with varying interactions in different rivers (Duan et al., 2013). In addition, extreme events such as floods can cause massive accumulations of sediment, significantly compromise phosphorus and nitrate distribution in the river systems.

Duan et al. (2013) showed that the estimated seasonal loads of TN, TP, and SS fluctuated widely over time fluctuated widely over time with the greatest loads occurring in the spring and the smallest loads occurring in the winter In the Ishikari River and its tributaries. In a study by Hubbard et al. (2011) showed increased flow during the flood resulted in near-peak totaled 4.95×10^7 kg of nitrogen (N) and 2.9×10^6 kg of phosphorus (P) which accounted for about 22 and 46% of the total average annual nutrient yield, respectively sediment from Iowa basins into the Mississippi River. Fluxes of dissolved and particulate nitrogen (N) and phosphorus (P) variables exhibited great seasonality due to variation in water discharge in upper Longchuanjiang River, China. High particulate loads were contributed to the erosion of phosphorus-rich soils during heavy rains in the wet season (Lu et al., 2011) .

2.2.4 Surface Water Pollution

Because of indispensability, surface water pollution is a major concern all over the world. In any region, surface water quality is influenced by both natural processes and anthropogenic changes through alteration of its hydrochemistry. The addition of various kinds of pollutants and nutrients through different sources into the water bodies brings about a series of changes in its quality resulting in the pollution of water. Table 2.1 lists the main pollutants and their source, together with the most representative effects.

Table 2.1 Main pollutants, their sources and effects

Pollutant	Main Representative Parameters	Source				Possible effect of the pollutant
		Wastewater		Stormwater		
		Domestic	**Industrial**	**Urban**	**Agriculture**	
Suspended solids	Total Suspended solids	xxx	←→	xx	x	• Aesthetic problems • Sludge deposit • Pollutant adsorption • Protection of pathogens
Biodegradable Organic Matter	Biochemical Oxygen demand	xxx	←→	xx	x	• Oxygen consumption • Death of fish • Septic condition
Nutrients	Nitrogen, Phosphorous	xxx	←→	xx	x	• Excessive algae growth • Toxicity to fish(ammonia) • Illness in new –born infants (nitrate) • Pollution of groundwater
Pathogens	Coliforms	xxx	←→	xx	x	• Water –borne diseases
Non-biodegradable organic matter	Pesticides, some detergents, other	x	←→	x	xx	• Toxicity • Foam (detergents) • Reduction of oxygen transfer(detergents) • Non-biodegradability • Bad odour (phenol)
Metals	Specific elements (AS,Cd, Cr, Cu, Hg, Ni, Pb, Zn, etc)	x	←→	x		• Toxicity • Inhibition of biological sewage treatment • Problem in agriculture use on sludge • Contamination of groundwater
Inorganic dissolved solid	Total dissolved solid conductivity	xx	←→		x	• Excessive salinity-harm to plantations • Toxicity to plants(some ions) • Problem with soil permeability

x: small; xx: medium; xxx: high; ←→ variable; empty: usually not important

Source: (Von Sperling, 2017)

2.2.4.1 Pollution Sources

Pollutant inputs into water bodies are classified as point and non-point sources (Table 2.2). The spatial and temporal characteristics of these two sources vary considerably. Typically, major point sources of pollution are continuous, while non-point sources of pollution are largely intermittent over time. Non-point sources tend to be spread widely, while point sources are confined to particular locations. Point source pollutants are comparatively simple to measure and regulate because of their identifiable nature. In contrast, non-point source pollutants are harder to control than point sources of pollution because sources of pollution are often not clearly identified, and any improvement in water quality does not usually occur immediately when they are. Nowadays, non-point source pollution is considered as the most problematic and largest agent of pollution because of its geographic scale and increasing activity in and around the watersheds, especially urbanization and agricultural development.

Table 2.2 Source of point and nonpoint chemical inputs to lakes, rivers, and oceans

Point sources
Wastewater effluent (municipal and industrial)
Runoff and leachate from waste disposal sites
Runoff and infiltration from animal feedlots
Runoff from mines, oil fields, unsewered industrial sites
Storm sewer outfalls from cities with population > 100000
Runoff from construction sites > 2 ha
Nonpoint sources
Runoff from agriculture (including return flow from irrigated agriculture)
Runoff from pasture and range
Urban runoff from unsewered areas and sewered areas with a population < 100000
Septic tank leachate and runoff from failed septic systems
Runoff from construction sites < 2 ha
Runoff from abandoned mines
Atmospheric deposition over a water surface
Activities on land that generate contaminants, such as logging, wetland conversion, construction, and development of land or waterways.

Source: Carpenter et al. (1998)

2.2.5 Application of Water Quality Assessment

Water quality is affected by a combination of natural and anthropogenic factors, the relative influences of which change with temporal and spatial scale (Mouri et al., 2011). Hence, the assessment of spatio-temporal variability along with its pollution sources is significantly imperative for water resources management and ecosystem sustainability. Water quality assessment includes the monitoring program to define the status of water, to detect the spatial and seasonal variations and trends and to provide the information enabling the establishment of cause-effect relationships. It is also widely used to identify the source of water quality pollutions.

2.2.5.1 Application of Water Quality Assessment in Worldwide

Due to the seasonal and regional characteristics of river hydrology and water quality, evaluation of spatio-temporal variability and trends as well as possible pollution factors of water quality has become a major focus of research at the watershed scale. As the river water constitutes the main water resources for domestic, industrial, and irrigation purposes, it is crucial to assess its water quality for the proper of conservation as well as the implementation of sustainable water use management strategies. (Mei et al., 2014; Ogwueleka, 2015)

Most of the water quality studies have generally focused on river reaches found within rural, urban, and industrial areas, reflecting the impacts of land use patterns, urbanization and human disturbance (Chen and Lu, 2014; Kilonzo et al., 2014). The physico-chemical and biological composition, as well as the nutrients and sediment loadings, were commonly monitored for the purpose of water quality assessment. Concerning the applications, the water quality studies mainly involved in assessing spatial and temporal variations, identifying possible pollution factors/sources, data reduction, grouping and discrimination of variables that influence water system all over the world. Researchers applied a number of techniques for water quality studies. Most of them applied statistical analysis (Ajorlo et al., 2013; Mei et al., 2014; Ogwueleka, 2015) while some used model (Kang et al., 2010; Wu and Chen, 2013) and a few used only graphical presentation based on ionic concentrations (Kozaki et al., 2016; Kozaki et al., 2017) to explore the characteristic of water quality status within a river/watershed.

In various watershed scale, the spatial and temporal variations of water quality influenced by point and diffuse source pollution are assessed to manage the river environment sustainably. Zerga (2015) investigated the physico-chemical status and biological integrity of the Upper Mara River and its two main tributaries in Kenya and found that the variability in TP and TN concentrations increases downstream for both tributaries and is more pronounced for TN than for TP suggested the influence of anthropogenic interference in agriculture streams. Lam et al. (2012) studied the spatio-temporal variations of the water quality of Kielstau catchment, Northern Germany and showed that water quality was influenced by diffuse sources from agricultural areas and by point sources from municipal wastewater treatment plants. They also revealed that shallow groundwater is the major contributor to total nitrate load in the stream accounting for about 93% of the total nitrate load, while only about 7% originates in surface runoff and lateral flow. Mei et al. (2014) showed that DO, COD, BOD, NH_4 -N, TN, TP, and EC were the most important indicators of degraded water quality in the Wen-Rui Tang River, Eastern China. A similar study at the Oued Fez and the Sebou River in Morocco were characterized by severe pollution downstream from the city of Fez, particularly TN, TP and TCr under the influence of domestic and industrial wastewater inputs, particularly tannery effluents (Perrin et al., 2014). In a study in the Tigris River, Turkey, Varol (2013) revealed that TN and TP concentrations of water were higher in the wet season than those in the dry season. In the East River (Dongjiang in Chinese) of southern China, the temporal (seasonal) and spatial distributions clearly indicated the critical time period (from late dry season to early wet season) and pollution source areas within the basin (middle and downstream agricultural land) (Wu and Chen, 2013).

Different statistical approaches and model are commonly used in water quality assessment in worldwide. Among those, the multivariate statistical techniques have become a widely accepted method and the most convenient for designing monitoring network for effective management of water resources (Chen and Lu, 2014; Singh et al., 2005). Multivariate analysis methods such as cluster analysis (CA), principal component analysis (PCA), factor analysis (FA) and discriminant analysis (DA) have been widely and successfully applied to analyze and interpret large complex water quality data sets, assess water quality, understand temporal/spatial variations, and identify latent pollution sources of river water (Ogwueleka, 2015; Wang et al., 2014).

CA was applied with a view to group the similar sampling sites (spatial variability) spread over the river stretch and similar sampling periods (temporal variability) using the river water quality data set (Li et al., 2014; Shrestha and Kazama, 2007; Singh et al., 2005). FA/PCA was performed to identify the factors/sources responsible for river water quality variations (Wang et al., 2012; Xue et al., 2015). DA allowed a reduction in the dimensionality of the large data set, delineating a few indicator parameters responsible for large variations in water quality (Li et al., 2014; Vieira et al., 2012; Zhang et al., 2011).

A number of scholars analyzed and interpreted large complex water quality datasets using multivariate methods to investigate and identify the spatial and temporal variations, potential sources of pollution and data reduction (Ogwueleka, 2015; Ruzdjak and Ruzdjak, 2015; Shrestha and Kazama, 2007; Singh et al., 2005). Singh et al. (2005) applied multivariate statistical techniques such as CA, FA, PCA and DA using 3-years monitoring data (34 parameters for eight sites) of the Gomti river, Northern India. They showed that CA grouped the sampling sites into three clusters of similar characteristics; FA indicated the major parameters responsible for water quality variations. DA rendered five parameters affording more than 94% right assignations in the temporal analysis, while 10 parameters to afford 97% right assignations in spatial analysis of three different regions in the basin. Similarly, Shrestha and Kazama (2007) used CA and DA to identify the significant parameters and optimize the monitoring network of the Fuji River (Japan) using 8 years monitoring data of 12 parameters at 13 different sites. In their study, DA allowed a reduction in the dimensionality of the large data set, delineated a few indicator parameters responsible for large variations in water quality. Multivariate statistical techniques, including CA, PCA, and FA had been integrated to evaluate and interpret spatiotemporal variations and identify latent sources of water pollution in the Songhua River Harbin region, China with a 5-years monitoring data (15 parameters for six sites) by Wang et al. (2013). They used HCA to group all the sites into three clusters and used PCA/FA to explore five latent factors determining the spatiotemporal dynamics of water quality in Songhua River. For the evaluation of seasonal and spatial variations and the interpretation of a large and complex water quality dataset obtained during a 7-year monitoring program (18 parameters for 18 sites) of the Sava River in Croatia, CA and PCA were applied (Ruzdjak and Ruzdjak, 2015). Multivariate statistical techniques CA and PCA/FA were also used to investigate the temporal and spatial variations and to interpret large and complex water quality data sets (8 stations, 17 parameters for 5 years) collected from the Kaduna River (Ogwueleka, 2015). A number of water quality studies all over the world for water resource management were also reviewed and shown in Table 2.3.

A number of researchers applied hydrological/water quality model mainly for nutrient and suspended loadings for quantitatively predicting stream water quality. Wu and Chen (2013) used the physically-based hydrological/water quality model, Soil and Water Assessment Tool, to investigate the influence of PS and NPS pollution on the water quality of the East River (Dongjiang in Chinese) in southern China and revealed that NPS pollution was the dominant contribution (>94%) to nutrient loads except for mineral phosphorus (50%).The performance of multiple linear regression models and constrained least squares models was compared for quantitatively predicting stream water quality in the Yeongsan River (South Korea) suggested that industrial and urban land-uses are major contributors to the stream concentrations of *Escherichia coli* (EC), *Enterococci bacteria* (ENT), whereas agricultural, industrial, and mining areas were significant sources of many heavy metal species (Kang et al., 2010).

Some of the scholars attempted to integrate water quality data and GIS-based mapping technique to derive a reliable, simple and useful output for water quality monitoring in water resource environment (Li et al., 2014; Pratt and Chang, 2012). Using the integrated approach, Jha et al. (2015) demarcated healthy and polluted areas in the coastal waters of Andaman Sea, India. Surface water quality maps for dissolved oxygen, ammonium, ortho-phosphate, manganese and total coliforms were developed to highlight hotspot in the Vietnamese Mekong Delta (Wilbers et al., 2014). Aminu et al. (2015) used a GIS-based water quality model for sustainable tourist planning of Bertam River in Cameron Highlands, Malaysia. Water contaminant maps also revealed spatial and seasonal heterogeneity in Danjiangkou mountainous watersheds using GIS application (Ai et al., 2015).

Results from above reviewed revealed that most of the water quality studies were highly linked with land use patterns and discharge from industry and/or sewage as well as agricultural runoff. All these studies demonstrated that spatial-temporal variations of water quality strongly depend on the spatial and temporal scales of analysis.

Table 2.3 Recent studies conducted on water quality assessment

Reference	Applied techniques	Study (To evaluate)	Location	Findings
Alberto et al. (2001)	CA, FA/PCA, and DA	Spatial and temporal changes	Suquia River (Argentina)	DA affords the best results for both temporal and spatial analysis; Variations pattern associated with seasonal variations, urban run-off, and pollution sources
Bengraïne and Marhaba (2003)	PCA	Factors associated with water variability	Passaic River (USA)	The impact of organic, biological, and chemical patterns; The extracted patterns were of natural, urban, industrial, and agricultural origins.
Ouyang et al. (2006)	PCA	Temporal variations	Lower St. Johns River (USA)	Importance of parameters in contribution to river water quality variation varied seasonally.
Li et al. (2009)	CA, ANOVA GLM	Spatio-temporal variations	Upper Han River (China).	The concentration of nutrients increased in the wet season; High nutrient contents associated with the urban and agricultural production areas.
Bu et al. (2010)	CA, FA, and gridding method	Temporal and spatial variability	Jinshui River (China)	Water quality progressively deteriorated from headwater to downstream areas.
Wang et al. (2012)	CA, FA/PCA, and DA	Spatio-temporal patterns	Xiangxi River (China)	Variations mainly related to soluble salts (natural), point source pollution of phosphorus and non-point pollution of nitrogen (anthropogenic)
Garizi et al. (2011)	ANOVA, DA, PCA, FA	Temporal variations of river pollution	Chehelchay watershed, Iran	Variations were strongly affected by rock-water interaction, hydrologic processes, and anthropogenic activities.
Zhang et al. (2011)	CA, PCA, and DA		Kowloon, Hong Kong	DA provided better results both temporally and spatially. Organic, industrial, nonpoint, and fecal were latent factors for pollutions
Ajorlo et al. (2013)	CA, DA, FA	Seasonal variations	TPU catchment, Kuala Lumpur, Malaysia	Fecal Coli, NH_3, and E. coli were the best predictors for distinguishing clusters in temporal; Biological and physiochemical sources were responsible for variations.

Table 2.3 Continued

Reference	Applied techniques	Study (To evaluate)	Location	Findings
Vieira et al. (2012)	Correlation PCA and CA	Spatial variations and pollution sources	Lis River Basin, Portugal.	The anthropogenic sources caused a strong impact on water quality compared to the natural contributions.
Li et al. (2014)	Correlation, CA PCA and DA	Temporal and spatial variations	Xin'anjiang River, China	DA identified significant parameters for variations which classified the water quality into three groups and periods.
Xu et al. (2015)	CA, DA, PCA, FA, and FCA	Spatio-temporal variations and pollution sources	Yuqiao Basin, North China	DA identified significant variables affecting spatial and temporal variations. Nutrient, organic, inorganic, and natural factors were major sources for water quality variations:
Wang et al. (2014)	CA, PCA, and DA	Spatial variance of water quality	Tamsui River basin, Taiwan, Taipei City	Anthropogenic pollution, the nitrification process, seawater intrusion, and geological and weathering processes were major factors that predominantly influence the water quality
Wilbers et al. (2014)	PCA	determined the levels of pollution	Vietnamese Mekong Delta, Vietnam	Urbanization, metal from soils, aquaculture, and tidal regime causes the variance of surface water quality. DO, NH_4^+, PO_4-P, manganese and total coliforms were major pollutants.
Lu et al. (2011)	Interpolation and extrapolation	Annual nutrient loadings and seasonal variability	Longchuanjiang River, Yunnan Province, China	Dissolved N and particle-associated P contributed 56% and 99% of the total nitrogen and total phosphorus yields of 549 and 608 kg/km2/yr and exhibited great seasonality.
Barakat et al. (2016)	Correlation, PCA, and CA	Spatial and temporal water quality variation	Oum Er Rbia River(Morocco)	The variations are mainly related to domestic and industrial wastewater, agriculture activities), as well as weathering of soil and rock.
Mustapha et al. (2012)	Correlation, PCA, and sample *t*-test,	Spatio-temporal variations	Jakarta River, Indonesia	The source of pollution in the area was concluded to be of anthropogenic origin in the dry season and natural origins in the wet season
Kilonzo et al. (2014)	PCA and CCA	Water quality status	Upper Mara River, Kenya	The variability in TP and TN concentrations increases downstream and is more pronounced for TN than for TP.

2.2.5.2 Water Quality Assessment in Malaysia

Malaysia is blessed with abundant amounts of water resources with an average annual precipitation of 3000 mm. About 95% of its usage water comes from the inland river systems. As the country progresses towards realizing the Vision 2020 (i.e., becoming a developed nation) through the implementation of its policy agenda for heavy industrialization, infrastructures, and urban-expansions, water demand has increased steeply and greater pressure is on preserving the current water resources as well as finding alternative courses of action to improve water quality (Othman et al., 2012). Thus, the degradation of river water quality has become an important issue in Malaysia. For understanding the river water quality in Malaysia, the present status of river water quality, common sources of pollution, the methods applied for river water quality classification, and recent river water studies are reviewed in detailed.

Despite the enforcement of the Environmental Quality Act (EQA) in 1974, most of the rivers are following a deteriorating trend in water quality due to the impacts of tremendous development that Malaysia is going through (Al-Mamun and Zainuddin, 2013). According to the environmental quality report 2014 by the Department of Environment, 52% of the total 473 rivers were clean with 39% slightly polluted and 9% polluted (DOE, 2015). Compared with the river condition in the year 2013, the percentage of rivers being polluted and slightly polluted were increased by 4% and 3%, respectively in 2014. The decrease in the number of clean rivers was attributed to an increase in the number of polluting sources such as sewage treatment plants and agro-based industries which contributed to a high pollution loading. BOD, NH_3-N, and SS were detected as the major pollutants. High BOD can be attributed to untreated or partially treated sewage and discharges from agro-based and manufacturing industries. The main sources of NH_3-N were livestock farming and domestic sewage while the sources for SS were earthworks and land clearing activities (DOE, 2015). In 2014, based on BOD level, 89.3 % rivers were categorized as polluted and 10.7% as slightly polluted while based on NH_3-N, 28.6% rivers were categorized as polluted, and 42.1% as slightly polluted (Table 2.1). On the other hand, 13.6% rivers were categorized as polluted and 15.7% as slightly polluted by SS. Comparative statement showed that BOD based contaminated rivers (class III and IV) are rising 34.6% (in 2010) to 89.3% (in 2014) of the total monitored river (Afroz and Rahman, 2017). Domestic sewage and industrial wastewater are the main point sources responsible for degraded river water in Malaysia. In 2014, more than 1.48 million point sources of water pollution were identified included manufacturing industries, agro-based industries, and sewage treatment plants. The sewage treatment systems formed about 86 percent of some 1.48 million water pollution sources recognized throughout the Peninsular Malaysia (Afroz and Rahman, 2017; Ariffin and Sulaiman, 2015)

Table 2.4 The percentage of the polluted river based on water quality index (DOE)

Year	**Suspended solid**			**Biochemical oxygen demand**			**Ammoniacal Nitrogen**		
	Clean	Slightly Polluted	Polluted	Clean	Slightly Polluted	Polluted	Clean	Slightly Polluted	Polluted
	Percentage (%) of river			Percentage (%) of river			Percentage (%) of river		
2010	47.6	18.8	33.6	8.4	55.2	36.4	24.5	46.1	29.4
2014	70.7	15.7	13.6	-	10.7	89.3	29.3	42.1	28.6

Source: Afroz and Rahman (2017)

In Malaysia, there are two methods mainly used to classify the water quality of the river, namely the National Water Quality Standards (NWQS) and the Water Quality Index (WQI). The Water Quality Index (WQI) is used as a basis for assessment of a watercourse in relation to pollution load categorization while designation of classes of beneficial uses are specified in the National Water Quality Standards for Malaysia (NWQS) (DOE, 2015). Both the NWQS and WQI are good water quality benchmarking tools. The NWQS defines six categories (I, IIA, IIB, III, IV, and V) referred to the classification of rivers based on descending order of water quality where Class I being the "best" and Class V being the "worst". In NWQS, the standard values of 72 parameters are established to classify the rivers mainly for beneficial uses of water. This method mainly focused on water for domestic water supply, fisheries and aquatic circulation, livestock drinking, recreation and agricultural use (Zainudin, 2010). It can also form a basis for target water quality in river rehabilitation efforts.

On the other hands, the WQI primarily used in Malaysia (also referred to as the DOE-WQI) is an opinion-poll formula where a panel of experts is consulted on the choice of parameters and on the weight age to each parameter. Six parameters were chosen for the WQI; Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD_5), Chemical Oxygen Demand (COD), Suspended Solids (SS), Ammoniacal Nitrogen

(AN) and pH. In WQI, calculations are performed not on their measured values, but on their sub-indices values. The sub-indices are named SIDO, SIBOD, SICOD, SISS, SIAN, and SIPH. The Best Fit Equations are used to estimate the six index values. Finally, the calculated sub-indices are combined to calculate the WQI (Gazzaz et al., 2012a; Gazzaz et al., 2012c; Norhayati et al., 1997). The WQI summarizes a large number of water quality data for a specific river into a single value and corresponding status as clean, slightly polluted and polluted (DOE, 2010). This makes it easily understandable for communities in the river basin and for river basin management. It can also be used to monitor the health of the river.

Realizing the seriousness of the threat potentially posed to river water, many studies have been done in Malaysia to monitor the river quality status and to improve the river water quality in recent years. Water quality studies mainly include the monitoring program to assess the status and condition of water quality, to characterize the spatial and seasonal variations and trends as well as to detect the pollution sources of water quality (Akinbile et al., 2013; Ling et al., 2017; Soo et al., 2017). The assessment also applied for finding the suitability of river water for different usage purposes (Aris et al., 2014)

In Malaysia, water quality studies mostly are done based on two renowned methods, namely WQI and NWQS to assess the water quality condition in the river. Suratman et al. (2015) studied both WQI and NWQS to evaluate the water status of the Terengganu River basin, Malaysia. In their studied WQI results indicated the impact of various anthropogenic activities that contributed to the values of BOD, COD, TSS and AN at the middle and lower parts of the basin. However, NWQS results determine the quality of the basin suitable for the sustainable conservation of the natural environment, for water supply without treatment and as well as for very sensitive aquatic species. Naubi et al. (2016) applied the spatial trend of water quality index (WQI) and its sub-indices values for determining the locations of major pollutant sources in the Skudai and its tributaries. They identified that ammonia-nitrogen (NH_3-N) was the major pollutant with the lowest WQI index value of 38 responsible for declining the water quality at downstream of the watershed. Kozaki et al. (2017) applied NWQS in Galing River, Kuantan to understand the anthropogenic environmental load using water quality monitoring data and showed that western side of the river indicated lower class levels of

AN, COD, and DO as a result of higher anthropogenic influence compare to the eastern side. The inflow of industrial wastewater at upstream and the effect of household wastewater or untreated raw sewage wastewater were identified as an environmental burden for polluting the Garling River. In another study, Othman et al. (2012) applied WQI to assess the water quality status and to establish a trend analysis of the WQI for Klang River, Selangor, Malaysia using monthly WQI data from 1997 to 2007. The applied methods detected a statistically increasing trend of the WQI in the downstream of Klang River's main stem in 2002-2007, while the trend started in 1998 for the upstream reaches. The results also showed that the middle reaches improved from Class IV to Class III and some tributaries also exhibited some improvements in terms of WQI.

Although most of the researchers used WQI and NWQS for water quality assessment, some researchers also use some other Index and standards to study the water quality in Malaysia and also to prove the potentiality of these Index. Aris et al. (2014) used World Health Organization (WHO) and the Ministry of Health (MOH), Malaysia standards to understand the water quality status and its suitability for usage. Hasan et al. (2015) applied WQI and JPS River Index (JRI) to monitor the health of the Pelus River, Perak, Malaysia. The results of their study indicated that the water of the river quality during wet season was polluted (class III) as per WQI values. However, JRI considered the quality as clean (class IIA) as the index includes specific flow, total suspended solids, total dissolved solids, and turbidity as parameters.

A number of scholars applied multivariate statistical analyses to explore and identify the spatial and temporal variations and potential sources of pollution (Abdullah et al., 2015; Hua et al., 2016a; Soo et al., 2017). These techniques highlight the potential for reasonably reducing the number of WQVs and monitoring stations for long-term monitoring purposes as well as for complex datasets (Gazzaz et al., 2012c). Hua et al. (2016a) applied CA, DA and principal component analysis (PCA) to assess the spatial variation of Malacca River water quality. Their results indicated that CA has grouped all locations spatially into two clusters as moderate pollution sources and high pollution sources based on physico-chemical and biological water quality data and trace elements in water. DA analysis indicated that temperature, salinity, coliform, EC, DO, BOD, COD, As, Hg, Cd, Cr, and Zn are the most significant parameters that reflect the overall river water quality for discrimination in clustering. PCA results showed six components with 54% of total variance in moderate pollution cluster and eight components with 62% of total variance in the high polluted cluster. In a similar study, Gazzaz et al. (2012c) used factor analysis (FA), cluster analysis (CA), and discriminant analysis (DA) to identify the latent structure of a water quality dataset of Kinta River, Malaysia. They showed that FA identified the WQ parameters responsible for variations and emphasized the roles of weathering and surface runoff in determining the river's WQ. CA grouped the monitoring locations into two clusters; low levels of water pollution and relatively high levels of river pollution. DA analysis confirmed these clustering in their study. In another study, Gazzaz et al. (2012b) applied artificial neural network (ANN) modeling for computing the WQI in the same river. Modeling results showed that the WQI predictions of this model had significant, positive, very high correlation ($r = 0.977$, $p < 0.01$) with the measured WQI values, implying that the model predictions explain around 95.4% of the variation in the measured WQI values. Accordingly, this study emphasizes that the ANN constitutes an effective tool for assessment of the river WQ that simplifies the computation of the WQI and that saves substantial efforts and time by optimizing the calculation.

Some researchers also applied the water quality assessment to provide information for establishing the cause and effect relationships. Akinbile et al. (2013) showed that most of the pollutants were mainly from infrastructural development and agricultural activities in Bukit Merah Reservoir (BMR) in Malaysia. Hua et al. (2016a) in their study also confirmed that major sources of pollution in Malacca River come from agricultural and residential areas along the Malacca, as well as from sewage treatment plants and industrial activities. The anthropogenic activities such as deforestation and agriculture were expected to influence the stability of the water quality in Pelus River (Hasan et al., 2015). Kozaki et al. (2016) studied the water pollution levels in three suburban rivers, namely, Kuantan, Belat, and Galing Rivers in Kuantan, Malaysia using WQI. Their results portrayed that the pollution levels in the three rivers (Kuantan River: Classes I–III, Belat River: Classes I–III, and Galing River: Classes I–V) are linked with the urbanization level of the river basin area.

In the study area, previous research studies on the water quality mainly concentrated in the upper Bertam region. Eisakhani and Malakahmad (2009) studied the temporal variation of water quality parameters in upper Bertam during average and high water flow period. Khalik et al. (2013) studied the seasonal variation of physicochemical parameters in Bertam River and showed that the water quality has degraded with seasonal changes.

In the present study, the spatial and temporal variations of water quality as well as river water condition are assessed using both the mostly used National Water Quality Standards (NWQS) and the Water Quality Index (WQI) methods. The designations of classes of beneficial uses are identified using the average concentrations of parameters compared with classification based on NWQS. The Water Quality Index (WQI) is used as a basis for assessment of a watercourse in relation to pollution load categorization (DOE, 2015). In addition, the widely accepted multivariate statistical methods such as CA and PCA have been used to evaluate temporal/spatial variations in water quality and identify latent sources of water pollution in the studied catchment. Water contaminant maps have also been prepared to assess the spatial and seasonal heterogeneity of water quality parameters and WQI and to clearly visualize the clean to polluted zones using GIS software. Data processing and analyses have been conducted within the available instrumental facilities at Universiti.

2.3 Landuse Change

The land is a basic natural resource that provides habitat and sustenance, as well as facilitates economic development. Land use change is a general term to identify the human modification of Earth's terrestrial surface. People undertake different arrangements, activities, and inputs in a certain type of land to produce a change or maintain it, generally characterized as landuse (FAO, 1999). The usage of land is mainly controlled by the socio-economic demand coupled with growing population. The increasing trend of these factors gives rise to unplanned and uncontrolled changes in usage practices. These changes mostly include deforestation, agricultural intensification and urban sprawl at local, regional and global scales. Such changes ultimately create major impacts on natural environmental processes and ecosystems. Many researchers have reported the impact of such changes on soil quality (Brackin et al., 2013; Prokop and Płoskonka, 2014), soil erosion and sedimentation (Moghadam et al., 2015), surface runoff and sediment yields (Zhang et al., 2010b), water flow and water quality (Amin et al., 2014; Kibena et al., 2014a; Zhou et al., 2012), biodiversity loss (Masum et al., 2017), and subsequently climate changes (Pathirana et al., 2014; Williamson et al., 2014).

Land use can be visualized from two broad dimensions. Firstly, the manner or nature in which humans alter the biophysical attributes of land cover and secondly, the intention underlying those alterations. Land use change can be categorized mainly into land use conversion and land use modification (Lambin et al., 2001). Land use conversion is the replacement of one land pattern type to a different type, for example, the shift from forest to agricultural or a change from agriculture to urban. In landuse conversion, there is a complete change of the previous land pattern type. On the other hands, land use modification reflects certain changes that affect the character of the land use without a complete change in the land cover itself. When this occurs, land fragmentation develops which in turn changes the structural complexity of the landscape (Fischer and Lindenmayer, 2007; Wadduwage et al., 2017). Both land use conversion and or modification affect a lot of biophysical aspects of land and subsequently alter biotic diversity, actual and potential primary productivity, soil and water quality, runoff quality, sediment transportation and a host of other attributes that are associated with the terrestrial landscape (Kindu et al., 2015; Masum et al., 2017).

2.3.1 Methods of Assessment of Land Use Change

An accurate and up-to-date understanding of land usage activity and changes both in types and patterns is essential for the evaluation of landuse impact assessment. The spatio-temporal distribution of land usage and activity and its changing trend analysis are the prime and major tasks to assess and manage the landuse practices for sustainable environmental management.

A number of techniques have been developed over the years to extract and detect landuse change information from different data sources, such as aerial ortho-photographs, Landsat satellite images, topographic maps, landuse maps and historical maps (Fichera et al., 2012; Glavan et al., 2013; Kang et al., 2013). In the spatial analysis, landuse/cover information through satellite remote sensing has gained prominence with the commencement of the Landsat satellite program in the early 1970s. However, topographic maps, landuse maps, and historical maps are also the most important databases for various spatial analyses of land use changes and for assessing the land use transfer matrix (Glavan et al., 2013; Horn, 2010). Methods used to extract landuse/cover information from satellite images are broadly divided into unsupervised classification techniques (Hasmadi et al., 2017; Horning, 2010), and supervised techniques (Butt et al., 2015; Li et al., 2015; Rawat and Kumar, 2015; Shen et al., 2014). Conversely, for extraction of landuse/cover information from different maps, georeferencing, geometric correction and on-screen digitization process are commonly applied (Horn, 2010; Kang et al., 2013).

A number of change detection techniques have been developed and widely used to measure landuse changes, its spatio-temporal pattern and landuse matrix over time. Change detection can be defined as the process of identifying differences in the state of an object or phenomenon by observing it at different times (Singh, 1989). The process is usually applied to Earth surface changes at two or more times. The aim of change detection process is to recognize land use change features of interest between two or more dates on digital images. It is therefore considered an important process for monitoring and managing landuse/cover change as it provides quantitative analysis of the spatial distribution of the population of interest (Al-doski et al., 2013).

Change detection is useful in many applications related to landuse and land cover changes. The change technique effectively contributes to sustainable urban planning and management (Dewan and Yamaguchi, 2009; Rawat and Kumar, 2015), coastal management (Yao, 2013), environmental management (Kotoky et al., 2012), catchment management (Efiong, 2011; Kashaigili and Majaliwa, 2010), land degradation (El-Kawy et al., 2011), urban sprawl (Hegazy and Kaloop, 2015; Mallupattu and Sreenivasula Reddy, 2013; Rimal, 2011), deforestation (Wyman and Stein, 2010), water quality management (Roberts, 2016; Zhou and Li, 2015) as well as in biodiversity and ecosystem (Schulz et al., 2010).

Although remote sensing, in conjunction with Geographical Information System (GIS), has been widely applied and been recognized as a powerful and effective tool in detecting land use and land cover changes (Butt et al., 2015; Hasmadi et al., 2017; Hegazy and Kaloop, 2015; Li et al., 2015; Shen et al., 2014; Zhao et al., 2013b); GIS approach for detection of such change using geo-spatial information of different maps also becomes one of the imperative and advanced tools (Glavan et al., 2013; Kang et al., 2013; Zhang et al., 2010b). This technique integrates past and current maps of land use with topographic and geologic and landuse data by overlaying process in revealing the change dynamics quantitatively in each category (Zhao et al., 2013a).

2.3.2 Factors Involve in Landuse Change

Land use change was recognized as an important driver of environmental change, including climate change, biodiversity loss and the pollution of water, soil, and air. Land use change is caused by a number of factors which are labelled as landuse drivers. Drivers of land change relate to anything that directly or indirectly influences a change in the natural characteristic of land cover. Land cover change is traditionally driven by two types of forces; anthropogenic factors and natural forces (Turner and Meyer, 1991). Recent studies on landuse/cover change have expanded the composition of drivers to include cultural, political, institutional and economic forces (Hegazy and Kaloop, 2015; Kindu et al., 2015; Mustard et al., 2012).

Anthropogenic drivers are mainly responsible for changes in landuse/cover and are categorized into proximate and underlying factors (Lambin et al., 2001; Meyer and Turner, 1992; Wilson, 2015). Proximate factors are human activities that directly modify or completely change the land cover. It involves a physical action on the land cover which is normally limited to a predefined set of activities as agriculture, construction of infrastructure, and forestry. These factors operate at the local level such as the individual farmer, household, or community (Lambin et al., 2003). On the other hands, underlying factors are those that support the proximate causes of land cover change. Underlying causes of land cover change include social, political, economic, demographic, technological, cultural, institutional, and biophysical factors (Kindu et al., 2015; Li et al., 2015; Zerga, 2015). Any change in one of these underlying factors has a flowing effect on one or more of the proximate factors (Lambin et al., 2003).

Anthropogenic factors widely influence the composition, configuration, and trend of land use/cover changes with potential implications for surface water quality. Both underlying and proximate factors are responsible to affect the pattern of runoff, non-point source pollution production, transportation that sequentially influence on water quality in streams, lakes, and other aquatic environments (Hua et al., 2016b; Tu, 2013; Wilson and Weng, 2011; Zamani et al., 2012). Zampella et al. (2007) revealed that 10 % or more of land use alteration can result in significant changes in surface water with heavily polluted water. Zhao et al. (2013b) evaluated in their study that population growth along with economic development and industry policy were the dominant driving force for land use and land cover change in the mainstream of the Tarim River Xinjiang, China. Wilson (2015) revealed that 32 to 59 % of total suspended solids and 31 to 42 % of phosphorus-related water quality impairment was accounted for proximate drivers of landuse/cover change in the Lower Chippewa River Watershed, Wisconsin.

2.3.3 The Relationship Between Landuses and Water Quality

It is widely accepted that strong relationship exists between land uses and the water quality within a catchment (Ai et al., 2015; Bu et al., 2014; Shen et al., 2014). Recent patterns and trend of change in landuses along with spatial configurations are extremely useful to know when addressing the impacts of land use changes on surface water quality in any watershed or catchment. Land use changes actually affect water quality through changing the hydrological and chemical runoff processes in any watershed or catchment. When runoff carries pollutants from upland areas into a river system, the spatial composition and patterns of the watershed or catchment modify the land use effect on the adjacent aquatic systems. Subsequently, the water quality is affected by these changes through point and non-point source pollutions (Kibena et al., 2014b; Lee et al., 2009; Zhou et al., 2012).

Land cover influences water quality in as much as land cover determines the type and quantity of NPS pollutants that may enter the water body. Runoff drains from the different land surface, which carries the residues from the land and is enriched with different kinds of contaminants. The relative amounts of particular landuse types will affect the water quality in a watershed (Lee et al., 2009). The larger portion of pollutant loads delivered by different events evidenced that major pollutant loads were generated from agricultural and urban runoff. Agricultural activities have been identified as major sources of NPS pollutants and are known to have major impacts on water quality. Urban areas have the potential to generate large amounts of NPS pollutants from storm-water discharge. The imperviousness of urban areas increases their hydrological activities and is capable of washing accumulated pollutants into surface waters. The surface areas covered by forest or rangeland, the terrestrial and aquatic environments are in dynamic equilibrium, hence, forest and rangeland have minimal effects on water quality (Kibena et al., 2014b; Tong and Chen, 2002; Zhou et al., 2012).

Researchers have tried to identify the relationship between specific land change and its impact on water quality using a historical change of land use. Many of them have documented the significant relationships between landuse/cover change and water quality on the basis of their specific land type impact. Many studies have measured different pollutant loads from agricultural or urban landuse. Majority of them have focused on total suspended solids (TSS), ammonia (NH_4N), total nitrogen (TN) and total phosphorus (TP) (pollutant loading into watershed from a specific land types in different regions (Dasa et al., 2013; Kibena et al., 2014b; Pratt and Chang, 2012; Tong and Chen, 2002) . Their results support a close relationship between past land use and water quality. The effects of specific land types on surface water quality are reviewed detailed in the following sub-sections.

2.3.3.1 Agricultural Land Impact in Water Quality

Agriculture activities indicate a human alteration of natural Earth environment, which can often lead to the intensive land pattern changes and subsequently impacts on water quality degradation. In any heterogeneous watershed, land use changes as a result of agricultural activities have the potential to release a variety of pollutants into local surface waters mainly nutrients, agro-chemicals, salt and sediments (Table 2.5). It depends on the type and intensity of agricultural activity and is directly influenced by local geophysical, hydrological and meteorological conditions (Secretariat, 2016). These pollutants disseminate from agricultural land, transportation along the hydrological cycle and concentration in water bodies. Typical pollution pathways are: i) percolation to groundwater; ii) surface runoff, drainage water, and flows to streams, rivers and estuaries; and iii) adsorption onto sediments from natural or human-induced soil erosion to sediment-rich streams (Connor et al., 2017).

Agricultural activities often include wide applications of fertilizer, manure, and chemicals in the watershed, which are subsequently vulnerable to leaching, runoff, and volatilization. Nutrients and chemicals not immediately absorbed by crops can be transported to near surface water either by process of agricultural irrigation and surface runoff or by groundwater percolation.

Table 2.5 Categories of major water pollutants from agriculture and the relative contribution from agriculture production systems

Pollutant category	Indicators/Examples	Crop production	Livestock	Aquaculture
Nutrients	Primarily nitrogen and phosphorus that are present in chemical and organic fertilizer, animal excreta, and present in water as nitrate, ammonia or phosphate	***	***	*
Pesticides	Herbicides, insecticides, fungicides, and bactericides, including organophosphates, carbamates, pyrethroids, organochlorine pesticides and others (many, like DDT, are banned in most countries but their illegal use persists)	***	-	-
Salt	Including sodium, chloride, potassium, magnesium, sulfate, calcium and bicarbonate ions, among others*	***	*	*
Sediment	Measured in water as total suspended solids or nephelometric turbidity units – especially from pond drainage during harvesting	***	***	*
Organic matter	Chemical or biochemical substances that require dissolved oxygen in the water for degrading (organic materials, such as plant matter and livestock excreta)**	*	***	**
Pathogens	Bacteria and pathogen indicators, including *E.coli*, total coliforms, fecal coliforms and *Enterococci*	*	***	*
Metals	Including selenium, lead, copper, mercury, arsenic, manganese and others	*	*	*
Emerging pollutant	Drug residues, hormones, feed additives, etc.	-	***	***

*Measured in the water, directly as total dissolved solids, or indirectly as electric conductivity
**Measured in the water as COD and BOD

Source: (Connor et al., 2017)

Surface runoff from agricultural land use has much more nitrogen and phosphorus, especially after rainstorms (Das et al., 2011; Tong and Chen, 2002). Moreover, agricultural activities increase the soil erosion and subsequently increase surface runoff and thus sedimentation to near-surface through runoff (Mouri et al., 2013). Hence, agriculture runoff has long been recognized as a significant non-point source pollutant of water pollution (Wu and Chen, 2013).

A number of researchers have concluded that water quality had a strong correlation with intensification in agricultural practices, particularly with the massive applying of inorganic fertilizers. Agricultural coverage strongly influenced water nutrient loading as nitrogen, phosphorus, and ammonia (Chará-Serna et al., 2015; Kibena et al., 2014b; Mouri et al., 2011). Moreover, their studies have shown that nitrogen and phosphorus concentrations and loads increase with the proportion of land area used for agriculture compared to watersheds mainly covered with forest.

Tong and Chen (2002) studied such relationships in the watersheds of the Ohio State, the USA at a regional scale and showed that TN and TP, values were much higher in the agricultural watersheds than the urban and forest areas. Their findings also found that sodium and heavy metals had significant strong negative relationships while organic matters showed non-significant relationships with agricultural land areas. Similarly, in Upper Manyame of Zimbabwe, the water quality parameters are associated with increases in pollution load from 1995 to 2012, from 130 kg/day to 376 kg/d for TP and TN from 290 kg/day to 494 kg/d which can be attributed to expansion or increase of agriculture and urban areas by 24.4% and 41.6% (Kibena et al., 2014b).Bu et al. (2014) showed a seasonal relationship between land use patterns and water quality of Taizi river basin, China. The authors demonstrated that agricultural land uses had significant effects on river water quality and associated with most physicochemical variables and nitrogen during the rainy season. Wu and Chen (2013) investigated the effects of pollutant loads on the river water quality and showed a noble relation between agricultural land management and nutrient loads. Chará-Serna et al. (2015) showed in their study that local agricultural practices affected the headwater streams of the Colombian coffee-growing region by increasing the concentration of NH_3-N in the water by reducing the riparian forest.

A number of authors have studied that agricultural coverage strongly influenced total suspended solids and sediment yields on water bodies Glavan et al. (2013) explained historical agricultural land use situations (1787, 1827, 1940, and 1984) have very adverse effects on the water quality showed an increase in the quantities of pollutants in watercourses, especially significant is increase in sediments. Similarly, Perazzoli et al. (2013) observed that the agriculture land produced the highest sediment loads impacting the water availability in the Concórdia River basin.

Khoi and Suetsugi (2014) investigated the impact of agricultural areas on hydrological processes and sediment yield in the Be River catchment, Vietnam. Their results indicated that 14.89% expansion of agricultural land had increased the annual flow (by 1.2%) and sediment load (by 11.3%) within the catchment.

Unsustainable land use and improper tillage and soil management in agriculture are major causes of erosion and sediment runoff into rivers and reservoirs. Sediment in river systems is a complex mixture of mineral and organic matter, which can cause reservoir siltation and affect aquatic life by altering and suffocating habitats and clogging fish gills. Sediments can also be a carrier of chemical pollutants, such as pesticides or phosphate. These pollutants are not soluble and tend to get adsorbed to soil particles. It enters water bodies attached to sediments through soil erosion.

2.3.3.2 Urban Land Impact in Water Quality

An inevitable result of rapid economic development and population explosion is the process of urbanization. Urbanization process can change the land use; while at the same time bring increasing impacts on the environment and the ecosystem. Urban land cover, incorporating the effects of increased population, and urban wastewater, is thought to be an important cause of surface water quality degradation (Carpenter et al., 1998; Mouri et al., 2013). Thus, it is included as an important explanatory variable for the variations of all water quality parameters.

Urban wastewater includes both municipal wastewater and urban runoff. Municipal wastewater originates from domestic, industrial, commercial and institutional sources within a given human settlement or community. Accelerated urban growth poses dramatic increases in the generation of municipal wastewater (Connor et al., 2017). Due to lack of adequate treatment facilities, untreated or partially treated municipal wastewater discharges into water systems give rises to water quality pollution. Moreover, in absence of proper drainage systems, sewage mixes with stormwater causing further pollution. It is estimated that up to 90% of all wastewater in developing countries is discharged untreated directly into rivers, lakes or the oceans, causing major environmental and health risks (Connor, 2015). The major pollutants found in urban runoff include sediments, nutrients, increased alkalinity, phosphorous, nitrate and nitrogen, metals and BOD (Ai et al., 2015; Khoi and Suetsugi, 2014; Pratt and Chang, 2012; Tu, 2013; Zhou et al., 2012). The products of urban wastewater are also shown in Table 2.1. Although nutrients are mostly contributed by agricultural activities in less-urbanized areas, but they can also come from various human activities in highly-urbanized areas, such as discharges of residential, municipal, and industrial sewage, fertilizer and pesticide use in lawns or anthropogenic nutrient sources (i.e., lawn fertilizers, pet waste, septic tank effluent, accelerated erosion). A number of documents illustrated that highly fragmented urban land uses with an extensive impervious surface tend to increase runoff and river flow, and negatively affect water quality by carrying nutrients, sediments, and other pollutants into surface water (Ayivi, 2017; Kibena et al., 2014b; Lee et al., 2009). Ayivi (2017) conducted a comprehensive investigation of spatio-temporal variation of water quality in Reedy Fork Buffalo Creek watershed in Guilford County, North Carolina and showed that nitrate increase at a significant rate due to conversion of forest and grass into impervious surface. de Jesus-Crespo and Ramirez (2011) showed that urbanization negatively effect on the physico-chemical condition of water quality in a tropical urban watershed (Rio Piedras Watershed) in Puerto Rico. They found that DO and Mg^{2+} decreased and PO_4^{3-} and K^+ increased with the higher proportion of urban cover in the sub-watershed in Puerto Rico. Mouri et al. (2013) examined relationships among land use and water quality and showed that urban land cover positively influenced BOD, TP and SS. They investigated that a 10% conversion of catchment area from forest to urban land cover resulted in increased average streamwater concentrations of 2.0 mg/L for BOD, 2.5 mg/L for TN, 0.27 mg/L for TP, and 9.6 mg/L for TSS . Kibena et al. (2014b) studied that expansion of urban area by 41.6% have a strong positive relationship in COD is attributed to sewage effluent contributing to the organic pollution load in the river. In a study at Nanfei River in Hefei City, China, it was shown that the nonpoint pollutants from the urban catchments contribute 34%-47% of the total pollutant inputs (i.e., the COD, the BOD_5, and the NH_3-N), despite their low flow component of 13.4% (Xue et al., 2015)

In the Dongjiang River watershed, China, urban land use was positively correlated with the concentrations of EC, NH_3–N,NO_3–N, and water flow and negatively with the concentration of DO (Zhou et al., 2012). Tu (2013) investigated that percentage of urban land has significant positive correlations with all the dissolved nutrients a non-significant negative relationship with DO in the watersheds of northern Georgia, USA. Zhang et al. (2015) analysed the role of urban rivers in regional nitrogen pollution in Hangzhou, China and found that concentrations of ammonium nitrogen in urban rivers were 3-5 times higher than that in regional rivers. Across watersheds close to the Danjiangkou Reservoir, China higher levels of ammonia nitrogen, total phosphorus, potassium permanganate index and petroleum, and lower levels of dissolved oxygen. were strongly influenced by urbanization (Ai et al., 2015). (Das et al., 2013) showed that the highest export rates of TSS, TN and TP were found from urban areas while the lowest export rates of those were from forest areas on water quality in the Yarra River catchment, Victoria, Australia.

A number of researchers focused on the seasonal relationship between urban land use pattern and water quality. Pratt and Chang (2012) showed that most wet season water quality parameters (EC, DO, NO_3-N, and TS) are associated with urban land covers in the Portland Metro region of Oregon and Clark County, Washington areas, USA. Lee et al. (2009) examined that the proportion of urban land uses within watersheds in South Korea was closely correlated with BOD and COD in spring. In fall, the proportion of urban land uses was positively related to BOD and COD, as well as TN and COD. Chen and Lu (2014) demonstrated the strong positive correlations between urban land and BOD_5, COD, TN, DN, NH_4^+ -N and TP and the strong negative correlations with DO and pH. They also revealed that TN, pH, and temperature were higher in the rainy season, whereas BOD_5, DO and turbidity were higher in the dry season in a mountainous watershed with intensive agricultural production in East China. Yu et al. (2016) applied GIS and correlation matrix to determine the seasonal relationship between land use types and stream water quality at the sub-basin scale in the Wei River basin, China and found that temporal variations were weaker in rainy seasons than that in dry seasons. Comparing with other land uses, agriculture and urban lands had a stronger relationship with water quality variables in both the rainy and dry seasons.

All these documented results suggested that it was significantly important to integrate the water quality management and land use planning. Since municipal and urban wastewater production is heavily dependent on the form and function of urban systems, the current and future patterns of urbanization must be critically examined in order to develop more sustainable approaches to wastewater management in the coming decades (Zhang et al., 2015; Zhou et al., 2012)

2.3.3.3 Forest Impact on Water Quality

Different from urban and agricultural land covers, the forest was observed as the smallest contributor to water quality degradation in all cases (Wilkins et al., 2015). The more forested a watershed is, the less sediment and nutrients load the stream will have. Water quality is likely better if forest patches are un-fragmented, have a high value for the largest patch proportion, have complex patch shape, and are aggregated (Kibena et al., 2014b; Lee et al., 2009).

Forests have an extensive root network and a great ability to generate porous and filtering soils. Under forest cover, nitrate levels are low due to nitrogen recycling. Due to the limited use of pesticides and fertilizers in forests, it was expected that the water resources under forest cover often non-contaminated compare to land used for agriculture (Abildtrup et al., 2013). Many scientific studies have been done on the relationship between forest and water quality. Singh and Mishra (2014) observed that every one percent decrease in the forest cover will increase turbidity, TSS and E. Coli by 8.41%, 4.17%, and 3.91%, respectively while it would decrease calcium hardness by 0.49% when other variables are kept constant. The old forests were 2.2 and 2.74 times more effective than the open and disturbed forests in reducing turbidity and TSS, respectively. Significant effects of clearfelling on water temperature, flows, DO and stream metabolic (photosynthesis, respiration) rates were revealed by O'Driscoll et al. (2016). According to their findings, stream temperature and discharge significantly increased in the stream following clear-felling. In-stream ecosystem respiration increased significantly following clearfelling, indicating an increase in the net consumption of organic carbon

In a study by Lee et al. (2009) showed that the area of forest had negative relationships with BOD, COD TN and TP in all the seasons within the watershed in

South Korea. Similarly forested land cover was not significantly correlated with water quality variables in Dongjiang River watershed, China (Zhou et al., 2012). Tu (2013) also showed opposite relationships with water quality to the percentage of urban land. In the study, the forest had significant negative relationships with all the dissolved nutrients and a significant positive relationship with DO indicated that higher percentage of the forest is related to better water quality and it is a good predictor of water quality. (Das et al., 2013) showed that the highest export rates of TSS, TN, and TP were found from urban areas while the lowest export rates of those were from forest areas on water quality in the Yarra River catchment, Victoria, Australia. Moreover, deforestation in Penang State, Malaysia revealed a rapid biodiversity loss with increasing landslides, mudflows, water pollution, flash flood, and health hazard (Masum et al., 2017).

2.3.4 Research Studies in Study Area

The study on the landuse changes is still very limited in Cameron Highlands, though the noticeable pattern of land alteration is significant over time. Gasim et al. (2009b) studied the percentage of different landuse changes during 1984-2002 in the southern part of Cameron Highlands. Ismail et al. (2014) examined the rate of loss and pattern of fragmentation of the mountain forests in the Highlands using remote sensing approaches and landscape matrics during 2000-2010. Till date, there is no up to date study on the spatio-temporal and changing trend patterns of landuses within the Highlands.

For the present research study, GIS approach has been applied in conjunction with 4 (four) time series (1984-2010) landuse maps, topographic map as well as different raster and vector data of the study area as data sources to determine the change patterns and trends of land usage. Statistical correlation has also been applied to determine the seasonal relation among the landuse types and water quality variables.

2.4 Soil Erosion Study

Soil erosion is the detachment, entrainment, and transport of soil particles from their place of origin by the agents of erosion, such as water, wind, and gravity (DID, 2010). It depends on a number of factors such as vegetation cover, topographic features, climatic variables and soil characteristics. Although soil erosion is characterized as a natural phenomenon, anthropogenic activities can accelerate the soil erosion process further by altering the vegetation cover (Karydas et al., 2009). It has been considered the direct consequence of land pattern changes in any region. Deforestation makes soil prone to erosion and leads to increase soil erosion. With increasing surface runoff this process leads to sedimentation into local river systems. Unsustainable land use and improper tillage and soil management in agriculture are major causes of erosion and sediment runoff into rivers and reservoirs. Agriculture intensification has frequently come with increased soil erosion and higher sediment loads in surface water. Pollutants that absorbed onto sediments mainly transported from natural or human-induced soil erosion to sediment-rich streams (Connor et al., 2017). Hence, Highland watersheds, when converted for agriculture and other activities, face high risks of soil erosion and nutrient depletion, increased runoff from more impermeable subsoil and build-up of sediment on the land surface or the bed of a watercourse.

Assessment of soil erosion is useful in planning and conservation works in a watershed or basin. Spatial and quantitative information of soil erosion contributes significantly to the soil conservation management, erosion control, and general catchment areas management. Modeling can provide a quantitative and consistent approach to estimate soil erosion and sediment yield under a wide range of conditions. Therefore, a quantitative assessment is crucial to infer the extent and magnitude of soil erosion problems so that sound management strategies can be developed on a regional basis with the help of field measurements. (Prasannakumar et al., 2012; Priess et al., 2015).

2.4.1 Factor Involved in Soil Erosion

The rate of soil erosion is mainly affected by a number of natural factors such as topographic features, soil characteristics, climatic variables and land use and land cover, etc. The most important climatic variable is considered to be precipitation intensity. Concerning topographic features, slope, slope length and shape affect mostly rill and erosion (Ali and Hagos, 2016; Ganasri and Ramesh, 2016). In addition, the human factors consist of development or activities related to agriculture, mining and constructions. Such activities generally remove the protective vegetation cover, resulting in accelerated erosion by both water and wind (DID, 2010). Natural factors commonly affect the upper soil layer as compared to human-induced factors. Both contribute a significant amount of soil loss due to water and wind erosion In fact, the assessment of soil erosion requires the specific knowledge of soil parameters (susceptibility of soils to erosion, soil protection, etc.), as well as physical parameters (precipitation, temperature, slope, surface areas, etc.), all highly variable in space and time.

2.4.1.1 Rainfall

Rainfall is the principal agent of soil erosion process for eroding away soil particles from the earth surface. It is directly involved in the loss of soil quality during torrential rain, comparisons all other climatic parameters (Mohtar et al., 2015). Factors such as total rainfall, rainfall intensity, rainfall duration, size, velocity and shape of raindrops as well as the kinetic energy of the rain contribute a great influence on erosion. Upon reaching the ground, the raindrops supply the main energy for soil detachment. Other rainfall characteristics such as intensity, duration and total rainfall influence on the resulting runoff (Teh, 2011). The surface runoff washes the soil particles down the slope until there is insufficient water to transport the soil particles further. This process will end up with deposition. About 83.3% of rainfall falls with an intensity greater than 10 mm/day have enough energy for soil detachment highlighting the major role of rainfall in soil erosion (DID, 2010). The extent to which a region is affected by soil erosion varies greatly depending on the frequency and intensity of the rainfall as well as the sustainability of the soil strata.

The erosive force of a specific rainfall is expressed as rainfall erosivity. It is determined as a function of the volume, intensity, and duration of rainfall and can be computed from a single storm, or a series of storms to include cumulative erosivity from any time period (Panagos et al., 2015a; Prasannakumar et al., 2012; Renard and Freimund, 1994). Rainfall erosivity factor (R), an erosion index for the given storm period in MJmm/ha/h. This is an important parameter for soil erosion risk assessment under future land use and climate change (Mohtar et al., 2015).

2.4.1.2 Soil Properties

Soil erodibility defines the resistance of the soil to detachment and transportation by raindrop impact and surface runoff. It is known that the most easily eroded soil particles are silt and very fine sand and the less erodible soil particles are aggregated soils because they are accrued together making it more resistible (Kim, 2014).

Soil erodibility is an important index to measure soil susceptibility to water erosion, and an essential parameter needed for soil erosion prediction. Erodibility is a function of soil texture, organic matter content, and permeability (DID, 2010; Renard, 1997). The most widely used and frequently cited relationship to estimate the K factor is the soil-erodibility nomograph using measurable properties. The soil erodibility nomograph comprises five soil profile parameters: percent of modified silt (0.002-0.1mm), percent of modified sand (0.1-2mm), percent of organic matter (OM), a class for soil structure (s) and permeability (p) (Teh, 2011). The soil erodibility factor (K) measures the resistance of the soil to detachment and expresses as the average soil erodibility factor (tons MJmm/ha/hr).

2.4.1.3 Topographic Factors

Topography factor plays a major role in soil erosion since it dominates the surface runoff rate. The topographic factor is related to the slope steepness factor (S) and slope length factor (L) and is considered to be a crucial factor for the quantification of erosion in terms of gradient/ percent slope. The slope has a major effect on the rates of soil erosion. As the slope gets steeper, the higher is the velocity of overland flow, thus increasing the shear stresses on the soil particles. Moreover, as slope length increases the overland flow and flows velocity is also steadily increased, leading to greater erosion forces applied to the soil surfaces (Alexakis et al., 2013; Ranzi et al., 2012). The two effects have been evaluated separately in research and are represented in the soil loss equation by L and S, respectively. In field application, however, considering the two as a single topographic factor, LS, is more convenient.

2.4.1.4 Management Factor

Cover Management Factor (C) and Support Practice Factor (P) are two management factors that can be used to control soil loss at a specific site. The Cover Management Factor (C) represents the effect of vegetation and management on the soil erosion rates. It is measured as the ratio of soil loss of a specific crop to the soil loss under the condition of continuous bare fallow. C value is equal to 1 when the land has continuous bare fallow and have no coverage and equal to 0 is vice-versa. .The Support

Practice factor (P) represents the soil conservation operations or other measures that control the erosion, such as contour farming, terraces, and strip cropping. It is expressed as the ratio of soil loss with a specific support practice to the corresponding loss with up-and-down slope culture (Alkharabsheh et al., 2013; Chicas and Omine, 2015; Renard, 1997)

2.4.2 Methods of Assessing Soil Erosion

Spatial and quantitative information of soil erosion loss and sediment yields contribute significantly to the soil conservation management, erosion control, and general catchment areas management (Prasannakumar et al., 2012). Modeling can provide a quantitative and consistent approach to estimate soil erosion and sediment yield under a wide range of conditions (Ganasri and Ramesh, 2016).

A plenty of models exist for study of the soil erosion and sediment yield processes. However, no useful model to predict the sediment yield precisely and practically has been developed, because the erosion process inherently contains many uncertainties that are difficult to solve analytically (Santos et al., 1998). In reality, all these models vary significantly in terms of their capability and complexity, input requirements, representation of processes, spatial and temporal scale accountability, practical applicability, and types of output they provide (Pandey et al., 2016). Hence, on the basis of application of models in physical process simulation, data dependency of models and model algorithm, models are mainly categorized in three classes: empirical, conceptual, and physically based (Baja et al., 2014; Jha and Paudel, 2010). Nowadays, soil erosion modeling has moved from empirically-based models towards physically-based mathematically complicated models. However, the empirical models seem to be the more practical since they are mathematically simple, though they are limited to the area where they have been developed, and they are based on standard runoff plots on uniform slopes (Santos et al., 1998).

2.4.2.1 Empirical Models

Empirical models are primarily based on observations and data response characterization (Wheater et al., 1993). Compared to conceptual and physically based models, data and computational requirements for such models are less, but these are capable of working with coarser measurements and limited data (Jakeman et al., 1999).

These are black box type simple models which relate sediment loss to either rainfall or runoff using a typical relationship: $Qs = aQ^b$, where Q is water yield, Qs is sediment yield, and a and b are constants (Pandey et al., 2016).

To estimate the amount of soil loss, Wischmeier, Smith and others has developed the empirical model Universal Soil Loss Equation (USLE) in 1965. The USLE predicts the long-term average annual soil loss, composed of six factors namely, rainfall erosivity factor, soil erodibility factor, length of the slope, slope factor, crop management factor and conservation practices factor (Wischmeier and Smith, 1978). With additional research, USLE has been revised and another equation namely Revised Universal Soil Loss Equation (RUSLE) was produced in 1997 whereby the formula and factors remained the same but has several detailed improvements in determining factors (Renard, 1997). The improvements made are revised isoerodent maps, a time-varying approach for soil erodibility factor, a sub factor approach for evaluating the cover management factor, a new equation to reflect slope length and steepness and lastly is new conservation-practice values (Renard et al., 1994). Further, by including the runoff as an independent factor in modeling erosion, MUSLE has an improved accuracy of soil erosion prediction over USLE and RUSLE (Williams, 1975; Williams and Berndt, 1977). Moreover, various advancements incorporated in RUSLE resulted in the RUSLE2015, a modified version of the RUSLE model (Panagos et al., 2015b), RUSLE3D (Aiello et al., 2015; Mitasova and Mitas, 1999), the USPED (Aiello et al., 2015; Mitas and Mitasova, 1998).

As an empirical model, USLE possesses some strengths and limitations. Foster (1982) noted that the strengths of USLE and thus RUSLE as follows: 1) it is simple to implement, ii) its parameters are readily available; iii) it involves a large and comprehensive physical data base; and it can be applied non-uniform areas where no deposition take place. In addition, as each model parameter consists of discrete variables, the model is easy to specialize in a GIS environment. Its parameters are also adaptable to many different situations, leading to the establishment of a number of erosion prediction technologies which incorporate all or some parts of the principles of RUSLE. It is thus, RUSLE appropriate for use at a watershed scale.

On the other hand, RUSLE has several limitations, which are often viewed as preconditions set in the modeling procedures. They include the followings; i) the equation uses an empirical approach which does not represent the actual physical processes of soil erosion, ii) the equation is used to predict the average annual soil loss, and for single storm event; iii) it only estimates sheet and rill erosion; and iv) it takes no account of sediment deposition. In general, however, most field practitioners have been satisfied with the model's performance and the accuracy of erosion estimates with USLE (Toy and Osterkamp, 1995). This may be the reason why the model has to date employed for various purposes, especially as an indicator of land degradation for land use planning and management at a watershed.

2.4.2.2 Conceptual Models

In conceptual models, a catchment is represented as a series of internal storages. Without including the specific details of process interactions, which require detailed catchment information, the model tends to include a general description of catchment processes (Sorooshian, 1991). Parameters of conceptual models have limited physical interpretability. Conceptual models are based on generating synthetic sequences of data employing statistical methods and play an intermediate role between empirical and physically based models (Baja et al., 2014; Beck, 1987).

2.4.2.3 Physically Based Models

Physically based models are based on fundamental physical equations and their solutions describe sediment and stream flows in a catchment. Physically based soil erosion and sediment yield models are based on the concept of physics using transfer of mass, momentum, and energy as governing equations (Doe et al., 1999; Kandel et al., 2004) which are solved by various numerical methods. Most of the models, particularly long term soil loss computing models, use concepts of the empirical Universal Soil Loss Equation (USLE) (Wischmeier and Smith, 1978), or its revised the RUSLE (Renard, 1997), and modified the MUSLE (Williams, 1975). These models not only represent the essential mechanisms controlling erosion and sediment yield but also consider physical characteristics, such as topography, geology, land use, climate, and river flow characteristics. These models require many more input data and parameters for simulation efforts, and are generally over-parameterized. Use of larger number of parameters benefit to yield a better fit of observed data and increase in degree of freedom (Pandey et al., 2016).

Pandey et al. (2016) reviewed worldwide applications of 50 physically based soil erosion and sediment yield models with respect to their shortcomings and strengths and revealed that Soil Water Assessment Tool (SWAT), Water Erosion Prediction Project (WEPP), Agricultural Non-point Source Model (AGNPS), Areal Nonpoint Source Watershed Environment Response Simulation (ANSWERS) and Systeme Hydrologique Europian-TRANsport (SHETRAN) models to be the most promising ones for simulation of erosion and sediment transport processes, and therefore, these can be better used for implementation of best management practices (BMP). Conversely, Annualized Agricultural Non-point Source model (AnnAGNPS), Chemicals, Runoff and Erosion from Agricultural Management Systems (CREAMS), Ephemeral Gully Erosion Model (EGEM), Groundwater Loading Effects of Agricultural Management Systems modelling system (GLEAMS), LImburg Soil Erosion Model (LISEM), SHETRAN, WEPP, etc. are few of the models incorporating gully erosion. Most of the developed soil erosion and sediment yield models are well capable of simulating soil detachment and sediment delivery processes at hill slope scale; a limited development was found in the field of reservoir siltation and channel erosion.

2.4.2.4 Application of Empirical Model

Over the last decades, estimation of soil erosion using empirical models has long been an active research topic (Aiello et al., 2015). The empirical models are the most commonly used methods because of their simplicity of application, thanks to their minimal data required and ease of use (Ali and Hagos, 2016; Demirci and Karaburun, 2012). Among them, RUSLE has been proved to be the most commonly used methodology from different researchers all over the world. It has been extensively used to estimate soil erosion loss and to guide development and conservation plans in order to control erosion under different land-cover conditions (Chicas and Omine, 2015; Kim, 2014). This happened due to the fact that RUSLE is considered to be simple, incorporates easily available/accessible data (such as rainfall, satellite images) and has reliable results (Demirci and Karaburun, 2012; Kim, 2014).

The RUSLE model is a set of mathematical equations that are based on the estimation of soil loss per unit area and takes into account specific parameters such as precipitation data, topography, soil erodibility, erosivity, and runoff. The parameters of

RUSLE model were estimated using remote sensing and landuse data and the erosion probability zones were determined using GIS. The RUSLE model can predict erosion potential on a cell-by-cell basis (Shinde et al., 2010), which is effective when attempting to identify the spatial pattern of the soil loss present within a large region. GIS can then be used to isolate and query these locations to identify the role of individual variables contributing to the observed erosion potential value (Alexakis et al., 2013; Ganasri and Ramesh, 2016).

In the present study, the soil loss model, Revised Universal Soil Loss Equation (RUSLE) integrated with GIS has been used to estimate soil loss in the Bertam Catchment located in the Cameron Highland, Malaysia.

2.4.3 Application of Soil Erosion Assessment

Soil erosion is considered as a major environmental problem since it seriously threatens natural resources, agriculture and the environment (Aiello et al., 2015; Priess et al., 2015; Ranzi et al., 2012).

Soil erosion analysis is mainly used to quantify the soil erosion rate and to observe the spatio-temporal variations (heterogeneity) of soil erosion in any basin/ watershed/catchment. It is also applied to identify the soil erosion potential risk zones. Several studies (Alexakis et al., 2013; Alkharabsheh et al., 2013; Kagabo et al., 2013) have applied remote sensing and GIS methodologies to assess soil erosion hazards in different areas. Ranzi et al. (2012) in their study in Lo river basin, Vietnam observed that landuse changes mainly converted into agricultural crops and bushes and shrubs from forest increased 28% suspended sediment load in the basin. Agricultural and hill slope maintenance practices also modified the sediment erosion in the basin. Aiello et al. (2015) quantify the amount of soil erosion rate and to identify the spatial patterns of erosion and deposition in the large heterogeneous semi-agricultural Bradano River basin (southern Italy). Priess et al. (2015) studied the influence of landuse and landuse change on erosion risks and their impacts on water resources management in the Kharaa river basin (KRB) in Northern Mongolia, in which grazing and agriculture played key roles. Alexakis et al. (2013) applied integration of remote sensing, GIS and precipitation data in order either to evaluate soil loss or to map erosion risk. This research demonstrates the integration of RS, GIS and precipitation data to model soil erosion potential. Issaka and Ashraf (2017) reviewed that erosion causes both on-site and off-site effects on land and also on water bodies thereby affecting its quality.

In Malaysia, erosion by water is the major concern compared to the erosion by wind. Malaysia as tropical countries receives a heavy rain annually which leads to the soil erosion, particularly for the deforested and overgrazing areas. In Malaysia, soil erosion has become an important environmental problem in recent years, especially in areas where the intensive use of land for development, including urbanization and agricultural activities are being carried out. The encroachment of development into environmentally sensitive areas has resulted in accelerated soil erosion, water pollution, sedimentation and consequently, flooding in downstream areas. It has also had a tremendous impact on the communities within and around the affected areas. The effects of soil erosion and sedimentation in Malaysia have been reported by a number of investigators (Ashraf and Yusoff, 2015; Elsheikh et al., 2015; Mir et al., 2015).

Soil erosion processes is a major environmental issue in the study area, the Bertam catchment as because the area is subjected to extensive rainfall, rugged mountainous topography and characterized by agricultural activities on steep slopes. According to Midmore et al. (1996), most of these agricultural activities on steep and gentle slopes or hilltops, as well as on valley floors are the main cause of soil erosion in the catchment area, produced large amounts of sediments. Modification of the natural environment by mechanical excavations and different level of earthworks, preparations of broad platform terraces, cut out of the natural slope, estimated at 24 t/ ha/ year on average in Cameron Highlands. In the Similar area, Fortuin (2006) studied that the Upper Telom and Upper Bertam catchment have critical water erosion risks (>150 ton/hectare/year). Fieldwork pointed out, the cleared slip has high erosion risks (±140 ton/hectare/year). Research also proved this erosion risk could be reduced on slopes between 10-20° with 88% when the bare soil would be fully covered with vegetation. Aminuddin et al. (2005) showed that soil loss was in the range of 24–42 ton/ha/yr under vegetables and 1.3 ton/ha/yr under rain-shelter in the study area. Along with the change in land use and agricultural management situation, the development of soil erosion is also very much closely related with the terrain features such as slope length and slope steepness (Toriman et al., 2010). Deforestation and agricultural activities resulted in widespread land use changes leading to sedimentation on the Reservoir within the catchment area. As stated by (Teh, 2011), the rate of sediment filling in the reservoir was 50,000 m^3/ year in the early 1980's. With increasing sediment yield, it was predicted to be 282,465.5 m^3/ year for 1997 and 334,853.5 m^3/ year for 2006 within the Ringlet reservoir.

2.5 Social Survey for Sustainable Management

Survey research is one of the most important areas of measurement in applied social research. It is defined as "the collection of information from a sample of individuals through their responses to questions" (Check and Schutt, 2011). This type of research allows for a variety of methods to recruit participants, collect data, and utilize various methods of instrumentation. Survey research can use quantitative research strategies (e.g., using questionnaires with numerically rated items), qualitative research strategies (e.g., using open-ended questions), or both strategies (i.e., mixed methods) (Ponto, 2015). As it is often used to describe and explore human behavior, surveys are therefore frequently used in social and psychological research (Mertens, 2014) Now a day, it is getting popular in natural science to apply the social information to solve the problem in natural resource management and environmental issues. (Lund, 2015; Manandhar et al., 2015; Morrison et al., 2013; Perkins, 2011)

Selection of a research approach depends on a number of factors, including the purpose of the research, the type of research questions to be answered, and the availability of resources. Hence, a questionnaire is a good research instrument consisting of a series of questions for the purpose of gathering information from the respondents. It can range from asking a few targeted questions of individuals to obtain information related to behaviors and perceptions to a more rigorous in-depth study It can be anything from a short paper-and-pencil feedback form to an intensive one-on-one in-depth interview (Ponto, 2015). Different dimensional questions were included in the questionnaire. Demographic questions are an important aspect of any survey. These kinds of questions are designed to help survey researchers to determine what factors may influence a respondent's answers, interests, and opinions. Collecting demographic information can enable researchers to cross-tabulate and compare subgroups to see how responses vary between these groups (SS, 2017). The questions related to knowledge mainly capture what respondents know about a particular subject being surveyed. Concerning the attitudes, the questions reflect the people's feelings about a phenomenon of a problem or an object. Attitudes also explain the options that a subject can take in a practice and practices refer to behaviors that are observable actions (Huckett, 2010). In a survey, the awareness related questions play a key role to judge respondent attitudes regarding specific topics (Gachango et al., 2015). Perception surveys are most often used to find out how people understand or feel about their situations or environments. They are used to assess needs, answer questions, solve problems, establish baselines, analyze trends, and select goals. Surveys reveal what exists, in what amount, and in what context (Erickson, 2013).

In the present study, a well-structured questionnaire survey was conducted to understand the knowledge, perception, and awareness of local community on environmental issues in order to develop the sustainable management of Bertam Catchment especially focus on water quality.

2.5.1 Social Survey for Natural Resource Management and Environmental Issues

The type of society strongly influences communities' values, knowledge, attitude, behaviours and therefore their impact on ecosystems. Human attitude and behaviour are the central to many aspects of most environmental problems (Ogunbode and Arnold, 2012). Hence, the assessment of knowledge, perceptions, attitude, and awareness leads to the understanding of the relationship between people and environmental issues, the role of the human dimensions and their nature on resources, perceptions of the importance of environmental issues, and the willingness of the community to participate in reducing environmental impacts. All these aspects are essential for planning, developing and executing management strategies to reduce environmental issues.

2.5.1.1 People's Perception

Local people live close to nature have important and long-standing relationships with it. However, they build up an intimate and intuitive understanding of the environment over long periods of time. Local perceptions of natural resources derived from daily interactions with the environment. Therefore, the perceptions of local people can reflect local issues. In addition, these perceptions reveal the actual impacts of environmental change and its related consequences on the lives of people, especially for local factors that cannot be easily estimated through models (Manandhar et al., 2015). This perception research plays a very important part in global change and sustainable development.

Public perception on environmental issues has been of interest to many researchers and policymakers for several years. These have been elicited through a range of different methods, primarily quantitative social surveys and more recently in-depth qualitative studies (Ponto, 2015). Several studies have argued that people's perceptions and attitudes towards depletion of natural resources are influential to wise use and management of natural resources (Ayeni et al., 2016; Chicas et al., 2016) For example, Akter et al. (2017) conducted a survey program aimed at understanding water use and pollution issues in Dhaka, Bangladesh. They found that perceptions about water issues were mainly influenced by respondents' positive attitude and concerns as well as perception regarding water use would be useful to identify the target groups for management intervention. (Gachango et al., 2015) analyzed the level of adoption of water-pollution reduction technologies and the farmers' perception of water quality, existing regulatory measures and their implementation strategies through a social survey. They found that farmers perceived on the water quality to be above average and .the perceptions of catchment residents is important for the development of managing the land practices and education and programs designed to minimize risks associated with drinking water supplies in rural areas The findings of communities' perspectives on the main drivers, underlying causes, and effects of soil erosion in Toledo's Rio Grande Watershed, Belize are essential for consideration in planning, developing and executing management strategies to implement cost effective soil erosion prevention program (Chicas et al., 2016)

2.5.1.2 Peoples Participation

Public participation has been a field of much research interest in natural resource management over the last 40 years and was seen as a mean to reduce disputes arising from controversial governmental decisions (Rouillard et al., 2014). It has been increasingly acknowledged and emphasized as important in natural resource management since the establishment of the UN Aarhus Convention in 1998 (Hartley and Wood, 2005; Palerm, 1999). Moreover, it has become significant to achieve goals as diverse as enhancing good governance, promoting sustainable development and meeting the needs of concerned populations (UNDP, 1997; UNDP, 2003). The principle of participation derives from an acceptance that people are at the heart of both change and development (Rault et al., 2013)

Public perception is a planned process with the specific purpose of working with identified groups of people, whether they are connected by geographic location, special interest or affiliation, to address issues affecting their well-being (Myhill, 2003; Rolston et al., 2017). Blackstock and Richards (2007) identify three common justifications for using public participation in natural resource management. First, public participation leads to more legitimate and fair decisions since it offers a chance for those who are going to be impacted by the decision to expose their preferences and needs. Second, public participation improves decision-making in substantive terms because lay and local knowledge may complement expert and bureaucratic knowledge. Third, decision-making may be more effective because participation may increase trust and acceptability of the final decision. Reed (2008) reviews best practices for stakeholder participation in environmental management, and identifies eight important features for reaching success in the participation process including; that stakeholders should be involved in early stages of the process; clear objectives for the participation process need to be agreed among the stakeholders at the outset; appropriate methods for engagement and decision-making and skilled facilitators of the process. According to Reed (2008), the long-term success of participation processes may depend on institutional arrangements embedding stakeholder participation, which in some cases calls for reorganization and change of government agencies' culture.

Local peoples are key stakeholders in the arena of natural resource management (Sterling et al., 2017) and the role of public participation in basin management (Carr, 2015) is recognized as an important component in delivering water-related outcomes (Jingling et al., 2010) Voluntary involvement of communities' to take part in the implementation of the measures and contribute with knowledge and experiences regarding local conditions is one of the important factors regarding institutional arrangements for water councils and local stakeholder participation in water management (Franzén et al., 2015). Moreover, the implementation of local water engagement initiative can contribute in national River Basin Management planning, facilitate stronger connections between local communities and their water environment and encourage bottom-up initiatives that empower communities regarding local water management issues (Rolston et al., 2017).

Knowledge is also central to models of water-related engagement and environmental literacy (Aslin and Lockie, 2013) In this regard, Dean et al. (2016) examined demographics, psychosocial characteristics, exposure to water-related information, and water-related behaviors and policy support. Their finding showed that higher water knowledge was associated with older age, higher education and living in non-urban areas. Their findings also confirmed the importance the importance of community knowledge, and identify potential subgroups who may require additional targeting to build knowledge and support for water management initiatives.

2.5.2 Integration of Social Survey to Natural Science

Now a day, local communities, cities, states, countries and even international communities are facing many of environmental issues, including climate change, air, and water pollution, scarcity of fresh water resources, production of hazardous wastes, depleted natural resources, destruction of rainforest, habitat destruction, etc. All these environmental issues are a complex interaction between human and the ecosystems (Kanazawa, 2017). People usually modify the environment for their purposes and obtain benefits like water, timber, food, energy, information, land conversion for farming and much more from it, resulting in such environmental issues.

The complexity of human-environmental influences cannot be addressed properly through an individual approach like scientific or social research. A traditional approach of scientific investigation on environmental issues has primarily emphasized on biophysical environments. It usually underestimates or ignores the human perspective and human influences on the environment. Conversely, social research of the environmental issues has regularly avoided consideration of the biophysical features of landscapes, focusing mainly on peoples' perceptions and behaviors to explain degradation processes and natural resource management behaviors (Huckett, 2010). The research in individual disciplinarily plays a major role compared to involving two disciplines. Hence, parallel knowledge is developed in these two disciplines but remains disconnected for a prolonged period of time. In a current research environment, the association between two or more approaches with varying levels of integration of concept, methods, and findings has gained great promise for fruitfully studying a wide variety of environmental issues.   Now a day, interdisciplinary collaboration, particularly between natural and social sciences, is perceived as crucial to solving the significant challenges facing humanity (Barthel and Seidl, 2017)

Any resource management problems do not respond well from any single discipline to solve. The most successful solutions to these problems, throughout history, have drawn on ideas, insights, and methods from physical, biological, and social thought and understanding. Hence, integration of different research approaches have been increasingly acknowledged and emphasized to gain insights into solutions and to solve the problems for human well-being especially in natural resources and environmental studies (Holm et al., 2013; Kanazawa, 2017). Lund (2015).also reviewed that whenever social and physical approaches have brought together in any management aspects gave higher degrees of success and the development of social and physical visions formed the foundation of these successes.

In recent management study, integration of scientific assessment and public perception is crucial in the process of finding solutions to problems and sustainable management. Scientists pay their attention increasingly to the public perception to corroborate scientific findings and to adapt perspective views in solving natural resources as well as environmental issues (Ayeni et al., 2016; Chicas et al., 2016; Noi and Nitivattananon, 2015). Ayeni et al. (2016) investigated the perception of rural communities' local experts' on environmental change for evaluation the land cover change and its impact on the surface water in the woodland savanna and rainforest zones of south- western Nigeria. They found a good relationship between the results of remotely sensed data of LCC assessment and the communities' observations of land cover changes and changes in surface water resources in the region. Chicas et al. (2016) integrated social surveys and soil loss analysis to identify erosion vulnerable areas and to analyze varying perspectives among communities regarding the causes of erosion in Toledo's Rio Grande Watershed, Belize, Central America. This study provided significant information on the drivers, underlying causes and erosion vulnerable areas that would aid stakeholders to garner community support, develop and implement sustainable soil management practices. Moreover, the study highlighted the need to implement cost-effective soil erosion prevention programs and to assess the loss of soil nutrients and agricultural productivity in the study area. Eduful and Shively (2015) investigated perceptions and knowledge of urban land use and degradation of water bodies in Kumasi, Ghana. The study recommended that education and stakeholder participation (community involvement) should constitute the key components of any environmental regulations and policies aimed at protecting urban water bodies. Comparing questionnaire survey data with scientific observation, Deng et al. (2012) studied on the character of public perception on climate and cryosphere changes and their possible impacts on water resources, and adaptation measure choices by the public in the Ürümqi River Basin and the Aksu River Basin, China. They showed that public choices of adaptation measures for climate and cryosphere change are impacted by demographic factors such as age, gender, region, nationality, education, and occupation. In another study, Manandhar et al. (2015) investigated the perceptions of local people on climate change and related hazards in Yang Luang Village, Mae Chaem basin in northern Thailand using the local people perceptions and scientific observations. Their results showed that people knowledge and observations have correctly perceived rainfall changes, droughts and floods impacts, landslide reasons that have largely influenced the experiences and perceptions regarding climate-related hazards. Their findings are helpful to assess the needs in terms of actions and information to facilitate climate-related hazard management at the local level in Thailand.

In the study area, a number of researchers have conducted management studies mainly focus on agro eco-tourism. Ariffin et al. (2014) studied on the perception of local stakeholders and tourists on agro eco-tourism. Majority of respondents agreed that agro eco-tourism can generate a sustainable income and preserve the environment while ensuring sustainability through fair trade. In another study, Kunasekaran et al. (2011) developed a new measurement scale for determining farmers' perception on the agro-tourism industry in Cameron Highlands. Farmers' sensitivity towards the climate change in the highlands was also conducted through a qualitative survey study with a focus group discussion (Hamdan et al., 2014). Silva et al. (2011) determined contract farming entrepreneurs' acceptance of sustainable agricultural practices and the issues involved in their level of acceptance. Tan and Mokhtar (2010) evaluated social perception on water issues in Cameron Highlands by Principle/Factor Analysis. All the above studies related to social survey for sustainable highlands development. However, no survey study has been conducted on the basis of the scientific study.

2.6 Research Gap

From the overall literature review, it is revealed that interdisciplinary (integrated) approach is crucial in the process of finding solutions to problems and sustainable management. Although a number of researches have been conducted in recent years in relation to water quality, landuse-water quality relationships, and water resource management, most of the researches have focused on individual disciplines. The area of interdisciplinary approach is still lagging behind the goal. Based on the subject matter and literature review, there is no integrated study that has been carried out on social and scientific assessment for sustainable management on the river catchment in the studied area as well as in Malaysia till now.

It is, therefore, very much imperative to understand the community based indigenous knowledge on environmental changes (water quality, landuse, and soil erosion) that can be corroborated with the assessment of scientific findings as well as applied to sustainable development and management of local catchment. Keeping the study gap in utmost attention, the present research intends to propose an effective sustainable management model using integrative assessment of scientific findings (water quality and landuse study) with quantitative social information (communities' knowledge perception, and awareness). Therefore, implementation of the integrative assessment in this research is addressing a specific knowledge gap with the aim to improve authorities understanding on the sustainable management for the Bertam River Catchment

2.7 Summary

The water quality, landuse, and soil erosion studies in local, national and global contexts have been reviewed to understand the water quality status, its relationships with landuse and soil erosion in deteriorating the surface water quality within a watershed or catchment. The review has also been focused on the social studies of natural resource management and environmental issues as well as integration of social and natural sciences for better understand the sustainable catchment management.

The review of water quality studies revealed that most of the previous studies mainly involve in assessing spatial and temporal variations and their trends, identifying possible pollution sources, data reduction, grouping and discrimination of variables that influence water system. Different statistical approaches and model are commonly used in the assessment and evaluation of water quality. The NWQS and WQI are also used as important tools in assessing the water quality status of the river system. GIS-based mapping techniques are recently applied to derive a reliable and useful output for water quality monitoring in water resource environment. The reviewed also revealed that most of the water quality studies were highly linked with land use patterns and discharge from industry and/or sewage as well as agricultural runoff. All the studies demonstrated that variations of water quality strongly depend on the spatial and temporal scales, linked with natural and or anthropogenic activities and are significantly imperative for water resources management and ecosystem sustainability.

Previous landuse studies elicited that deforestation, agricultural intensification, and urban sprawl are the major changes in landuse at local, regional and global scales. The GIS approach using change detection technique has widely been applied and recognized as a powerful and effective tool in detecting land use and land cover changes. From the review, it was accepted that land use changes actually affect water quality through changing the hydrological and chemical runoff processes in any watershed or catchment. Most of the previous studies support a close spatial and seasonal relationship between specific land uses and water quality variables. Agricultural activities and urban development were identified major sources of point and non-point pollutants that impact on water quality. Most of the studies suggested that accurate assessment of the spatio-temporal distribution of land usage and activities are significant to integrate the water quality management and land use planning.

Previous studies on soil erosion highlighted that soil erosion is mainly characterized by a number of natural factors (such as rainfall intensity, soil characteristics as well as topographic features) play a major role in controlling soil movement. Anthropogenic factors further accelerate the soil erosion by altering the vegetation cover. Deforestation and agriculture intensification have frequently come with increased soil erosion and higher sediment loads in surface water. The literature review also revealed that the empirical modeling approaches are the most commonly used methods for soil loss estimation because of their simplicity of application. The RUSLE model has been extensively used to estimate soil erosion and to guide development and conversation plans to control erosion. Spatial and quantitative information of soil erosion contributes significantly to the soil conservation management, erosion control, and general catchment areas management.

In management point of views, previous studies elicited that people knowledge, perceptions, attitude, and awareness are important aspects of understanding the relationship between people and natural resource management as well as environmental issues. Communities' willingness to participate on such issues plays a vital role in reducing environmental impacts and sustainable management of natural resource. Review of management studies also emphasized that association between natural and social sciences are crucial for solving the significant challenges facing humanity. Integration approaches of scientific assessment and public perception are therefore crucial for sustainable management both in natural resources as well as environmental issues.

From the overall literature review, it is highlighted that interdisciplinary (integrated) approach is crucial in the process of finding solutions to problems and sustainable management. Although several research have been conducted in recent years in relation to water quality, landuse-water quality relationships, and water resource management, most of the researches have focused on individual disciplinary. The area of interdisciplinary approach is still lag behind the goal. Keeping the study gap in utmost attention, the present research intends to propose an effective sustainable management model using integrative assessment of scientific findings (water quality landuse changes and soil erosion study) with quantitative social information (communities' knowledge perception, and awareness).

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter describes the research approach used in the present research to fulfill the objectives mentioned in the earlier chapter. Firstly, the chapter introduces the overall information of the study area covering its topography, geology, soil, climate, hydrology, agriculture and agro-tourism. Secondly, it discusses on the measurements of surface water quality that includes criteria for sampling site selection, plans for sampling programs, field and laboratory procedures for measuring various parameters as well as data interpretation techniques with different software and equations. At the next section, data acquisition, georeferencing, digitization, change detection, land type proportion and slope analysis techniques are discussed to assess the trend and status of landuses. Subsequent section describes the factors those are used in soil erosion modeling. It also includes the procedures of soil erosion map generation and soil erosion rate estimation by applying RUSLE model in conjunction with GIS framework. Finally, the chapter details on the social survey for management that includes questionnaire preparation, survey techniques and statistical analyses on data interpretation. The overall methodological flow is given in Figure 3.1.

3.2 Description of Cameron Highlands

Detailed information on the study area is essential for understanding the research because the Cameron Highlands area is particularly important for its rich biodiversity, water resources, tea cultivation, and agricultural production (Aminuddin et al., 2005; Gasim et al., 2009a). Therefore, this section introduces the wider Highlands district first and then the Bertam Catchment in particular.

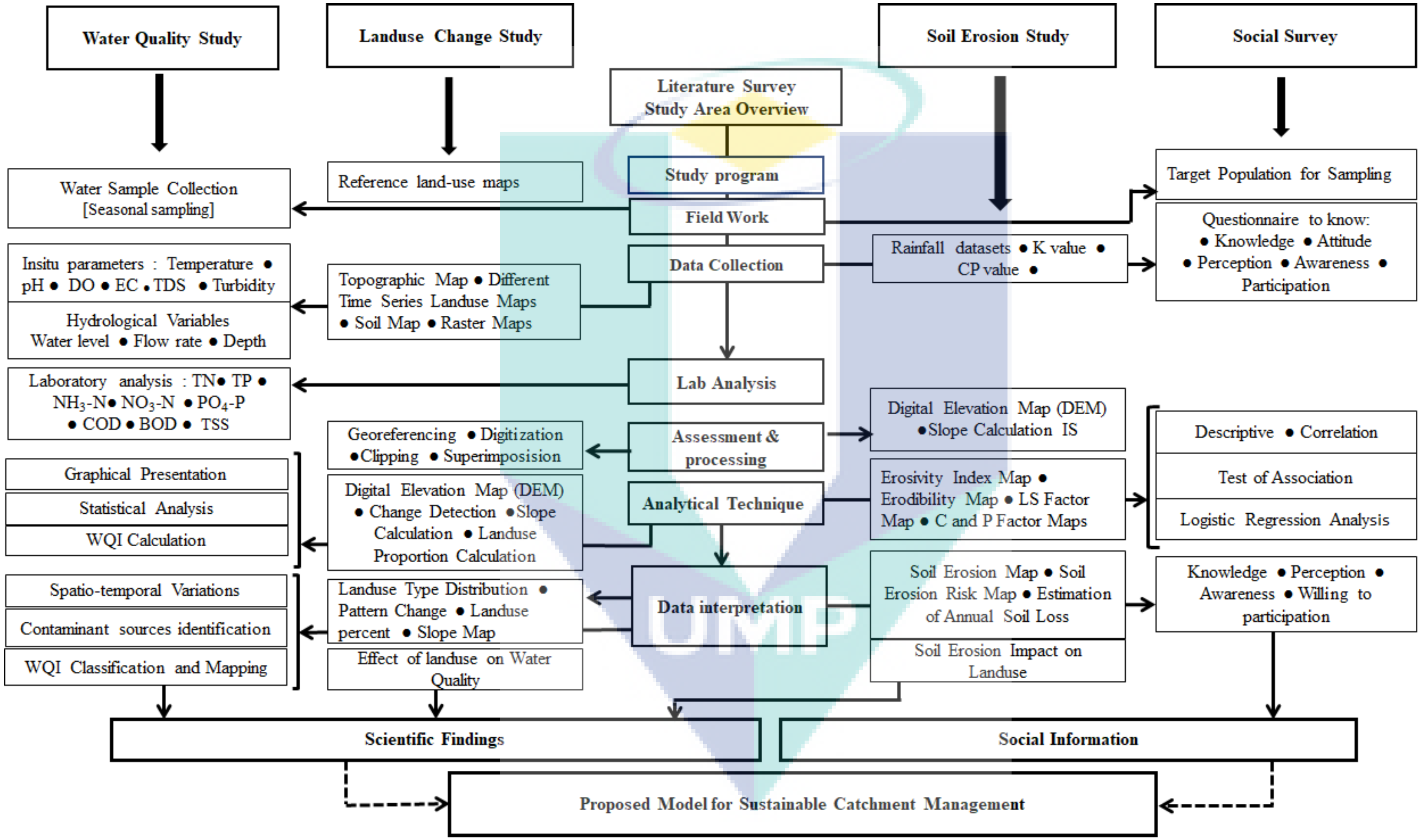

Figure 3.1 Flow chart of methodology which involved four major studis in Bertam catchment

3.2.1 Location

The study area, Cameron Highlands is situated in the Pahang Darul Makmur, the largest state of Peninsular Malaysia and located at the north-western corner of the state. It is the smallest of the eleven districts within the Pahang (2% of coverage) and covering an approximate area of 712 km^2 (Fortuin, 2006). It shares its borders with the state of Kelantan in the north and state of Perak in the west and the Lipis state on the south-eastFigure 3.2 A). The Highlands has distanced approximately 90 km from Ipoh (Perak state) and about 200 km from Kuala Lumpur or about 355 km from Kuantan, the capital of Pahang. The Cameron Highlands is located within geographical longitude 101°20' to 101°36' E and latitude 4°27' to 4°37' N.

Administratively, Cameron Highlands consists of three sub-districts, namely Ringlet (51.56 Km^2), Tanah Rata (20.27 Km^2) and Ulu Telom (639.9 Km^2). The district comprises three main townships and five settlements in the Highlands. The townships are Ringlet, Tanah Rata, and Brinchang, each plays different strategic roles in the socio-economic growth of the Highlands. Tanah Rata is the largest township consists of government and main facilities buildings and is the administrative center of the Highlands. Ringlet town plays a major role to commercialize vegetables and active with transit activities. Brinchang town supports commercial facilities and hotels for the tourists. Other small settlements are Bertam Valley, Habu, Kea Farm, Tringkap, Kuala Terla, and Kampung Raja. All these areas except Bertam Valley are linked via a 34 km long main access road that stretches from Ringlet in the south to Kampung Raja in the north Figure 3.2 B). The Bertam Valley is about two kilometers from Ringlet town, a scenic spot for growing fruits and vegetables. It is now the Highlands' new entrance from Pahang via Sungei Koyan from Raub or Kuala Lipis.

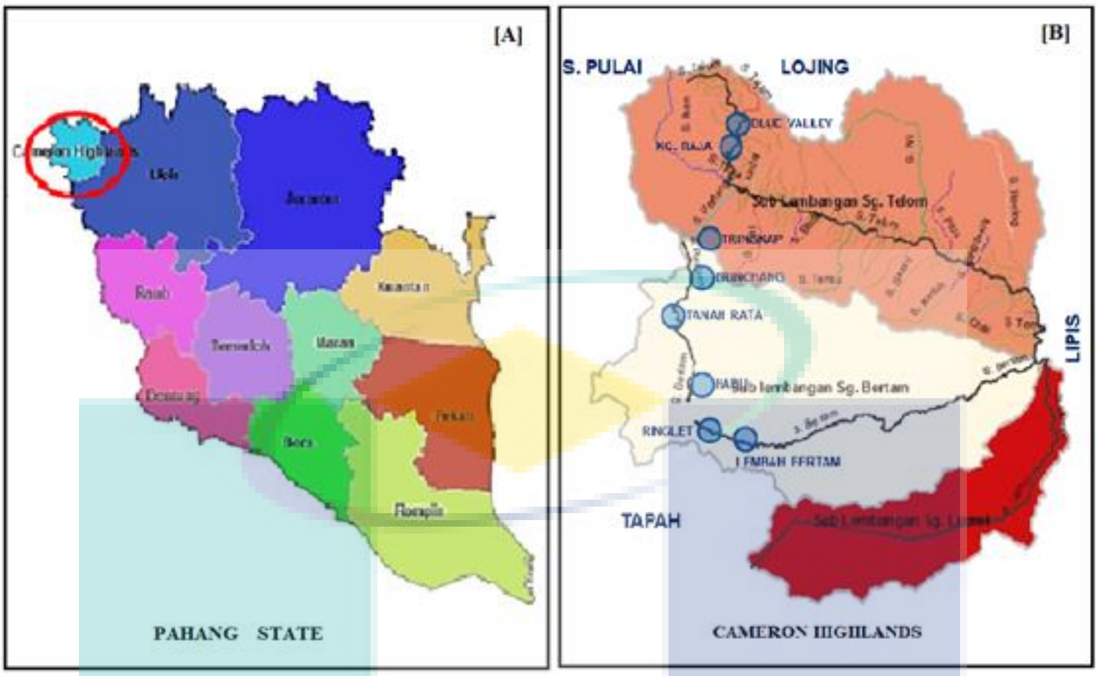

Figure 3.2 Map of Pahang State (A) and Cameron Highlands (B).
Source: DID, Cameron Highlands, Malaysia.

3.2.2 Topography

Topographically, the Cameron Highlands is situated within the main Titiwangsa Mountain Range of Peninsular Malaysia. The entire area of the Highlands is characterized by rugged mountainous topography. Its terrain heights vary in range from 1000 m at the river valley on the eastern boundary to 2031 m on the western boundary. About 75% of the area is located above the elevation of 1000 m above mean sea level (MSL) (Kumaran and Ainuddin, 2006). The maximum amount of flatland is located in Tanah Rata. This area is natural undulating plateau stretching about 12 km with an elevation ranging from 1524 m to 2032 m. The area is surrounded by numerous mountain peaks over 1500 m above MSL, namely Gurung Beremban (1812 m), Gurung Brinchang (2032 m), Gurung Ruil (1718 m) Gurung Perdah (1551 m) and Gurung Jasar (1704 m). The relief of the study area varies between 860- 2110 m above MSL (Pradha et al., 2011). Generally, the mountainous terrain of the Highlands is strongly dissected with 10°-35° slopes with more than 66 percent has a gradient of more than 20°. A large portion of the Cameron Highlands, however, embodied in areas greater than 40° (Abdullah et al., 2001).

3.2.3 Geology and Morphology

The geology of the study area mostly consists of granitic rocks followed by small portions of metamorphic rocks (Pradha et al., 2011). Alluvium covers most of its area. Overall geomorphology of the study area consists of an undulating plateau and the hill ranges are characterized by a rugged topography with varying elevations ranging from 600 to over 4800 m above MSL. As the area is situated in the mountainous zone, the geomorphology is dominated by denudation process and consists of deep highly weathered materials. Erosion features are very common in the exposed areas.

3.2.4 Soil

The Soils in the Cameron Highlands are mainly derived from two parent materials: (a) acid intrusive, which cover most of the area; and (b) a small part from schist, phyllite, slate, and limestone. The soils are mostly being sandy to sandy clay in texture and are classified as paleudults (Paramananthan, 1977). Within the area, 63.9 % is made of loamy type while 27.3 % is of laterite type. The topsoil (0–30 cm) from acid intrusive parent material has an average bulk density of 0.87 g/cm^3, 4.3 % organic carbon, and a pH of 4.9 whereas the metamorphic soil has those values of 0.78 g/cm^3 of bulk density, 3.2 % of organic carbon and a pH of 4.6. Both soils are classified as sandy clay loam with average 16% silt, 32% clay and 52% sand (Abdullah et al., 2005).

3.2.5 Hydrology and Water Resources

The drainage system of the Highlands is mainly controlled by three main Rivers-Telom River, Bertam River and Lemoi River along with many small tributaries that drain the northern, middle and southern parts of the Highlands, respectively Figure 3.2 B). These rivers flow eastwardly and join up with the Telom River and finally join the Pahang River. The river system is the only source of potable water supply for the local residents as well as the commercial utilization of the Highlands. Within the Telom and Bertam Catchment areas, the river system play a vital role in Cameron Highlands as sources of freshwater supply, irrigation for agricultural activities, hydroelectricity generation and for recreational activities. An estimated amount of 12.5 million liters per day (MLD) was abstracted and processed for potable water supply at several intake points along the river systems of the Highlands in 2009. The demand expected to rise up to 20.07 MLD by 2020 (NWRS, 2011). More importantly, Cameron Highlands' forests (79% of total 712 km^2 area) form the important headwater catchment area for rivers that drain down to the lowland areas, specifically to Pekan and Pahang Rivers (Fortuin, 2006; Hashim et al., 2006). Therefore, the river network of the highlands provides water supply not only to the local residents but also to the rest of Malaysians living further downstream of the catchment forests.

The ringlet reservoir is a man-made lake created on the upstream of the concrete dam of Bertam River and forms an integral part of the Cameron Highlands Hydroelectric Scheme. The dam is known as Sultan Abu Bakar Dam. It impounds the water of Bertam River and its tributaries and those of Sungai Telom, Sg Plau'ur, Sg. Kodol and Sg. Kial which have been diverted from Telom catchment through the Telom tunnel into the Bertam Catchment. The downstream river has changed as a result of water storage and regulation in the Ringlet reservoir. The changes include a reduction in discharge volume and water level downstream the reservoir (Jaafar et al., 2010).

3.2.6 Climate

The climatic conditions of the Cameron Highlands significantly differ from present Malaysia's lowlands because of altitude difference. The higher altitude of the Highlands results in higher rainfall, lower temperatures, and higher relative humidity (Van der Ent and Termeer, 2005). The average temperature of the Highlands is about 18°C while the mean maximum temperature and mean minimum temperature are about 22°C and 15°C respectively. These temperatures do not fluctuate much throughout the year.

The climate of the Cameron Highlands is of an equatorial type, which is influenced by monsoon air flows. Highlands intercepts moisture from the atmosphere, resulting in large amounts and high intensities of rainfall approximately between 2,500 and 3,000 mm per annum. Average rainfall data shows a bimodal annual pattern, with peaks in April-May and October-November. The wettest period is from October to November with rainfall of about 350 mm per month, while the relatively drier period occurs between January and February with about 100 mm per month.

From the meteorological records, the inter-annual variations of the average rainfall (1984-2014) reveal a gradual positive trend in the rainfall with an annual increase rate of 15.59 mm. Similarly, the annual temperature time-series clearly present a positive trend over the area with an annual increased rate of 0.007 °C. The humidity of the studied area is focused on a gradual negative trend with the annual decreasing rate of 0.0277 over the area (Figure 3.3). The inter-annual variations to average rain days showed a steady positive trend.

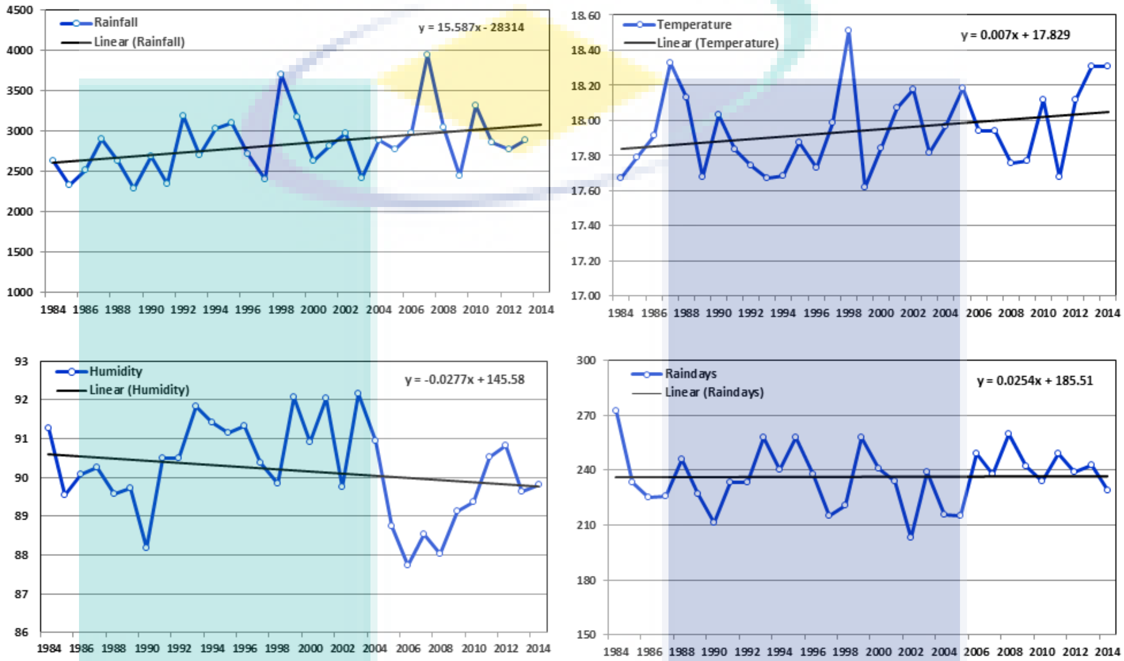

Figure 3.3 Trends of historical rainfall (mm), temperature (°C), humidity (%) and numbers of rain days (per year).

Source: Climatic variables data (1984-2014), Cameron Highlands station, Department of Meteorology, Malaysia

3.2.7 Agriculture

Agriculture is the major socio-economics' activity in Cameron Highlands although the majority of the total land (about 79%) is still under forest (Fortuin, 2006). In spite of steep and highly dissected topography, the relatively cold and temperate weather (14-24°C) with plenty of rainfall and sunshine all-round the year has allowed the Highlands area most suitable for the cultivation of many subtropical crops, temperate vegetables, and flowers. As a result, it becomes the most important temperate agricultural area in entire Malaysia. These agricultural products have a high demand on local and overseas markets (Abdullah et al., 2001). Some of the vegetables are unique because they are only commercially cultivated in Cameron Highlands and nowhere else in Malaysia. Statistically, the total annual vegetable production in Cameron Highlands was 421,935.87 and 649,836 metric tons and consequently earned RM 1446.11 and RM 2354.86 million as revenue in the year 2012 and 2013, respectively (Appendix A).

The total agricultural land use in Cameron Highlands is about 5251 hectare (16.4%). Out of the land usages, land cultivated with vegetables is the most extensive (47%/), followed by tea (44%/), flowers (7%), and fruits (1%) (Abdullah et al., 2001). Vegetable production in the Highlands has expanded over the past 25 years. About 60% of Malaysia's vegetables are being grown in Cameron Highlands. The most popular and variety of vegetables grown in Cameron Highlands are cabbage, lettuce, tomato, cucumber, eggplant, cauliflower, broccoli, mustard and other crops such as onion, French bean, Capsicum spp., and radish. Most farmers grow vegetables between two to five different species. In the Highlands, the popular flowers grown are chrysanthemums (52%), carnations (20%) and roses (17%) (Abdullah et al., 2001). After fulfilling the country's demand, the flowers additionally exported to further foreign countries, such as Japan, Singapore (Hamir et al., 2008). The short-term plants including strawberry and herbs as well as fruits including out-of-season fruits like orange and tangerine are commonly found in the study area. Moreover, Cameron Highlands is the most famous tea producer in Malaysia where more than 40% of the cultivated lands are covered by tea plantation. Most of them were established in the 1930s, by planting tea seedlings on slopes (Othman, 2011).

In Cameron Highlands, annual crops and tea are planted intensively on terraces and on leveled platforms built on valley floors, slopes and hilltops ranging from flat to slightly more than 400. Vegetables and flowers are also cultivated intensively on terraces and platforms taking place between 900 and 1400 m above MSL (Midmore et al., 1996). Two types of agriculture practices namely, open and rain shelter farming are common in the highlands area. Crops production is sustained mainly by high fertilizer and manure applications (Aminuddin et al., 2005).

3.2.8 Agro-tourism

Tourism is the second major economic force next to agriculture as the primary source of income. Cameron Highlands has a unique scenic beauty and offers nature and agro-based tourism. It is a treasured natural heritage of Malaysia and one of the long-established tourist destinations. It is also well known as one of the oldest and largest hill resorts in Malaysia (Chan, 2006). After Malaysian independence in 1957, the highland was promoted as a tourist destination. At the same time, more forest land has been developed into agricultural land and resorts and since the 1970's many vacation homes and hotels have been built in the area. Through the 9th Malaysian Plan, the government has opened opportunities for farmers to expand and diversify agricultural products and their related industries, such as agro-tourism in the area (Ariffin et al., 2014).

The appealing cool climate attracts a lot of people who want to escape the high temperatures in Malaysia's lowland areas. Farming culture, jungle trails, and mossy forest are the common tourist events in the Highlands. Different kinds of vegetables, flowers and fruits planted on terraces, valley floors and slopes, as well as hilltops, are the scenic beauties for visitors. The tea plantation landscape is the most preferred scene in Cameron Highlands (Othman, 2011). The scenic view of the tea plantation has been known ever since tea was introduced to Cameron Highlands in 1929. Tea land use has maintained as the main scenic icon of Cameron Highlands. Jungle trails is another adventure for the tourists to explore the Highlands forest that starts from Tanah Rata to different destinations. The 'Mossy Forest' that grows only at the highest elevations of Cameron Highlands is one of the most scenic places for enthusiast tourists. Along the main road, from Bertam valley to Kuala Terla of the Highlands, many tourist attractions are shaped such as strawberry farms, honey bee farms, cactus valley, butterfly gardens, rose gardens and insect farms for the tourists.

3.2.9 Bertam River Catchment, the Study Area

The study area, Bertam River Catchment is the core area of socioeconomic growth in Cameron Highlands having a total area of about 97.36 km^2. The catchment contains the major urban area of Cameron Highlands, which hosts most of its social and economic activities. The area lies in between longitude 101°20' 00" to 101°27'30" E and latitude 4°23'30" to 4°31'30" N (Figure 3.4). The present study was carried out at the upper and lower part of Bertam River up to 10 km downstream of the reservoir, as all the urbanized and agricultural area of the catchment is located within this area of interest.

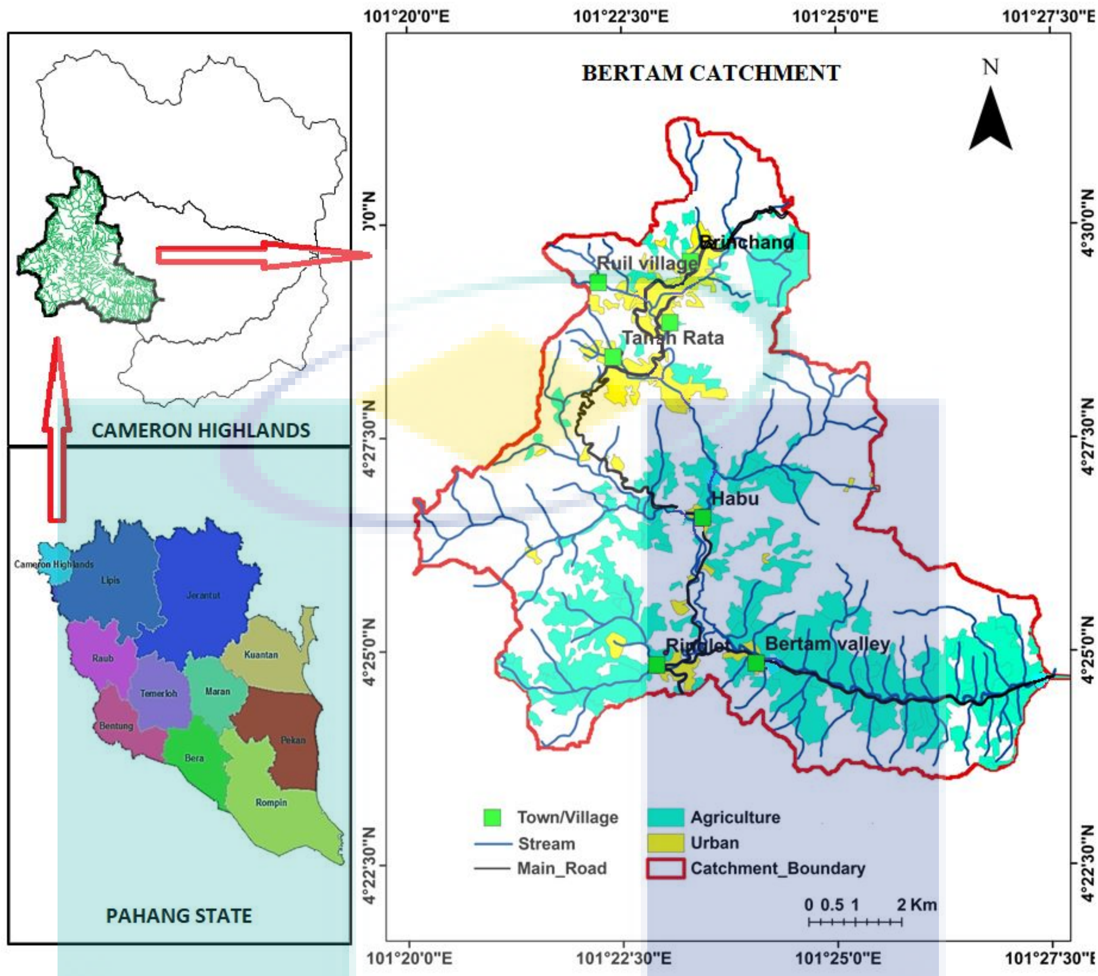

Figure 3.4 Location map of the Bertam River Catchment, Cameron Highland, Malaysia.

Source: Topographic map (1995), Department of Survey and Mapping, Malaysia.

3.2.9.1 Physical Characteristics of the Catchment

The topography of the study area is an undulating mountainous landscape with elevation ranging from 896.4m to 2021.7m above MSL. Around 20% area of the catchment has slope gradient more than 20°. The natural ground slopes of the areas located between 300 and 1600m are generally steep i.e between 20° to 30°. These slopes are convex-like and steep-sided with narrow valleys in between. However, several broad valleys are present in the town of Tanah Rata and Brinchang. At elevations exceeding 1600m, there have very steep ground slopes that range from 30° to 45° (Paramananthan, 1977). Granitic rocks followed by small portions of metamorphic rocks are the major rock types within the area. Alluvium covers most of the area. In general, the soils of the catchment are characterized by Rengam series with texture varying from sandy clay to sandy clay loam (Chan, 2002; UM and TNRB, 2001). The soils are mainly derived from the geologic parent rocks. The virgin soil comprises 40% sand, 16% silt, and 44% clay, with EC 0.13 mS/cm and pH 4.2. The high sand content of this type of soil is erosive in nature, especially when exposed to agricultural activities (Jamil et al., 2014).

The Bertam River Catchment reflects the typical drainage patterns of a mountainous catchment. It is drained by the main Bertam River and its tributaries, influenced by a hilly and undulating terrain system. It flows from Brinchang Mountain at the upstream, passes through the towns of Brinchang, Tanah Rata, and Habu, into Ringlet Reservoir in Upper Catchment and finally flows to the Telom River about 24 km downstream of the reservoir in Lower Catchment. The analyses carried out by UM and TNRB (2001) showed that the drainage patterns are basically dendritic, but the main channels of main major tributaries are much more elongated in nature, suggesting some form of structural controls. Along the upper stretches of Bertam River structural controls were mainly seen with sharp and angular bends. The important tributaries draining into Bertam Rivers are Burung, Ruil, Jasar, Uluh, and Batu Pipih, and Ringlet join with the main course of Upper Bertam River at different locations. Figure 3.5 also shows the major river system in Bertam Catchment.

The valley of Bertam river and their tributaries are generally narrow and slender and shows slight to moderate sinuosity. There are mostly very steep valley side slopes where the average gradient is more tham 45° (Chan, 2002; UM and TNRB, 2001). Besides certain stretches of the Bertam River, moderate accumulation of alluvium materials are found, which are mainly sandy loam with planty of mica flakes. On some valleyside slopes outcrops of granite are quite common suggesting the intense weathering and mass wasting processes on the slopes. At elevation above 1500m, highland peat and spodosols are widwspread (Chan, 2002). However, the valleyside slopes are generally stable when there are thick vegetation covers. The riverbed analysis indicates that the materials in the upstream of the Sg Bertam are gravels of granite or metasediment and few sand and silt (Toriman et al., 2010). The texture analysis also indicated that particle size for sandy type was in the range of 70.72-94.12%, silt type (3.40-17.93) % and clay type (1.64 to 7.22) %. The present texture study also revealed that sandy type was predominant fractions for sediment particle size at all the river stretches (Khalik et al., 2013).

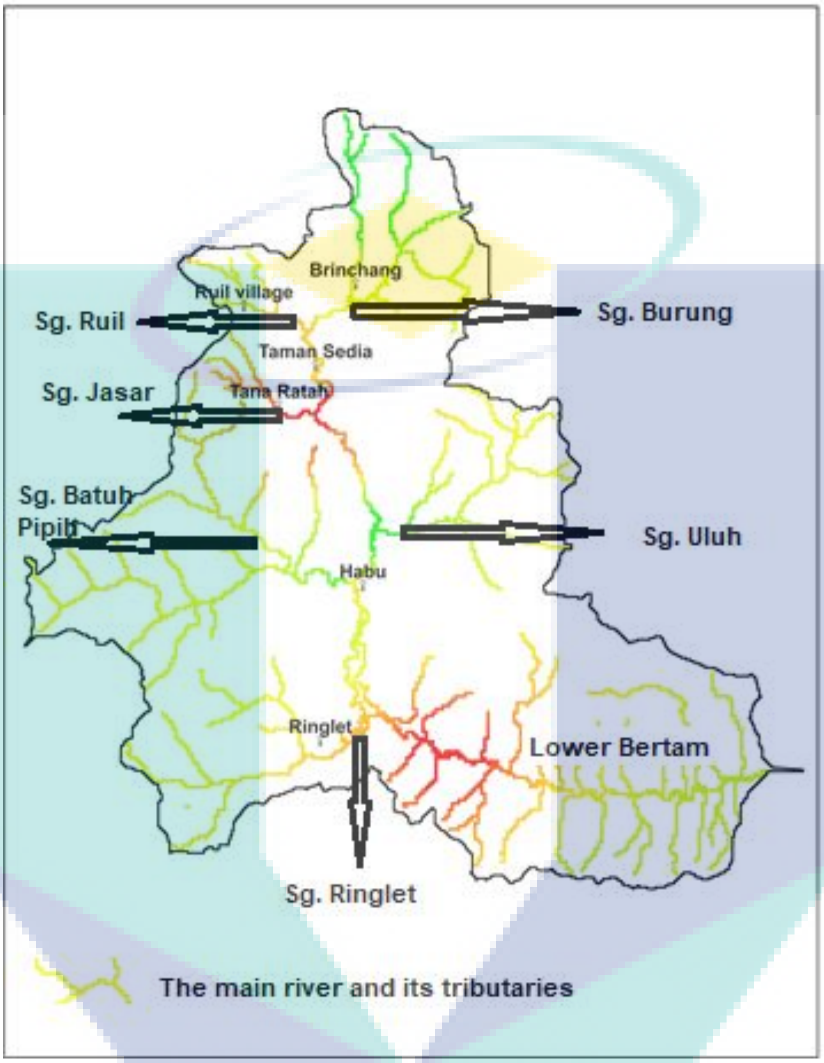

Figure 3.5 The major river systems in Bertam River Catchment area
Source: Topographic map (1995), Department of Survey and Mapping, Malaysia.

Within the catchment, forest land type has the majority of coverage (50.28%), followed by market gardening, tea, scrub, urban, and water body. Most market gardening takes place at altitudes between 900 m to 1400 m MSL (Midmore et al., 1996). Agricultural products are planted mainly on terraces and platforms, built on steep and gentle slopes or hilltops, as well as on valley floors under open and rain-shelter farming practices. Agricultural production is mainly sustained by high fertilizer, manure, and chemical applications (Aminuddin et al., 2005). . In the Upper Catchment, the municipal and domestic wastewaters that are directly discharged into the river are mainly produced from those towns and small villages located around the tributaries. In the Lower Bertam, Ringlet town and agricultural activities along the Lower Bertam Valley substantially influence river water quality.

3.2.9.2 Hydrological Characteristics of the Catchment

The results of rainfall data from 1984 to 2014 showed that the average monthly rainfall at Bertam catchment ranged from 117.53 mm to 366.10 mm. The average highest rainfall was recorded 366.10 mm in October while lowest was 117.53 mm in January (Figure 3.6). Maximum rainfall (wet season) is during October to November and April to May while minimum rainfall (dry season) is during January to March and June to August. (Razali et al 2018). The wettest period from October to November with average rainfall of more than 300mm per month while the driest months are between January and February with about 100mm rainfall per month. However, short 'dry spells' are felt in the months of June and July coinciding with low rainfall.

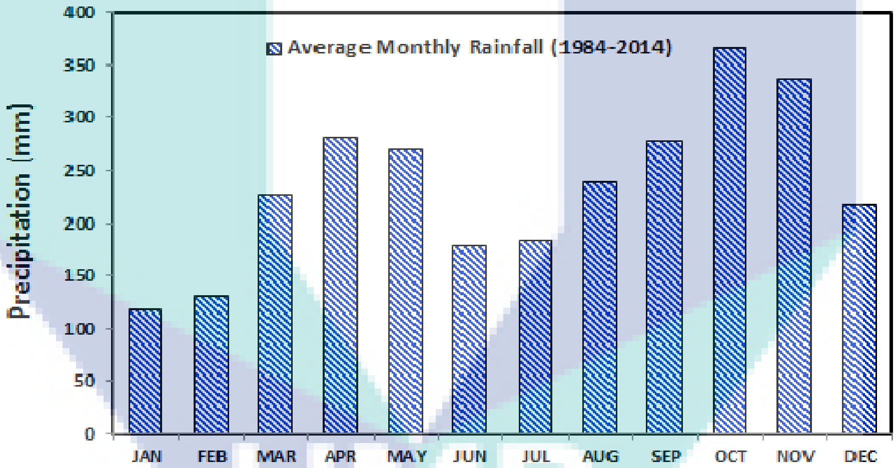

Figure 3.6 Average monthly rainfall of the study area during 1984 to 2014

The streamflow at different stations in the catchment depends mainly on the rainfall pattern of the area. In the drier periods, with a few days of dry weather the river runs with relatively stable flow rates. Within this period riverbed erosion takes place delivering bonded compounds in the riverbed to the water stream. Second, during rain or just after raining, the river is relatively unstable with rapidly increasing water rates with surface runoff of the surrounding land with compounds bonded to the surface layers of agricultural land being added to the water stream. (Eisakhani and Malakand 2009)

3.3 Water Quality Assessment

The aim of water quality assessment was to obtain quantitative information on hydrological, physical and chemical characteristics of surface water as a result of anthropogenic activities. Water quality assessment was done based on the methods approved by American Public Health Association (APHA) and Hach standard procedures (APHA, 2012; Hach, 2005). The assessment also proposed by Ward et al. (1990) had defined water quality assessment as a system, following the flow of information through six major components: sample collection, laboratory analysis, data handling, data analysis, reporting, and information utilization. The Figure 3.7 shows the detail water quality assessment procedures followed in the present research study.

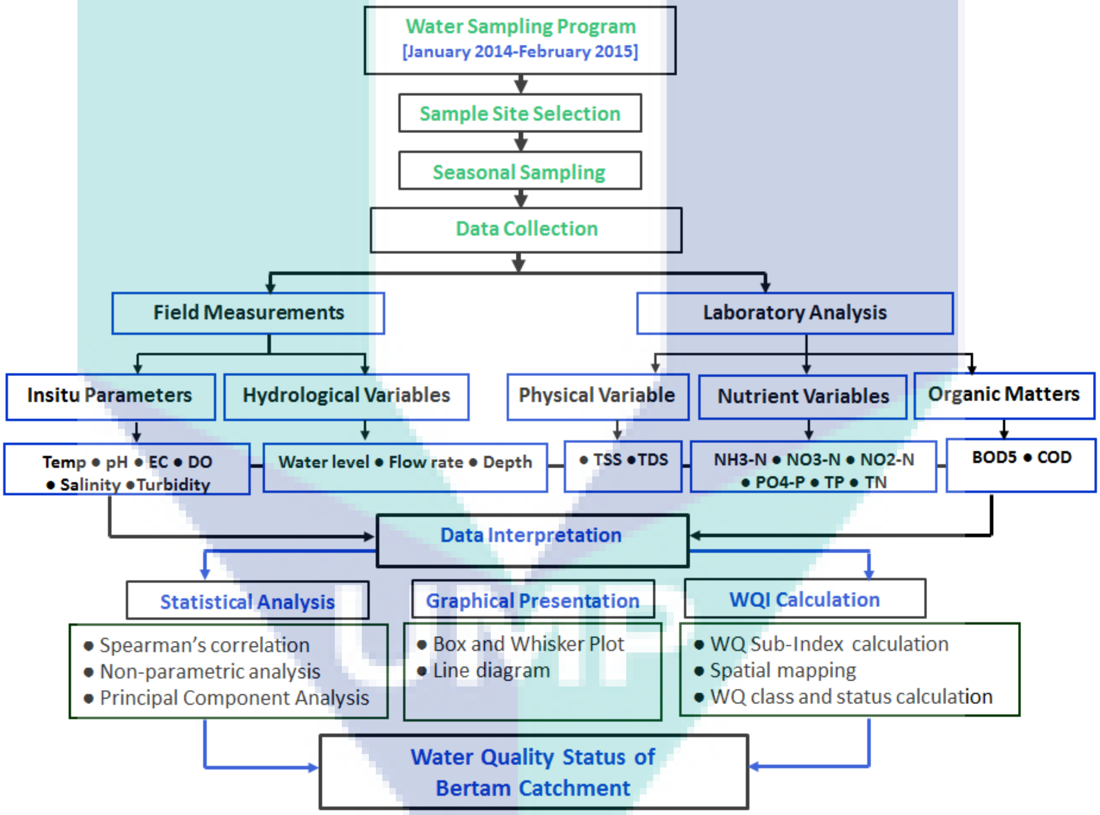

Figure 3.7 Flow diagram showing detailed assessment procedure of water quality status

3.3.1 Sampling Site Selection

A reconnaissance field survey was conducted in December 2013 to point out the possible locations for the collection of surface water prior to seasonal water sampling. Selection of sampling stations was done mainly based on the land use pattern, river network and location for potential point and non-point pollution sources criteria. A portable Global Positioning System (Garmin 76Cx) was used for determining the definite coordinate positions and elevations of the sampling stations. The sampling sites included seven stations along the mainstream of the Bertam River (UB1-UB5 and LB1-LB2) and five stations at different tributaries namely Burung Ruil, Jasar, Uluh and Batu Pipih (TB1-TB5). Among these, ten stations (UB1-UB5 and TB1-TB5) were located at Upper Bertam and two stations (LB-1 and LB-2) at Lower Bertam. Station UB1 was situated at the source point of the main River in the mountainous forest area. The stations were named as per catchment areas and tributaries and numbered from upstream to down within the study area. Sampling stations along with their coordinate, altitude and selection criteria are presented in Table 3.1 and their locations are shown in Figure 3.8.

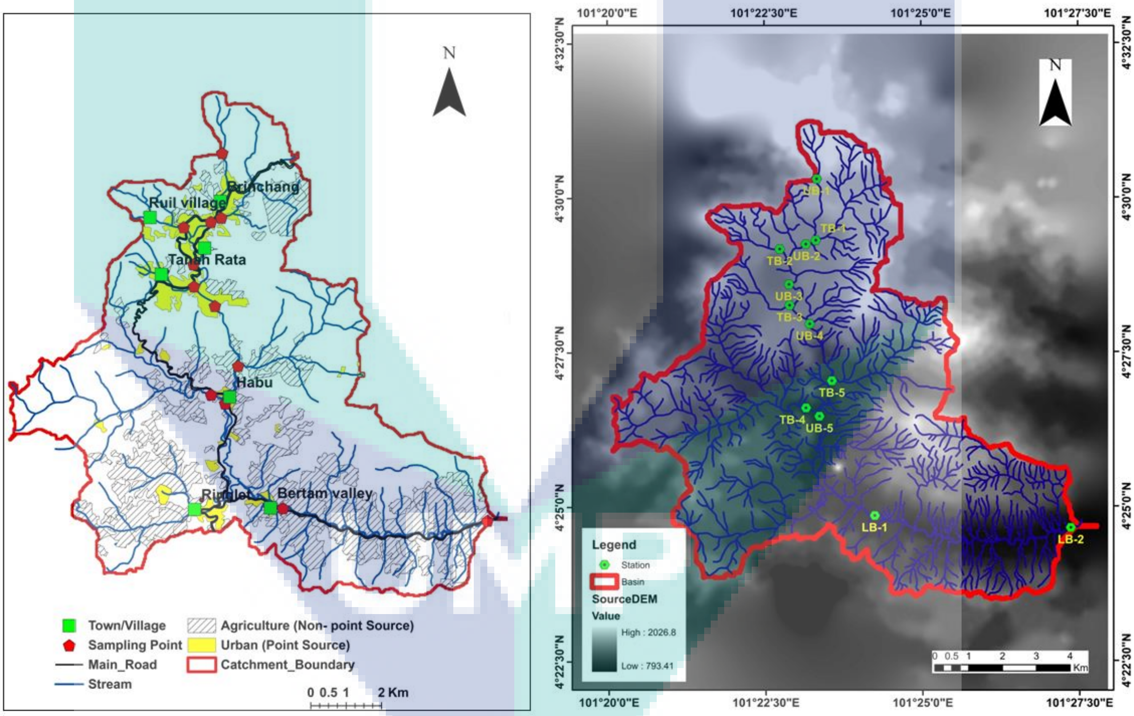

Figure 3.8 Location map and sampling stations in the study area.

Table 3.1 Description of sampling locations in Bertam Catchment area

Catchment	Station	Latitude Longitude	Altitude (m)	Station Description and Selection Criteria
Upper Bertam (Main River)	UB-1	04°30'18.4" 101°23'19.9"	1635	Sloppy mountainous and forest area. Source area of the river.
	UB-2	04°29'15.0" 101°23'09.3"	1463	Adjacent to Brinchang town and after the confluence of Sungai Burung (tributary).
	UB-3	04°28'36.0" 101°22'53.1"	1450	Adjacent to Taman Sedia residential area and after the confluence of Sungai Ruil (tributary)
	UB-4	04°27'57.6" 101°23'12.7"	1443	After Tanah Rata town and the confluence of Sungai Jasar.
	UB-5	04°26'27.9" 101°23'21.8"	1079	Before Ringlet Reservoir, after the confluence of Sungai Batuh Pipih and Sungai Uluh.
Upper Bertam (Tributaries)	TB-1	04°29'18.8" 101°23'18.8"	1469	Sungai Burung; farming and residential area.
	TB-2	04°29'10.3" 101°22'44.3"	1459	Sungai Ruil; village area.
	TB-3	04°28'15.7" 101°22'53.6"	1428	Sungai Jasar; the impact of a residential area and sewage treatment plant
	TB-4	04°26'36.0" 101°23'09.0"	1125	Sungai Batuh Pipih; around tea plantation and agricultural area
	TB-5	04°27'02.3" 101°23'33.8"	1087	Sungai Uluh; around tea and farming area
Lower Bertam	LB-1	04°24'51.3" 101°24'14.5"	1019	Intensive farming and residential area
	LB-2	04°24'39.1" 101°27'21.9"	915	Farming area

3.3.2 Seasonal Sampling Program

Sampling program was conducted from January 2014 to February 2015 to collect water samples from 12 stations. Samples were collected at six times from each station during dry (January, March, June'14 and February'15) and rainy (September and October'14) season. In each sampling program, three replicate samples were collected from each sampling station. A total number of 216 samples were collected during the study period.

Water samples were collected from 15 cm depth from the water surface following the grab method (Figure 3.9). Three replicate samples were collected at each sampling station using 1L high-density polyethylene bottles (HDPE) for physico-chemical analysis and 300mL black biological oxygen demand (BOD) bottles with glass robotic stoppers (Wheaton, USA) for BOD test. All samples were then stored in a cooler box filled with ice packs to keep the temperature below 4°C before transferring to the laboratory. In the laboratory, the samples were kept in a cold room at the same temperature, without adding chemical preservatives until analysis. APHA and Hach standard procedures were followed during sampling, sample transportation and preservation (APHA, 2012; Hach, 2005).

Figure 3.9 Water sampling from different stations during sampling program

3.3.3 Parameters Measurement

For water quality assessment, different desired physico-chemical parameters were measured in the field as in-situ measurement and in the laboratory as ex-situ measurement. The hydrological variables were also measured during the sampling periods. The historical changing trend in climate was observed using the climatic variables data.

3.3.3.1 Field Measurements

In-situ measurement of water quality parameters was recorded for temperature, pH, dissolved oxygen (DO), electrical conductivity (EC), total dissolved solids (TDS) and turbidity using portable YSI model 6600-V2 (YSI, USA) multiparameter water quality sonde (Table 3.2) in the field. The sonde was placed under the water and the readings were taken from the display window . The measurement was repeated thrice to avoid errors and obtain stable results (Figure 3.10). The sonde was calibrated in the laboratory before each sampling program.

Table 3.2 List of in-situ parameters and instruments use for measurements

Parameters	Abbreviation	Unit	Instrument
A. In-situ			
Temperature	T	°C	Portable YSI model 6600-V2 (YSI, USA) multi-parameter water quality sonde
pH	pH	-	
Dissolve oxygen	DO	mg/L	
Electrical Conductance	EC	µS/cm	
Turbidity	Turb	NTU	
Total Dissolve Solids	TDS	mg/L	

3.3.3.2 Hydrological Variables

Hydrological measurements (water velocity, depth, and width of the river) were carried out in a systematic way to determine the specific stream flow values of the main river and its tributaries at different stations. The cross-section width, depth, and flow velocity were measured at each station using a rangefinder and a flow meter respectively (Table 3.3 and Figure 3.10). These parameters were measured to determine specific discharge values. The cross-section of the river has been prepared by plotting the measured width, depth, and velocity on the square graph paper. Water flow (m^3/s) was calculated from the cross-section by using the following specific equation shown in Equation. (3.1). A flow meter (model SWOFFER 300) and a rangefinder (CMI 5m) were used to measure the stream flow, width, and distance of the river.

Table 3.3 List of hydrological variables and instrument used for measurement

Parameters	Abbreviation	Unit	Instrument
River width	w	m	Measuring tape
Water velocity	V	m/s	SWOFFER 300 Flowmeter
Depth of the river	d	m	CMI 5m measuring staff

Figure 3.10 Measurement of in-situ parameters and hydrological variables during sampling program.

Stream Flow Measurement

The cross-sectional length and depth, as well as flow velocity, were measured to determine specific streamflow values. Streamflow value (Q) is the product of average velocity (V) and cross-section area (A) or Q=VA. Cross-sectional area is derived from the product of depth (d) and width (w). By using the Equation 3.1, water flow (m^3/s) was calculated from the cross-section.

$$\text{Flow } (m^3sec^{-1}) = \sum(\text{Depth, d x Width, w}) \times \sum \text{Velocity of flow} \quad 3.1$$
$$= \text{Area } (m^2) \times \text{Velocity of flow } (msec^{-1})$$

3.3.3.3 Laboratory Analysis

Laboratory analyses were carried out to measure one physical variable (TSS) and seven chemical parameters in the collected samples from the study area. In the laboratory, samples were stored in cold room on the collecting day. All laboratory analyses were conducted within seven days of sampling time. All chemical testing and analyses were carried out in the Environmental Laboratory of the Universiti Malaysia Pahang (UMP). Methods of analysis and required equipment those were used to analyze the parameters are given in Table 3.4.

Selected chemical parameters included a five-day biological oxygen demand (BOD_5), chemical oxygen demand (COD), nitrate nitrogen (NO_3-N), ammonia nitrogen (NH_3-N), total nitrogen (TN), phosphorus phosphate (PO_4-P), and total phosphorus (TP) of the collected samples, which were analysed following the standard methods of analysis (APHA, 2012). Except for BOD_5, all parameters were finally measured using Hach DR 5000 spectrophotometer. COD measurement was carried out using reactor digestion and colorimetric determination method whereas BOD was obtained from five days incubator method. Total suspended solids (TSS) was determined using the gravimetric method. For, BOD_5 analysis, initial DO measurement was done just after arrival at the laboratory and the samples were kept in the incubator at 20^0C for 5 days to avoid any photosynthesis. Phosphate analysis was done within 48 hours of sample collection to avoid interference of other parameters. The list of chemical parameters that were analyzed in the laboratory is shown in Table 3.4 along with the methods and instruments adopted for analysis.

3.3.3.4 Climatic Variables

Four historical climatic variables as rainfall, temperature, humidity and total rainy days data were collected from the Meteorological Department of Malaysia for the station of Cameron Highlands (Table 3.5). The data which spanned from 1984 to 2014 were originally generated on monthly basis (Appendix B). The mean values of these variables were computed from the monthly data.

Table 3.4 List of chemical parameters and method/instrument used for measurement

Parameters	Abbreviation	Unit	Analytical Method/ Instrument
Total suspended solids	TSS	mg/L	Gravimetric method
Total nitrogen	TN	mg/L	Persulfate digestion method HACH DR 5000 spectrophotometer
Ammonical-nitrogen	NH_3-N	mg/L	Neslar Method HACH DR 5000 spectrophotometer
Nitrate-nitrogen	NO_3-N	mg/L	Cadmium Reduction Method HACH DR 5000 spectrophotometer
Total phosphorus	TP	mg/L	Acid persulfate digestion method HACH DR 5000 spectrophotometer
Orthophosphate-phosphorus	PO_4-P	mg/L	Ascorbic Acid Method HACH DR 5000 spectrophotometer
Biochemical oxygen demand	BOD_5	mg/L	Incubation Method as BOD_5 YSI 5100 Dissolve Oxygen Meter
Chemical oxygen demand	COD	mg/L	Reactor Digestion and Colorimetric Determination HACH DR 5000 spectrophotometer

Table 3.5 List of climatic variable data and their source

Parameters	Duration	Unit	Source
Rainfall	1984-2014	mm	Department of Meteorology, Malaysia
Temperature	1984-2014	°C	
Humidity	1984-2014	%	
Rainfall days	1984-2014	Nos.	

3.3.4 Data Presentation

Different graphical presentation and calculation were used for data interpretation. These are described under the following headings:

3.3.4.1 Graphical Presentation

Graphical analyses (box and whisker plot and line diagram) of the measured values of water quality parameters were used to interpret level and trend of the spatial and temporal variations and their relation to source pollutions. High standard deviation of data in most of the measured parameters indicates a strong spreading variability of the composition. The level of variability of different stations and seasons are compared by using box and whisker plots (95% confidence interval) as well as line diagrams.

3.3.4.2 Box and Whisker Plot

The box plot (also known as box and whisker diagram) is a standardized way of displaying the distribution of dataset based on the five-number summaries- minimum, first quartile, median, third quartile, and maximum (Figure 3.11). The simplest possible box plot displays the full range of variation (from min to max), the likely range of variation (the IQR), and a typical value (the median).

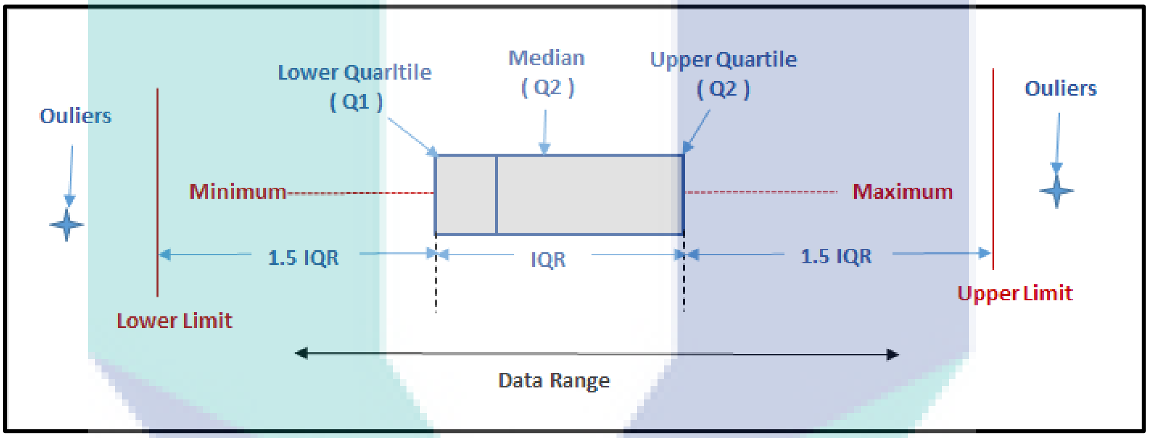

Figure 3.11 Box-plot with whisper from upper to lower limit and outliers

In this study, box-plots of all parameters were examined in all stations to observe the spatio-temporal variations. In a box-diagram, the line across the box represents the median, whereas the bottom and top of the box show the location of the first and third quartiles (Q1 and Q3). The whiskers are the lines that extend from the bottom and top of the box to the lowest and highest observations inside the region defined by Q1-1.5(Q3- Q1) and Q3-1.5(Q3- Q1). Individual points with values outside these limits are plotted with asterisks. Only the data that lies within lower and upper limit were statistically considered as normal and thus can be used for further study. Box-plot provides a visual impression of the location and shape of the underlying distributions. Boxplots with large spread indicate a seasonal variation of the water composition. Ispecting these plots, it was also possible to perceive differences among the stations (Bu et al., 2010; Kilonzo et al., 2014; Li et al., 2014; Ogwueleka, 2015).

3.3.5 Water Quality Index Calculation

The water quality index (WQI) was calculated to classify the surface water of the Bertam River and its tributaries within the Bertam River Catchment. For the calculation of the WQI, the Department of Environment-WQI (DOE-WQI), as the index of choice for assessing the WQ status of Rivers in Malaysia was applied (Zainudin, 2010). The DOE-WQI was developed by aggregation of sub-indices of six selected parameters namely DO, BOD, COD, SS, NH3-N, and pH. The sub-indices of each parameter were calculated by converting their values through the related sub-index rating curve (Kaurish and Younos, 2007; Norhayati et al., 1997). Locally, the calculated sub-indices are combined to calculate the WQI according to the following Equation 3.2 (DOE, 2010; Norhayati et al., 1997).

$$WQI = 0.22 \times SIDO + 0.15 \times SIAN + 0.19 \times SIBOD + 0.16 \times SISS + 0.16 \times SICOD + 0.12 \times SIpH \tag{3.2}$$

where,

SIDO	is the sub-index for DO (% saturation)
SIBOD	is the sub-index for BOD (mg/L)
SICOD	is the sub-index for COD (mg/L)
SIAN	is the sub-index for ammoniacal nitrogen (mg/L)
SISS	is the sub-index for SS (mg/L) and
SIpH	is the sub-index for pH

A series of best-fit equations were formulated from the rating curves for the sub-index calculation shown in Appendix C. The respective class designation for the sub-index and WQI values are also presented in Appendix C. The water quality class and status of the collected water samples were interpreted using the values.

3.3.6 Spatial Mapping of Water Contaminant

Water contaminant maps for Bertam Catchment were prepared to assess the spatial and seasonal heterogeneity. To generate such maps for the study, the base map of Bertam Catchment area was digitized from Survey of Malaysia toposheet (Series DNMM 5101, Sheet 74) using ArcGIS 9.3 software. The exact longitudes and latitudes of sampling points were imported in GIS platform. The sampling stations were geo-coded and the selected water quality data were attributed to specific stations.

Geographical Information System (GIS) using ArcGIS (ver. 9.3.1) was applied to interpolate the water quality parameters and WQI to generate a model for the spatial changes between dry and rainy seasons. The inverse distance weighted (IDW) interpolation technique with the help of spatial analyst modules was used for such spatial modeling. IDW is a process of using sample points with known values to estimate values at other points (Li and Heap, 2008). It is an exact method that enforces the estimated value of a point influenced more by nearby points than by those farther away (Ian, 2010). Thus, the entire area could be covered by developing such a model for the catchment area.

In each interpolated map, the values of parameters and WQI were grouped into uniform class ranges according to DOE-WQI (2010) standard using the natural break method. The gradient color bands were adopted for different values of parameters and WQI maps to clearly visualize the clean to polluted zones. Delineation was made between clean and polluted environment by different shades in dry and rainy seasons. The method has been frequently used for categorizing environmental data and in similar studies (Ai et al., 2015; Aminu et al., 2015; Jha et al., 2015; Pratt and Chang, 2012; Wilbers et al., 2014)

3.4 Landuse Classification

An accurate and up-to-date understanding of landuse activities, changes, and their changing trends are necessary for planning, utilization of regional resources and environment management (Zhao et al., 2013a). Measuring land use types within watersheds/catchments can be a convenient, indirect method of projecting human activities and can allow for cautious generalizations of the relationships between land use and water quality.

As part of the present research, changes in the pattern of land usage were investigated to understand the potential impact of such changes on water quality within the study catchment. Data acquisition, georeferencing, digitization, change detection and slope analysis techniques were applied to analyze the changing status and trends of land usage over time (1984-2010) using Geographical Information System (GIS) approach. Land use mapping was undertaken to utilize the topographical map, different land use maps, vector maps and ground survey. The succeeding flow chart was followed for landuse data processing using Arc GIS 9.3 software is shown in Figure 3.12.

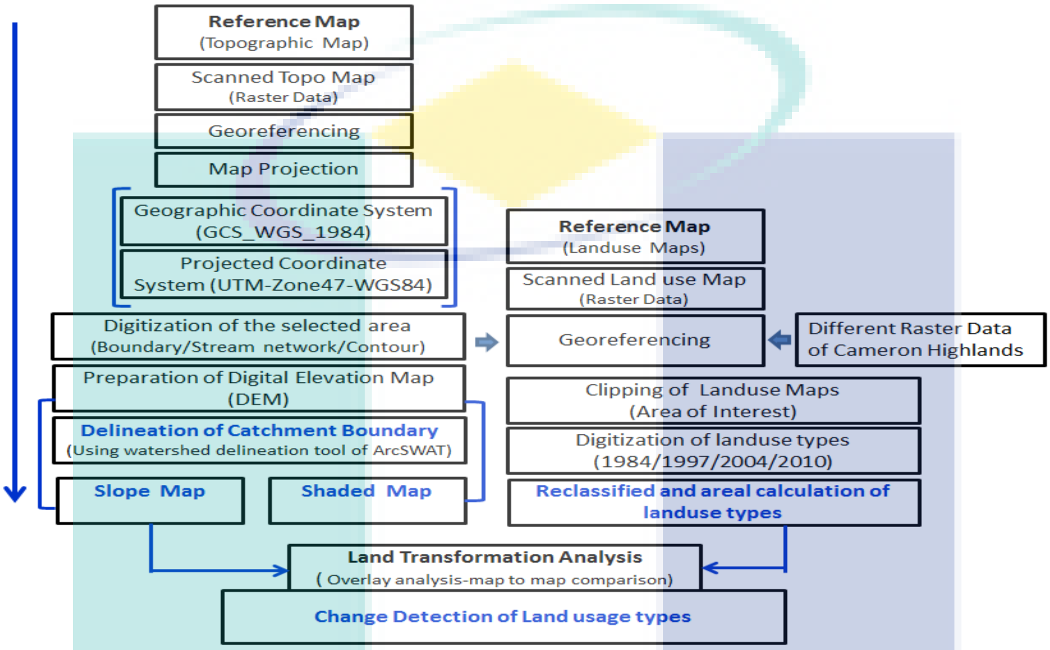

Figure 3.12 Flow chart of landuse data processing using GIS Approach

3.4.1 Data Acquisition and Pre-processing

For landuse evaluation of the study area, topographic map with a scale of 1:50,000 (1995) (series: DNMM, edition: 1-PPNM, sheet no.74 and 75) and four landuse maps for time periods (1984, 1997, 2004 and 2010) were collected from the Department of Survey and Mapping and the Department of Agriculture (DOA), Malaysia, respectively. In addition, different vector data layer (administrative boundary, river network, sub-basin boundary) of Cameron Highlands district were collected from JPS (Jabatan Pengairan Dan Saliran), Cameron Highlands, Malaysia. Data types and their sources are shown in the form of Table 3.6.

Table 3.6 Types of data for landuse evaluation and their sources

Types of data	Source of data
Topographic Map (1995) [1:50,000]	Department of Survey and Mapping, Malaysia.
Landuse Map and Soil Series Map [1987/1997/2004/2010]	Department of Agriculture (DOA), Malaysia.
Additional Raster Data [administrative boundary, river network, sub-basin boundary]	JPS, Cameron Highlands, Malaysia.

All the collected maps were scanned to convert them digital raster images at a resolution of 300 dpi due to import and analyses the maps in ArcGIS v9.3 software. Because of the large size, each map was scanned in different sections and was merged into a single image using Adobe Photoshop CS3 before georeferencing (Glavan et al., 2013). The conversion of digital raster images of the topographic map as well as land use maps of the different time period are shown in Figure 3.13 and Figure 3.14. and Figure 3.14. The digital files of the scanned maps do not contain any information relating the area represented on the map to its location on the ground. Therefore the maps need georeferencing to attach them to a real-world coordinate system.

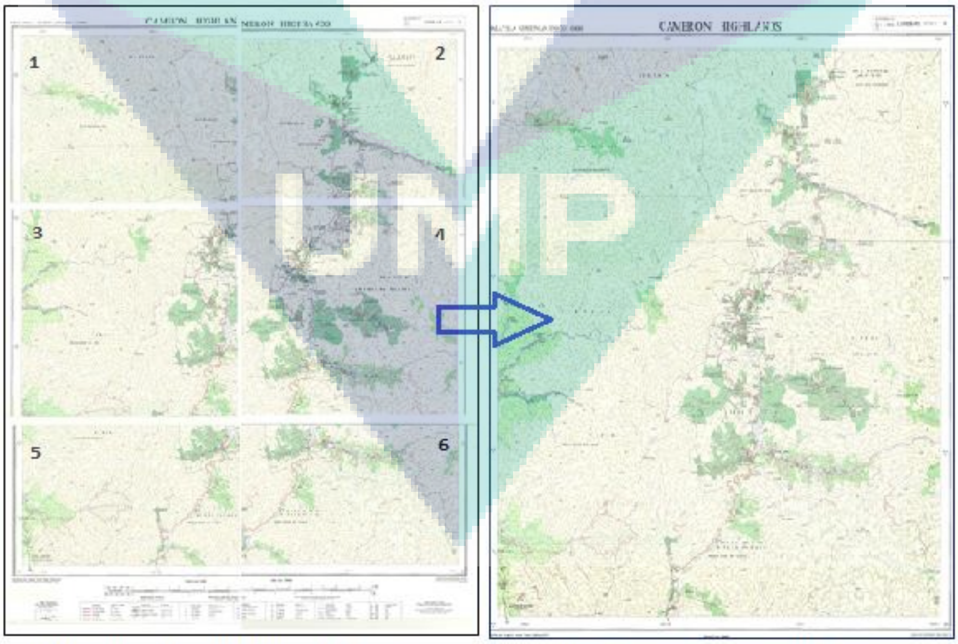

Figure 3.13 Raster conversion of topographic map

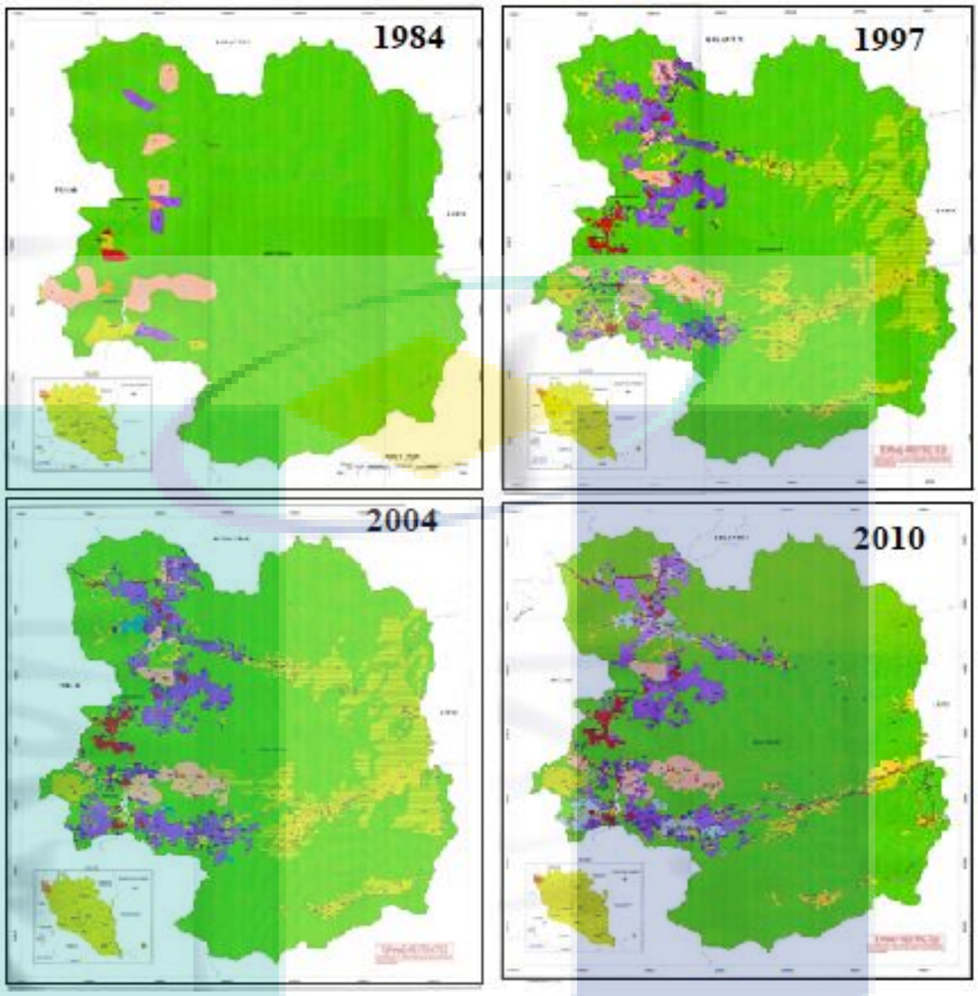

Figure 3.14 Raster conversion of landuse maps for 1984, 1997, 2004 and 2010

3.4.2 Georeferencing

Georeferencing refers to the process of referencing a map image to a geographic location. Georeferencing is the act of assigning locations to unknown points on the map by using locations of known points in terms of map projections or coordinate systems .In this study, each of the scanned topographic maps was first assigned individually to Geographic Coordinate System (GCS-WGS-1984) and then projected to Universal Transverse Mercator (UTM) Zone 47N Coordinate System using the World Geodetic System WGS84 as the study area is located within the zone of the coordinate system. The projected topographic map was then georeferenced by defining grid coordinates at four corners as ground control points. The map was then rectified to projection using with a polynomial warping function of first order (a first-order polynomial transformation with a RMS error less than 0.5 pixels) and nearest neighbor resampling was used. The district boundary of Cameron Highlands was then digitized from the georeferenced topographic map and was used to validate the land use maps of different time periods during the study.

Each of the landuse maps (1984, 1997, 2004 and 2010) were georeferenced individually by matching 40 to 50 control points on the map to the same features within prepared georeferenced topographic map along with different vector data layers of the study area. Georeference rectification was done using a polynomial warping function of first order maintaining the RMSE> 0.5 to stretch the map to the designated geographic area (Figure 3.15). The value of The Root Mean Square error (RMS) indicates the consistency of the transformation between the different control points (links).

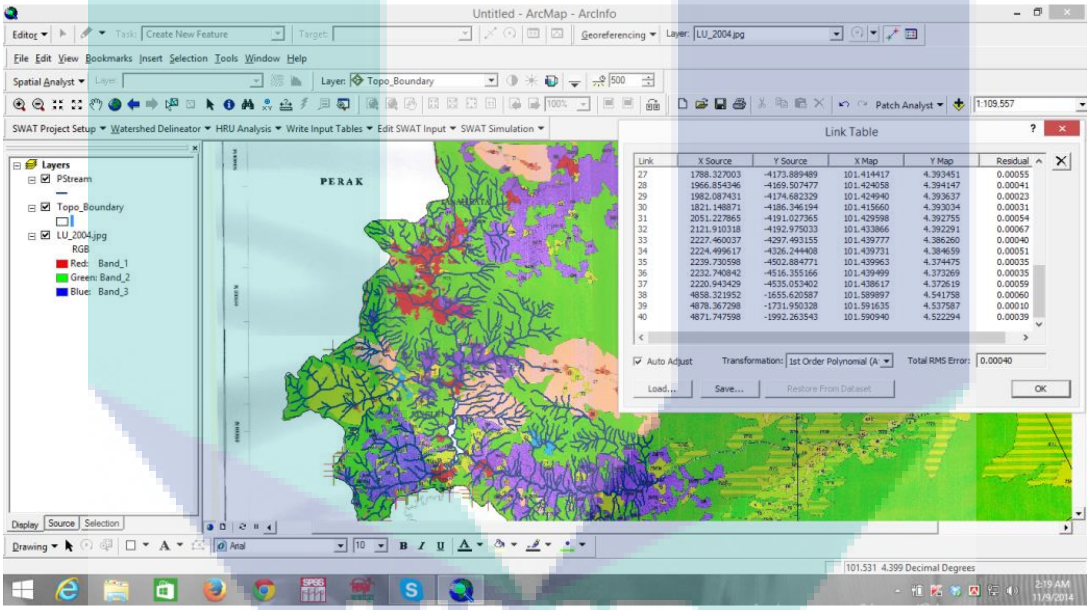

Figure 3.15 Processing of Georeferencing of landuse maps

3.4.3 Digital Elevation Model and Catchment Boundary

The boundary, elevation, contour and river networks of the selected study area were prepared after georeferencing the topographic map using on-screen digitization to generate a Digital Elevation Model (DEM) for the study area (Figure 3.16).

A DEM was generated from the topographic map with 30m interval contour map. The DEM and ancillary drainage system shapefile was then used to delineate and digitize the boundary of study catchment using watershed delineation tool of ArcSWAT (Soil and Water Assessment Tool), an extension software of ArcGIS 9.3 (Ai et al., 2015; Chen and Lu, 2014; Kang et al., 2013). This boundary shapefile of the catchment was being used as reference boundary for all the final map layouts of the landuse as an area of interest (Figure 3.17).

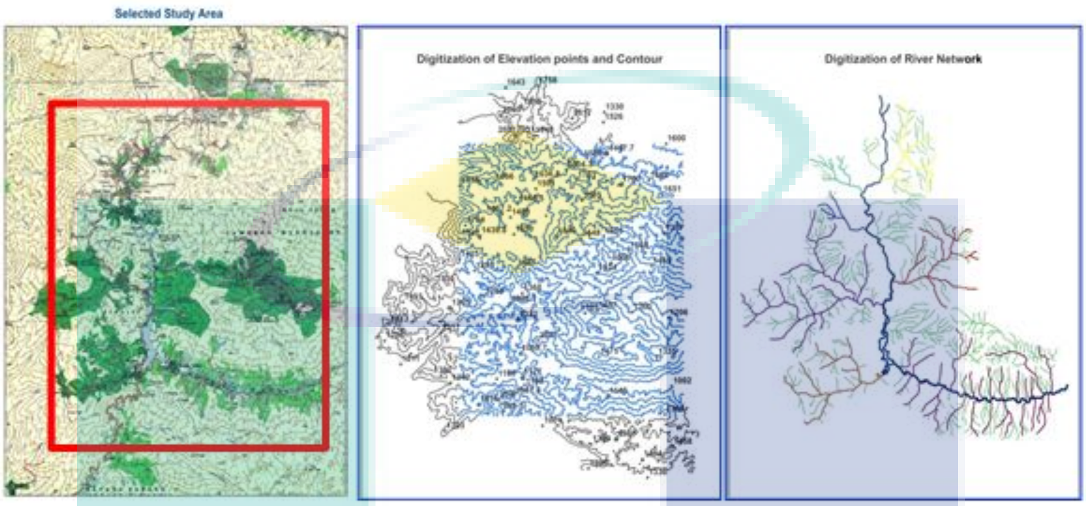

Figure 3.16 Digitization of boundary, elevation points, river network for the generation of DEM

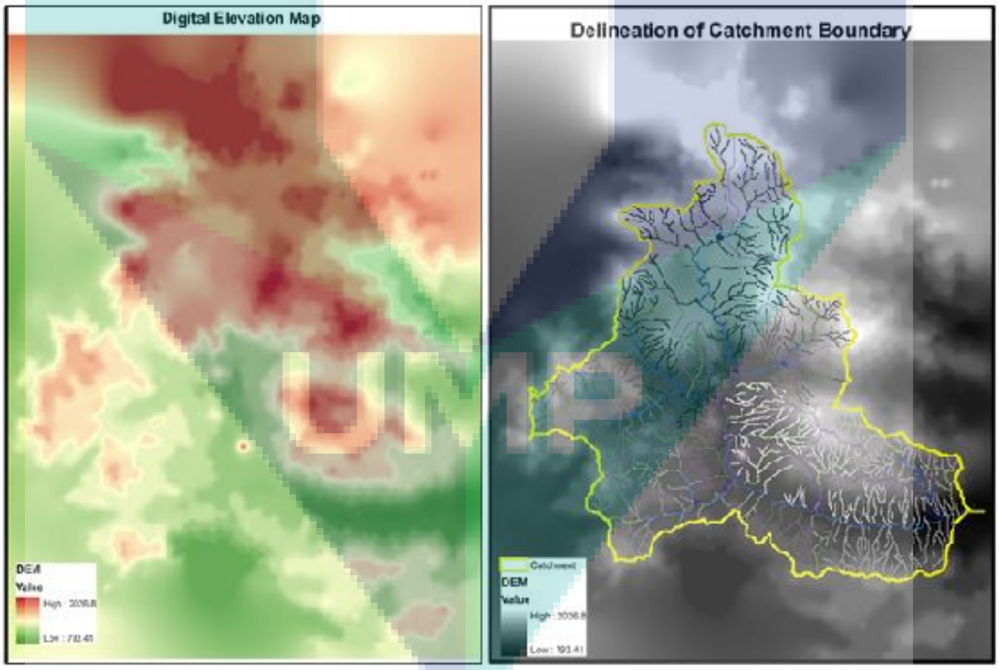

Figure 3.17 Generation of DEM and delineation of catchment boundary

3.4.4 Clipping of Landuse Maps

Landuse portion that intersects the catchment area was clipped for each map to outline the landuse composition of the catchment. The clipping was extracted from each georeferenced landuse map for the year 1984, 1997, 2004 and 2010 using raster processing of data management tool of ArcGIS 9.3 (Yao, 2013) (Figure 3.18).

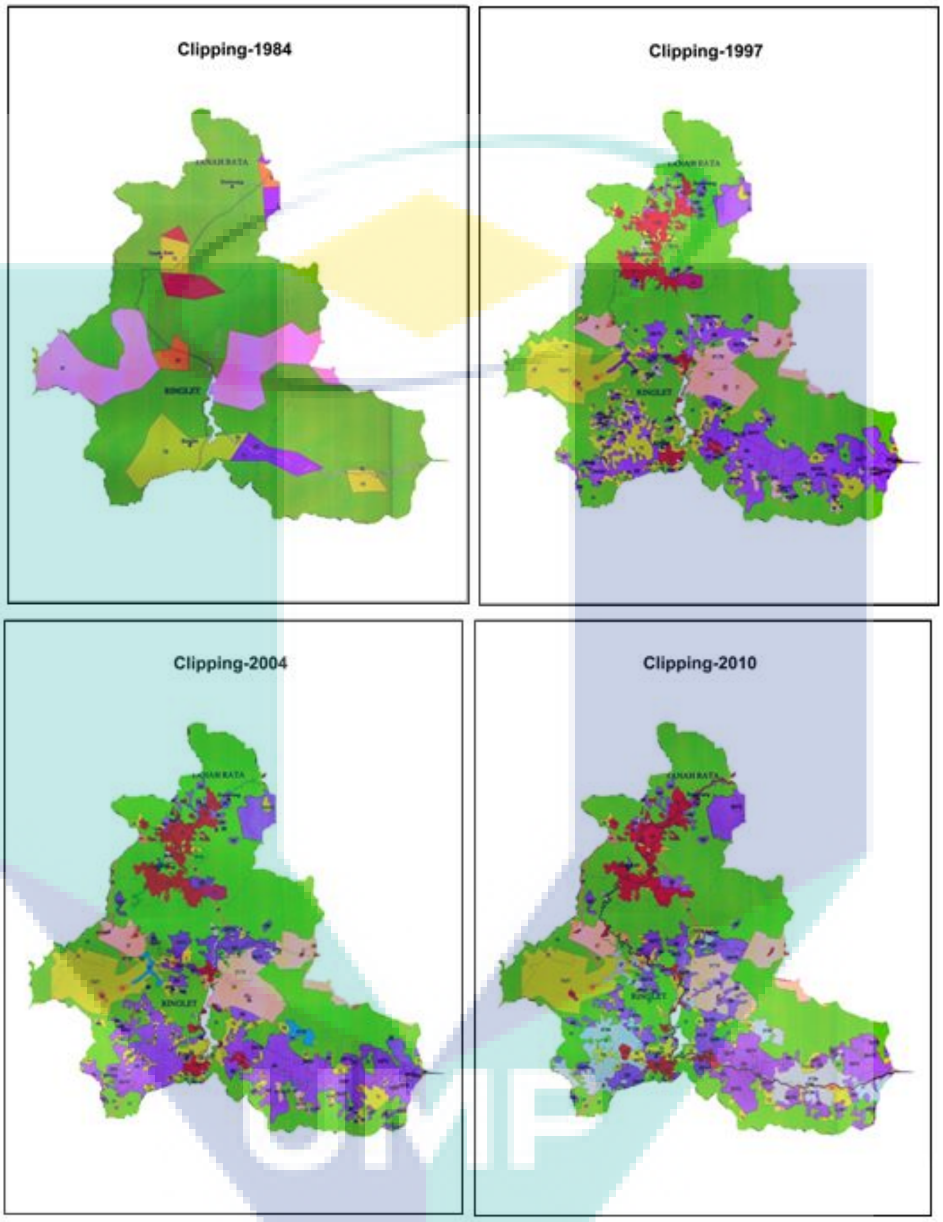

Figure 3.18 Clipping of landuse maps for the year 1984, 1997, 2004, 2010

3.4.5 Digitization of Landuse Maps

The on-screen digitizing technique was applied to extract the different land use types in the form of polygons from each land use map (Figure 3.19). After digitization, the area of each newly made polygon was calculated using the Calculate Areas tool under the Spatial Statistics Tools in ArcToolbox (Tavares et al., 2012).

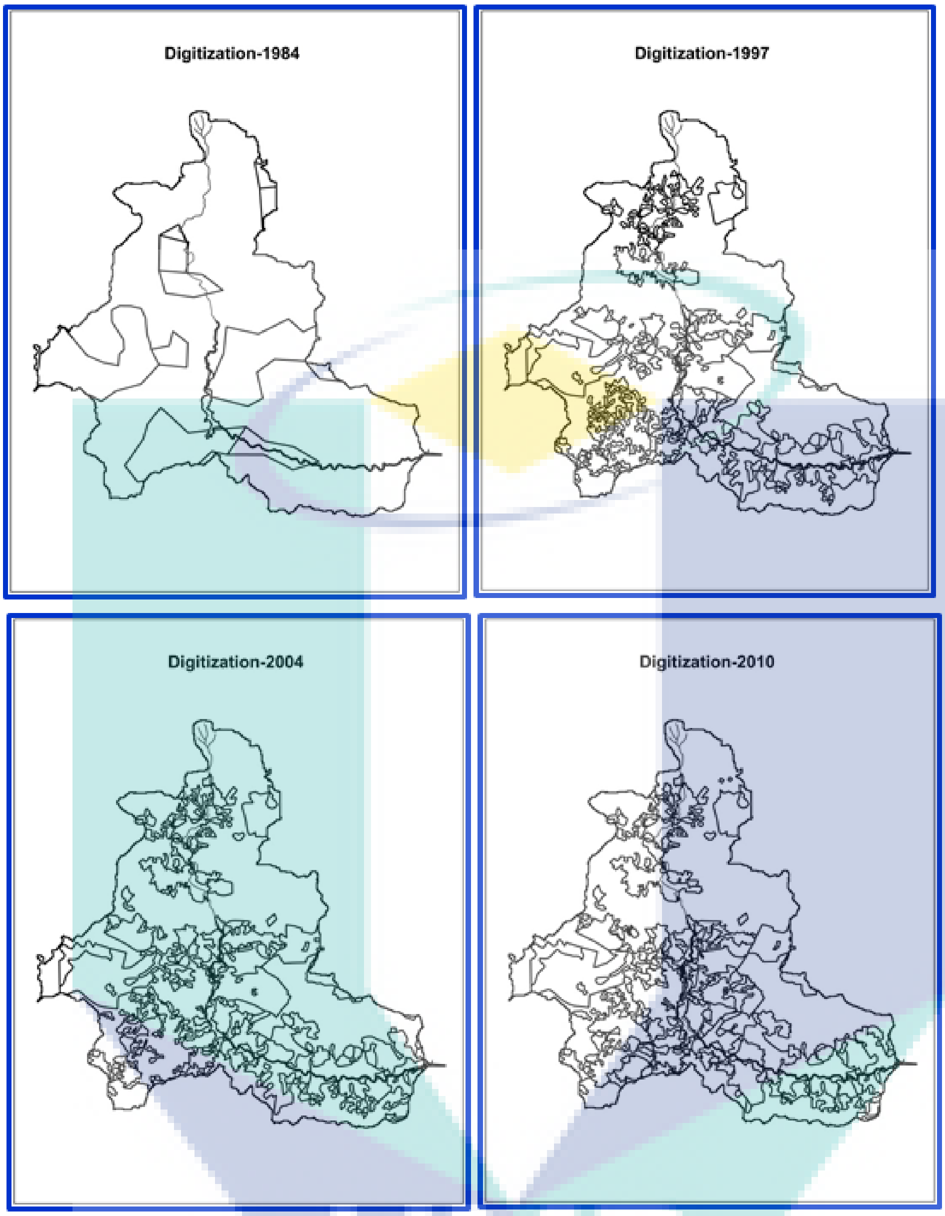

Figure 3.19 Digitization of landuse maps for 1984, 1997, 2004 and 2010

3.4.6 Superimposition of Landuse Maps

An overlay analysis by union method based on the map-to-map comparison technique was applied (Kang et al., 2013; Zhao et al., 2013a). Overlay operations identify the actual location and magnitude of change. It involves subtracting the polygon of one map from another that has taken place over the studied period. All the final layout of overlaying landuse maps for the study were prepared according to the region of interest (Figure 3.20).

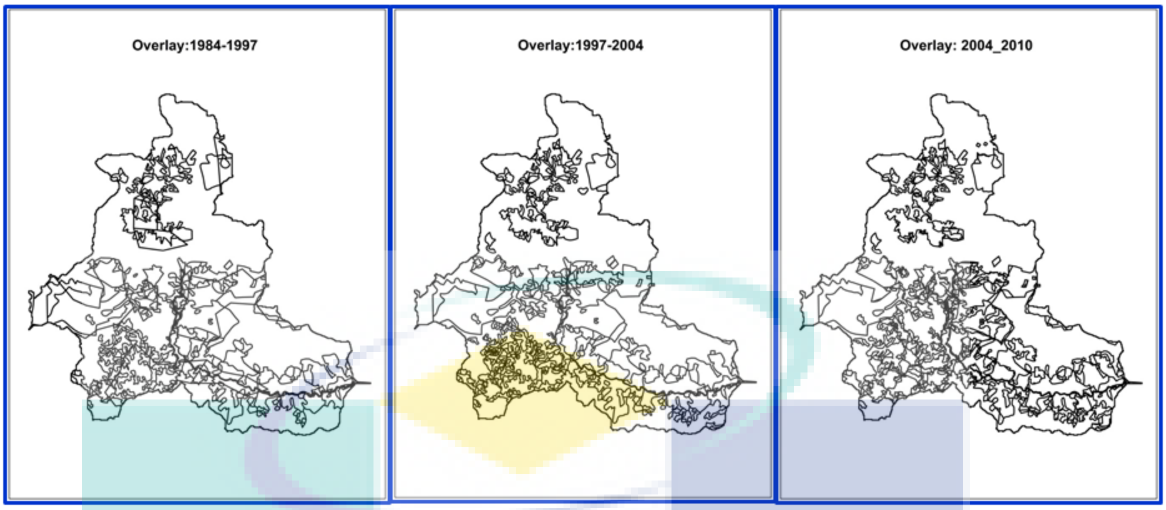

Figure 3.20 Superimposed of landuse maps 1984-1997, 1997-2004, and 2004-2010

3.4.7 Change Detection of Landuse Maps

Land transformation analysis was carried out by change detection technique in GIS approach. It is used to quantify the loss in the area for each land use type, and the type to which it is transferred (Figure 3.21). Before carrying out the change detection, each map was encoded into a number of different land types. The intersect analysis was then used by selecting the attributes as a method of calculating the transfer matrix for each landuse type area for each map (El-Kawy et al., 2011; Kashaigili and Majaliwa, 2010; Kotoky et al., 2012; Shalaby and Tateishi, 2007; Yao, 2013).

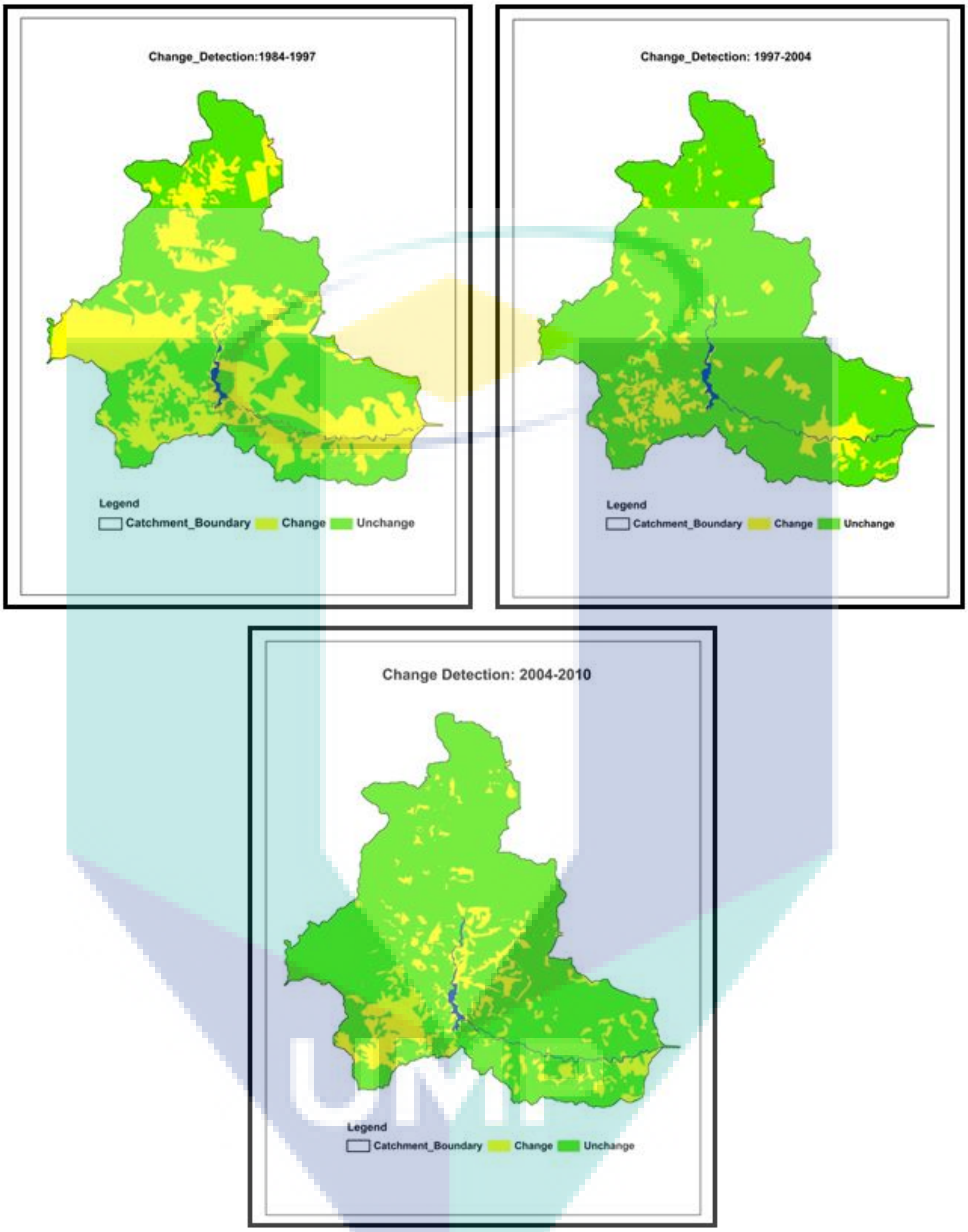

Figure 3.21 Change detection technique for determining the changing trends of land use patterns

3.4.8 Slope Map and Shaded Map

The digital slope map and shaded map were derived from the digital elevation model (DEM) for visual inspection purposes. Slope map showed changes in elevation over distance and identifies the maximum rate of change in value from each cell to its neighbours. The shaded relief image emphasizes on elusive morphological features. These features are important in understanding the topographical background of the study area (Ab d Manap et al., 2010). Slope analysis was performed using the 3D Spatial Analysis tool of GIS software. Slope classes, their areal percentage, and landuse type distribution were calculated. The slope map was re-classified into 5 different classes. Distribution of landuse type areas was then carried out by slope classes using overlay union method in ArcGIS platform Figure 3.22.).

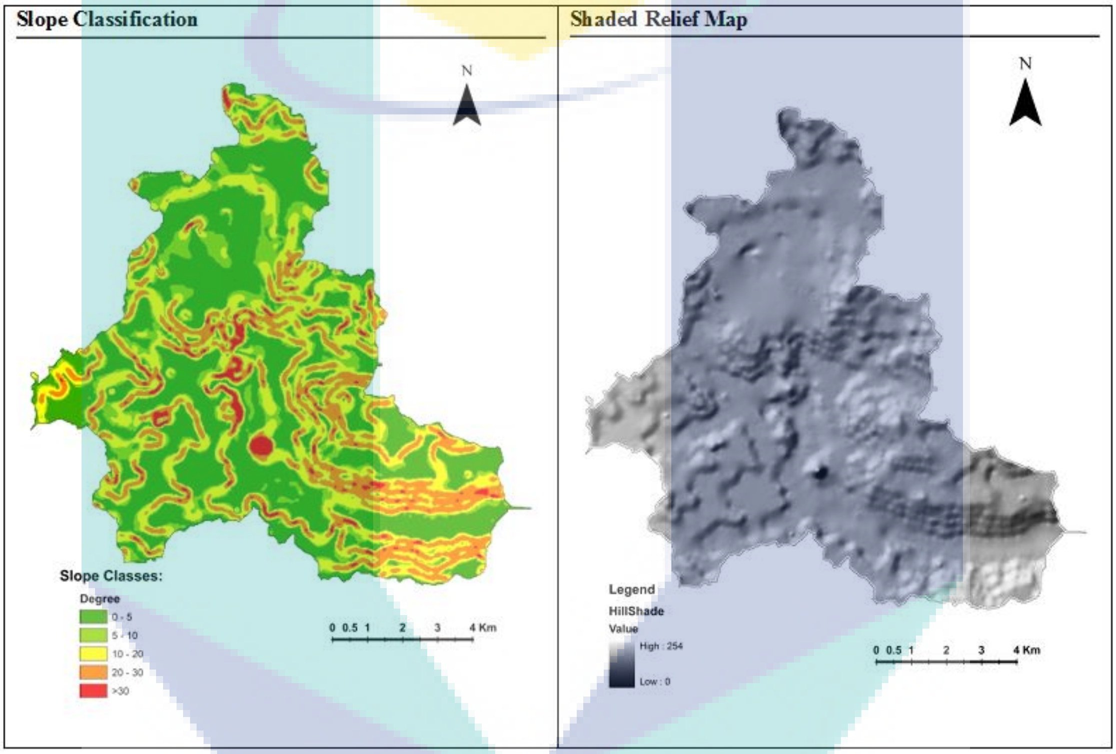

Figure 3.22 Slope classification map of the Bertam Catchment area

3.4.9 The Proportion of Landuse Types

Human activities on land usage could influence on different land types and degree of pollution. Therefore, measuring the proportions of certain land use types in a watershed or catchment would conveniently predict water quality (Bu et al., 2014).

For a clear understanding of the effect of different land types, the catchment was divided into twelve sub-catchments. Sub-catchment boundaries were delineated using the DEM (at 30 m x 30 m resolution), a digital river network and defined sampling locations (Figure 3.23). Each sampling station was specified to be the outlet point of each sub-catchment. The proportions of the different landuse types for each sub-catchment were then computed in percentage using Arc GIS-based overlay technique. The latest landuse map for the year 2010 was applied for landuse proportional analysis.

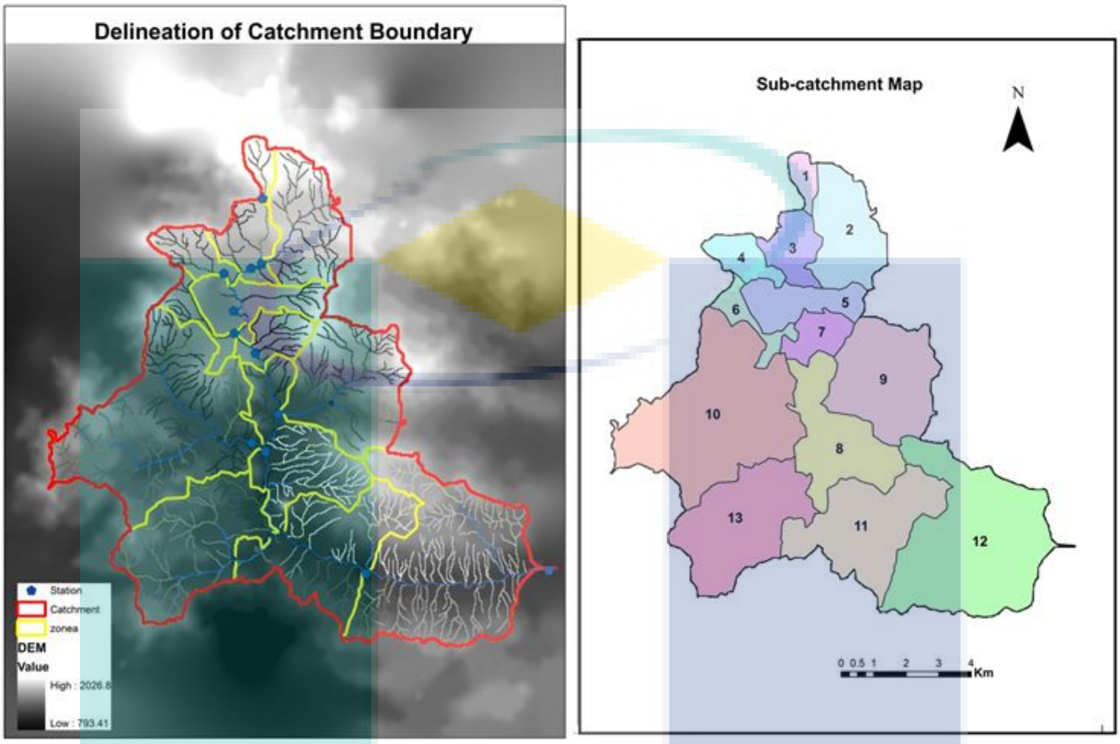

Figure 3.23 Delineation of sub-catchment zones and calculation of land type area

3.5 Soil Erosion Estimation

An assessment of soil loss under landuse conditions is valuable to understand how different landuse patterns can affect soil erosion and to predict the impact of anthropogenic influences.

The revised version of Universal Soil Loss Equation (USLE) (Wischmeier and Smith, 1978) named Revised Universal Soil Loss Equation (RUSLE) (Ranzi et al., 2012; Renard, 1997) was developed to predict the long-term average annual erosion from a designated area over a designated time. In the present research, RUSLE was adopted with GIS framework to assess the soil erosion rates within Bertam River Catchment. Then comparison with different land pattern changes of the catchment was done to assess the influences of land types.

3.5.1 Soil Erosion by RUSLE Model

The RUSLE is an empirical model to assess erosion, caused by rainfall, soil erodibility, topography, landuse and land management (Renard, 1997). The approach is the revised version of the Universal Soil Loss Equation (USLE) developed by Wischmeier and Smith (1978) and can be expressed by following Equation (Eq. 3.3):

$$A = R \cdot K \cdot LS \cdot C \cdot P \qquad 3.3$$

where,

A is the computed annual soil loss per unit area during a unit period of time (t/ha/yr)

R is the rainfall erosivity factor (MJ mm/ha/h/hr)

K is the soil erodibility factor (ton h/ MJ/mm)

LS is the topographic factor (dimensionless)

C is the cover management factor (dimensionless)

P is the support practice factor (dimensionless)

The overall methodology used in the present study is schematically presented in Figure 3.24.

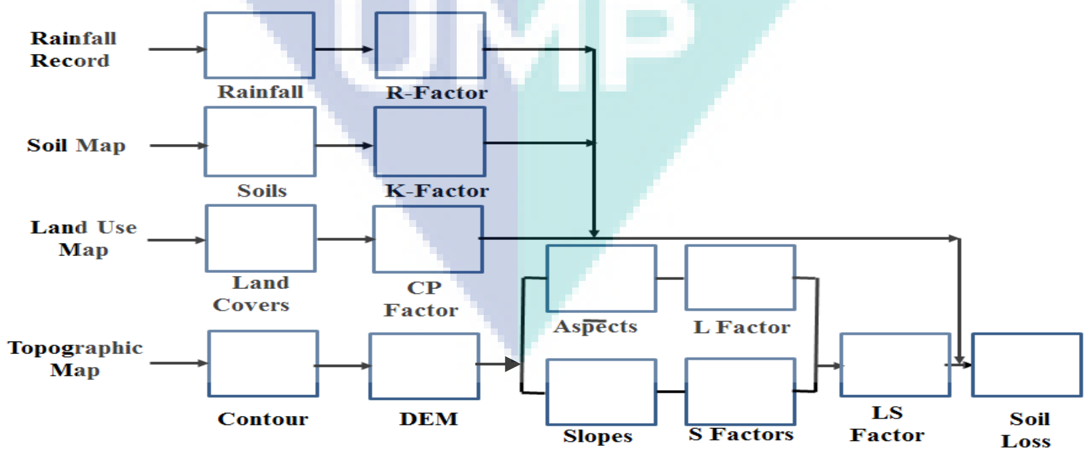

Figure 3.24 Schematic flow chart of the methodology for soil loss estimation.

The factors used in RUSLE, namely, R, K, LS, C, and P, are described below:

3.5.1.1 Rainfall Erosivity Factor (R)

The rainfall R factor is a measure of the erosive force of a specific rainfall. It is determined as a function of the volume, intensity, and duration of rainfall and can be computed from a single storm, or a series of storms to include cumulative erosivity from any time period (Prasannakumar et al., 2012; Renard and Freimund, 1994). In the present study, R factor has been calculated by Morgan (2005)and Roose (1977) methods. Average value of these two calculations was applied for the best estimate of erosivity index (Mir et al., 2015). The value of peak 30 minutes intensity (I_{30}) was set to 75 mm/hr for Morgan equation as recommended for tropical regions (Wischmeier and Smith, 1978).

Monthly rainfall datasets of 31 years (1983 to 2014) for the rain-gauge station in Cameron Highlands were collected from Meteorological Department of Malaysia (Annexure B). The annual rainfall was calculated using monthly rainfall values and was used for R factor calculation. By applying average P and I_{30} values, the best estimate of R-value was calculated. The R factor value calculation in the current study is shown in Table 3.7.

Table 3.7 Rainfall Erosivity (R) Factor Calculation

Method	**Calculation (in metric unit)**	**R-Value (MJ mm/ha/hr/yr)**
Morgan (2005)	$R = \dfrac{(9.28P - 883.8) \times I_{30}}{1000}$	1351.78
Roose (1977)	R = P x 0.5 x 1.73	2503.83
	Best Estimation	1927.80

For the studied catchment, the mean annual rainfall (P) and the erosivity index (R) values were calculated equal to 2894.60 mm and 1927.80 MJ mm/ha/hr/yr, respectively.

For the generation of an R factor map, the R factor value was added to attribute table of Bertam Catchment shapefile. Using ArcGIS, an erosivity index map for R factor was then developed. The produced map is shown in Figure 3.25(A).

3.5.1.2 Soil Erodibility factor (K)

The K-factor is an empirical measure of the intrinsic erodibility of a soil as affected by its properties such as grain size, drainage potential, structural integrity, organic content and cohesiveness (Aiello et al., 2015; DID, 2010; Xu, 2013).

In the present study, the K factor value was used to 0.066 applied by Teh (2011) according to soil series of Malaysia adapted by the Department of Agriculture (DOA. 2007). For calculation K factor map, a soil map shapefile was generated from soil series map of Cameron Highlands collected from Department of Agriculture (DOA). The K factor value was added to attribute table of the shapefile. Using ArcGIS an erodibility map for K factor was developed. The produced map is shown in Figure 3.25 (B).

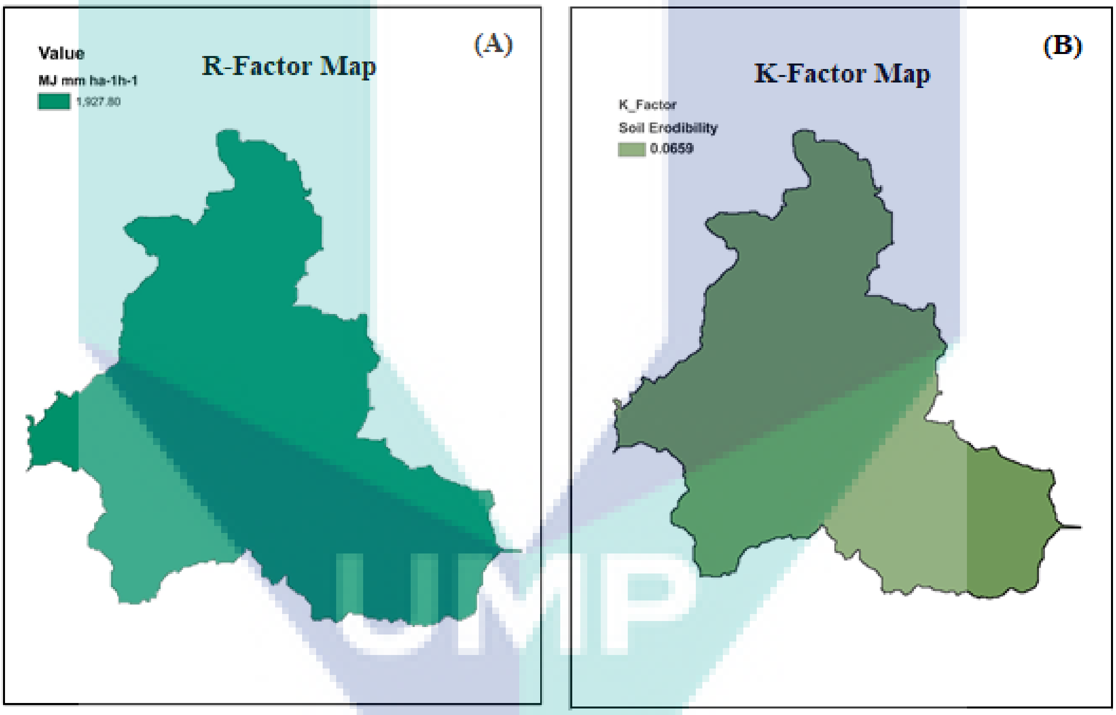

Figure 3.25 R factor and K factor maps using the values in ArcGIS

3.5.1.3 Topographic factor (LS)

Topographic factor represents the slope length (L) and slope steepness (S). It is the ratio of soil loss from a specific site to that from a unit site having the same soil and slope but with a length of 22.1m. This factor is considered to be a crucial factor for the quantification of erosion as it dominates surface run-off rate (Alexakis et al., 2013). Slope length (L) is the effect of slope length on the rate of soil erosion. As slope length increases, the overland flow and flow velocity steadily increase, leading to greater erosion forces applied to the soil surface (Ranzi et al., 2012). On the other hand, slope steepness (S) represents the effect of slope gradient on erosion. The effects of slope steepness have a greater impact on soil loss than slope length. Steeper the slope, the greater is the erosion. The worst erosion occurs between 10 and 25% slope (Ganasri and Ramesh, 2016).

For ArcGIS application, the slope length and slope steepness were considered as a single index of a topographic factor, LS (Aiello et al., 2015). In the present study, the LS factor was calculated using the equation (Eq. 3.4) defined by Wischmeier and Smith (1978) for ArcGIS purpose is shown next page:

$$LS = (X/22.13)^{0.5} * (0.065 + 0.045\ S + 0.0065\ S^2) \qquad 3.4$$

where, X is slope length (m) and

S is slope gradient (%)

The values of slope length (X) and slope gradient (S) were derived from Digital Elevation Model (DEM) for LS calculation. In ArcGIS 9.3, the X value was assessed from flow accumulation map that was derived from the DEM after conducting Fill and Flow Direction processes. By substituting X value, LS value was then calculated using the following equation 3.5:

$$LS = (\text{Flow Accumulation} \times \text{Cell value})/22.13)^{0.5} * (0.065 + 0.045\ S + 0.0065\ S^2) \qquad 3.5$$

Slope (%) is also derived from the DEM using the ArcGIS 9.3 software. The value of *m* varies from 0.2-0.5 depending on the slope as shown in Table 3.8. The value 0.5 is applied for *m* for the calculation of LS value in Bertam Catchment.

Table 3.8 m value for LS factor

***m* value**	**Slope (%)**
0.5	>5
0.4	3-5
0.3	1-3
0.2	<1

Source: Department of Irrigation and Drainage, Malaysia, 2010

LS factor methodology using ArcGIS

The DEM and slope map for Bertam Catchment generated during landuse map preparation (sub-section 3.4.2 and sub-section 3.4.3) were used for LS factor map generation in the ArcGIS9.3 framework in this study.

The DEM was first modified by filling the sink to avoid the problem of discontinuous flow when water is trapped in a cell, which is surrounded by cells with higher elevation. This was done by using the Fill tool under Hydrology section of Spatial Analyst Tools in ArcGIS. Flow direction was then generated from the fill raster map. This was also done by using the Flow Direction tool under Hydrology section of Spatial Analyst Tools in ArcGIS. The Flow direction tool identifies the down-slope direction for each cell taking consideration of the terrain surface.

Flow accumulation was calculated based on the flow direction. Flow accumulation denotes how much surface flow accumulates in each unit. Moreover, the output of flow accumulation represents the amount of rain that would flow through each cell, assuming that all rain became runoff and there was no interception, evapotranspiration, or loss to groundwater (Alexakis et al., 2013). This was done similarly by using the Flow Accumulation tool under Hydrology section of Spatial Analyst Tools in ArcGIS.

Finally, Raster calculator function under Spatial Analyst Tools was used to input the modified equation 3.5 to calculate LS factor. The flow accumulation raster and slope of DEM in percentage were selected to run the process. Cell value of 30 m was applied according to the cell value of DEM. The *m* value of 0.5 from Table 3.8 was selected for the equation as 59 % of the terrain of Bertam Catchment was steeper than 5º (Rasul, 2016).

The summary of the methodology along with the GIS maps created at each step to calculate the LS factor is shown in Figure 3.26. Slope length and steepness for LS factor was developed using the method described above. The theme produced is shown in Figure 3.22..

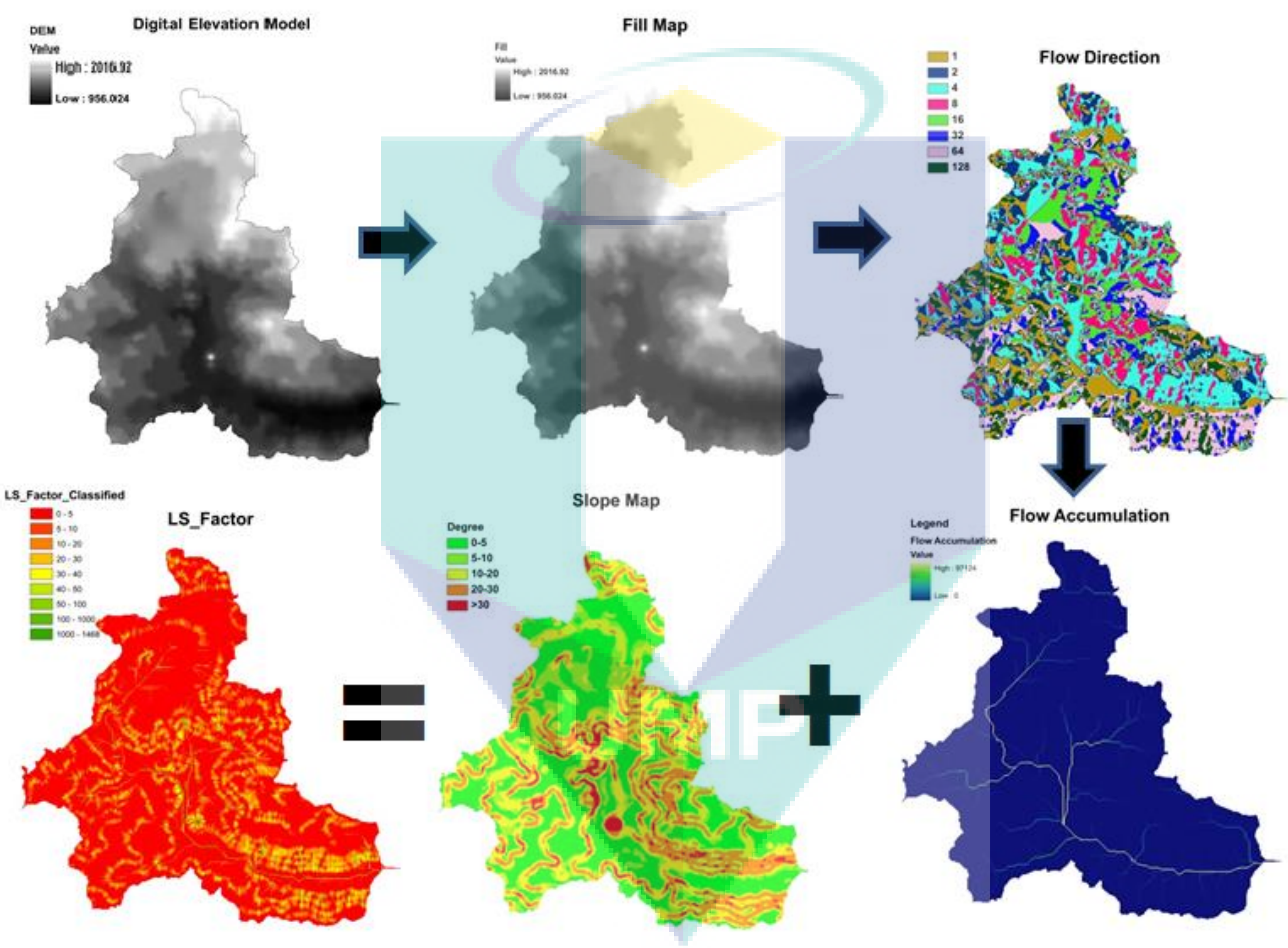

Figure 3.26 LS map generation for Bertam Catchment using RUSLE equation adapted in ArcGIS

3.5.2 Cover Management and Conservation Factor (CP)

The C and P factors are two management factors those play a critical role in determining the rate of erosion. CP factors mainly used to control soil loss at a specific site (DID, 2010) In this study, the C and P factor values for individual farming systems and landuse types within Bertam Catchment were selected from the list assigned by the Department of Irrigation and Drainage (DID, 2010) and are shown in Table 3.9.

Table 3.9 Land use in the Bertam Catchment with C and P-factor values

Land Use	C Factor	P Factor
Open land	1.00	0.70
Urban	0.25	1.00
Forest	0.03	0.10
Market gardening	0.38	0.40
Scrub forest	0.03	0.20
Orchard	0.35	0.40
Mixed agriculture	0.45	0.45
Tea	0.10	0.10
Water body	0.01	0.50
Agriculture experimental station	0.50	0.40

Source: DID (2010); Teh (2011)

To generate C and P factor maps, the values of C and P were added to the land use attribute table of Bertam Catchment. Adding new fields for C and P values were done under the Edit menu at attribute view. The theme was converted from vector to raster form with the cell size of 30m. The prepared C and P factor maps were developed for 2010 and are shown in Figure 3.27.

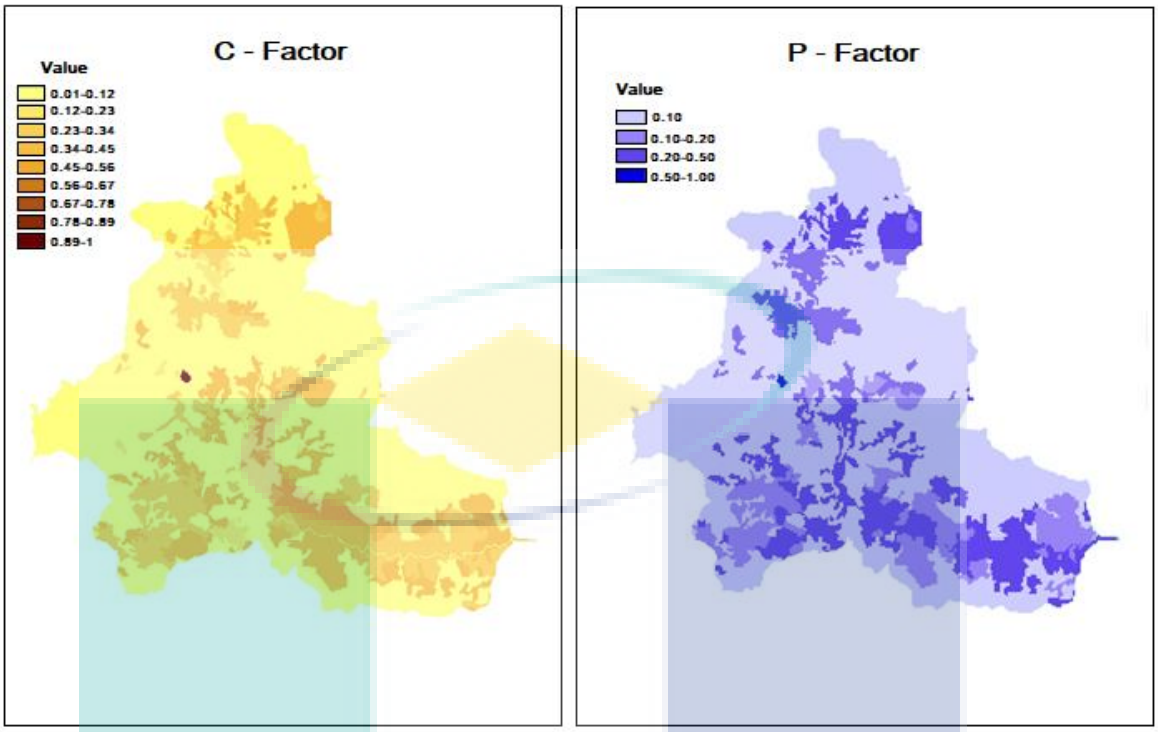

Figure 3.27 Spatial distribution of cover management factor (C) and conservation factor (P) over the Bertam Catchment area

3.5.2.1 Generation of Average Annual Soil Erosion Map using RUSLE

The RUSLE equation was used to calculate the annual average soil loss rate (A) in ton/ha/year. In order to predict the annual average soil loss rate in the Bertam Catchment of Cameron Highlands, the R, K, LS, C and P factors were multiplied using the raster calculator tool of ArcGIS as shown in Figure 3.28. The annual soil erosion rate (in t/ha/y) for the studied catchment was then calculated using Spatial Analyst Tools and raster calculator in ArcGIS.

The annual soil erosion rate (in t/ha/y) for the studied catchment was then calculated using Spatial Analyst Tools and raster calculator in ArcGIS.

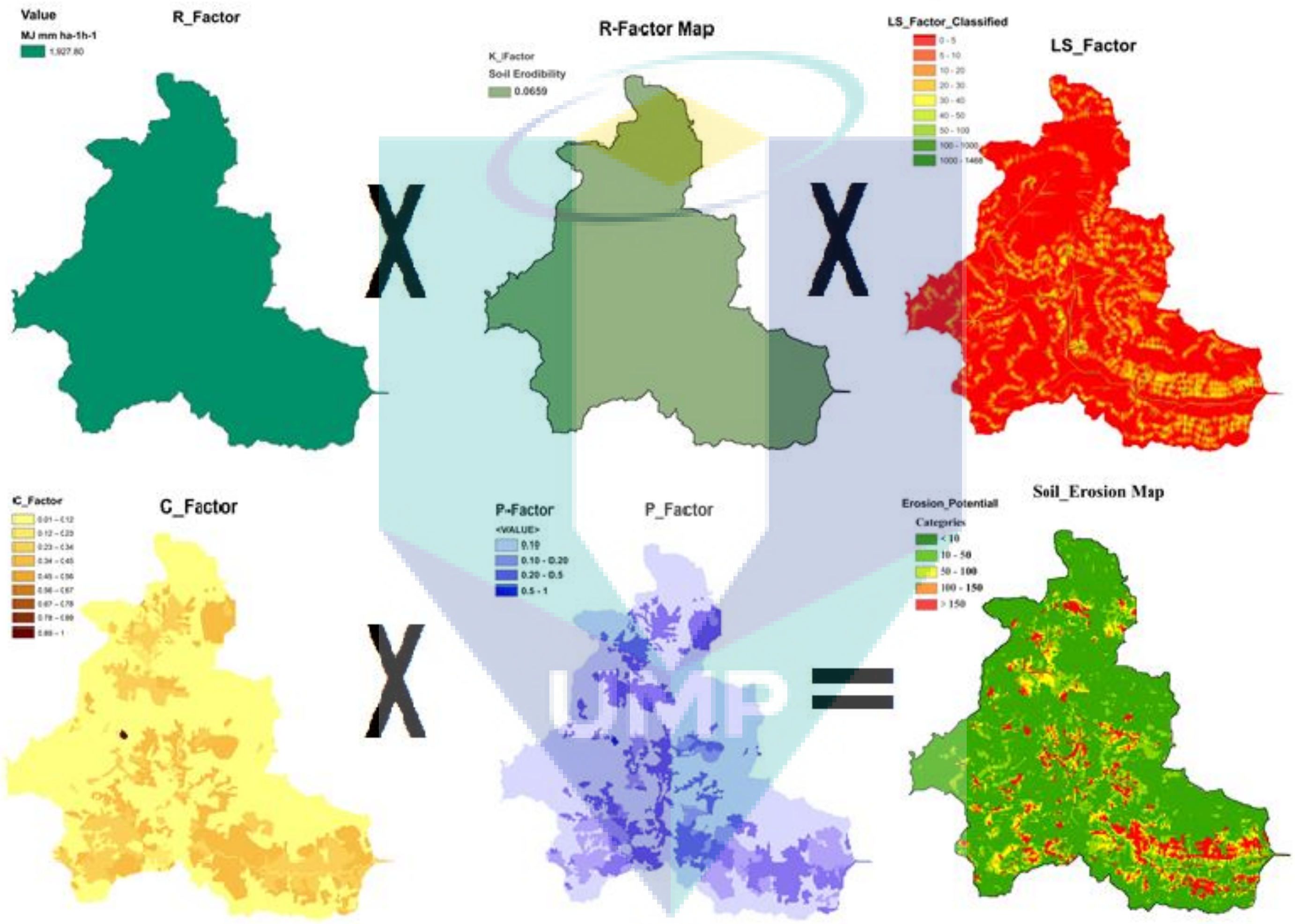

Figure 3.28 Generation of soil erosion map using RUSLE equation

Annual Soil Erosion Map for Sub-Catchment

To differentiate the soil erosion risk zones within the present study area, the catchment was classified into three sub-catchments, namely Upper, Middle and Lower sub-catchment. Accordingly, the annual soil loss map for each sub-catchment was produced by clipping each R, K, LS, C and P values of the selected sub-catchment area from the original factors. The raster calculator was used to overlay the clipped factors to produce the annual soil loss map for each sub-catchment. Using RUSLE equation, the annual mean soil erosion rate was calculated by cell by cell analysis. The result would estimate soil erosion ranges from minimum to maximum cell value with a mean value of soil erosion. The mean value can be considered as the representative of the current soil loss rate of the area.

Estimation of Soil Erosion Risk Map

For visual interpretation, the soil erosion maps of Bertam Catchment, as well as its three sub-catchments, were classified into five classes according to erosion potential categories as shown in Table 3.10. The areal percentages of each erosion category were calculated using the Calculate Areas Tool under the Spatial Statistics Tools in ArcGIS.

Table 3.10 Soil Loss Tolerance rates from erosion risk map of Malaysia

Soil Erosion Class	**Numeric Range (ton/ha/year)**	**Erosion Potential**
1	<10	Low
2	10-50	Moderate
3	50-100	Moderate-High
4	100-150	High
5	> 150	Very High

Source: Mir et al., 2015

3.6 Community-based Social Survey

A community-based survey was conducted using a well-structured questionnaire. The survey was carried out to better understand the community knowledge, perceptions, and awareness of environmental issues (water quality, landuse change, and soil erosion) within the studied area. The questionnaire was also designed to identify the socioeconomic characteristics of the respondent. Their engagement (willingness to participate) in the catchment management program were further elicited.

3.6.1 Questionnaire Preparation

A well-structured questionnaire was utilized to collect the data during the survey program. To make the survey easier for respondents, the questionnaire consisted of 36 closed-ended questions was designed with four categories covering respondents' demographic information, knowledge and perception on water quality, landuse change and soil erosion (environmental changes); source of information as well as awareness and willingness to participate as volunteer in catchment management program (Table 3.11).

Table 3.11 Structure of Questionnaire

Survey items	Number of questions	Main contents
Demographic information	7	Age, gender, race, occupation, educational level, living place, no. of family members and tears of living
Knowledge and perception	13	**Water quality (5):** water quality grade, changing trend; causes of pollution, limitations to protect pollution, importance to protect river environment. **Landuse change (4):** change observation, changing trend, causes and consequences **Soil erosion (4):** change observation, changing trend, causes, and consequences
Awareness and willing to participate	10	Responsibility, pollution effect, pollution protection, willing to contribute, protection impact, ecosystem impact, water pollution factor, the cooperation of authority, willing to participate in water environment protection/management program
Source of Information and opinion	6	Awareness program and discussion, source of information, program organized by public authorities and opinion.

To ensure the questions understandable to respondents, the questionnaire was used in three different versions, namely English, Malay and Chinese. The three versions were attached to Appendix E.

3.6.2 Data Collection

A questionnaire survey was conducted by using random sampling among the residents in Brinchang, Taman Sedia, Tanah Rata, Habu, Ringlet and Lower Bertam region covering the entire Bertam Catchment communities during the survey program in April 2016. A total number of 300 respondents participated in the questionnaire survey. For better understanding, the relationship between communities' knowledge and perceptions with scientific findings, the respondents were grouped into three main zones, as Brinchang, Tanah Rata, and Ringlet. Due to the proximity of locations, Taman Sedia was included with Brinchang while Habu and Bertam Valley were added with Ringlet. As shown by the spatial distribution in Table 3.12, the questionnaire number in Upper Bertam was 225 and in Lower Bertam was 75 within the catchment.

Table 3.12 Spatial distribution of the questionnaire

Catchment Area	**Number of respondents**	**Survey Area**	
		Town/village	Zones
Upper Bertam	107	Brinchang	Brinchang
	18	Taman Sedia	
	105	Tanah Rata	Tanah Rata
Lower Bertam	10	Habu	Ringlet
	40	Ringlet	
	20	Bertam Valley	
Total	300	Bertam River Catchment	

3.7 Statistical Analysis

A number of statistical analyses were carried out to find out the descriptive summary, correlation matrix and regression analysis for the identification of relations among variables. Multivariate statistical analysis such as Cluster Analysis (CA) and Principal Component Analysis (PCA) was also done. All the statistical analyses were performed using Statistical Package for Social Sciences (SPSS Version 21, SPSS Inc. 1995).

Significance levels used for the statistical correlation coefficients and associations were 5% and 1% level of significance. The significance level was interpreted as:

i. $p > 0.05$, insignificant

ii. $p < 0.05$, significant at the 5% level of significance (*)

iii. $p < 0.01$, significant at the 1% level of significance (**)

The different statistical analyses used in the present research for different assessment are described below.

3.7.1 Descriptive Analysis

Descriptive statistic provides the summaries of the samples and the measures (Helsel and Hirsch, 2002). A descriptive statistical analysis was performed to show the range (minimum-maximum), mean value and standard deviation of each water quality parameters. For social survey data, a descriptive analysis of respondents' demographic characteristics was conducted. The frequencies procedure was applied to summarize the measures of demographic information and presented in the form of bar diagrams. The analysis was also performed for communities' knowledge and perceptions on water quality, landuse change and soil erosion regarding the causes and consequences. Knowledge and perception measures were presented in the form of graphical bar diagrams.

3.7.2 Non-parametric Test

Prior to statistical analysis, water quality parameters were examined for normality of distribution using the Shapiro-Wilk's test ($p > 0.05$) (Razali and Wah, 2010; Shapiro and Wilk, 1965) visual inspection of their histogram, normal Q-Q plots, and box-plots. All the parameters showed a violation of the normal distribution and equal variance assumptions of the parametric tests. Hence, a nonparametric test was performed to compare significance differences.

Non-parametric tests were carried out in the statistical analyses due to non-normal distributions of the parameters. A non-parametric Lavene's test was used to verify the equality of variances ($p > 0.05$) (Martin and Bridgmon, 2012; Nordstokke et al., 2011). The nonparametric Kruskal-Wallis (Kruskal and Wallis, 1952) test was performed to estimate and the significance differences in water quality parameters under different sampling stations and seasons (p-value < 0.05) (Ai et al., 2015; Ling et al., 2017; Mei et al., 2014; Zhao et al., 2011).

3.7.3 Correlation Coefficient

To investigate the relationships among water quality parameters, correlation analysis was applied Due to the non-normal distribution of parameters, correlations among the parameters were tested using Spearman's correlation coefficients (r) with statistical significances at $p< 0.01$ and $p< 0.05$ levels (2-tailed), respectively (Li et al., 2014).

The statistical correlation is widely used as a measure of the degree of linear dependence between two variables and specifically for water quality analysis (Barakat et al., 2016; Mustapha et al., 2012). In this analysis, all water quality parameters were tested one by one. The correlation coefficient ranges from -1 to1 automatically calculated through "analyze-correlate-bivariate correlations" analyses in SPSS software, with both p-values at 0.01 and 0.05 levels for the permutation test. The closely correlated parameters were then calculated. A value of the correlation coefficient near ± 1 indicates that the two variables are highly correlated (Li et al., 2015; Vieira et al., 2012).

3.7.4 Association and Correlation Coefficient

Test of association and correlation (Liebetrau, 1983) were applied to observe the impacts of the demographic characteristic of respondents' knowledge and awareness. Association between the scientific findings and communities' perceptions of different environmental changes were also observed through the test of association and agreement test. The Chi-square test of association was utilized to determine significant attitude differences or association with other factors. The Chi-square with a p-value ($p<0.05$) was used as the strength of association among the variables (Gonzalez-Chica et al., 2015). The kappa value was also applied to understand the level of agreement between variables. Pearson's correlation coefficient measures the strength of linear relationship between two variables.

3.7.5 Multivariate Statistical Analysis

Multivariate statistical techniques, such as cluster analysis (CA) and principal component analysis (PCA) were used to interpret large datasets, to evaluate temporal-spatial variations, and to identify possible impact factors in water quality (Al-Mutairi et al., 2014; Wang et al., 2013).

3.7.5.1 Hierarchical Cluster Analysis (HCA)

Hierarchical cluster analysis (HCA) was applied to investigate the grouping of the sampling stations using the water quality parameters collected in the study area. Z-score standardization of the variables and Ward's method using Euclidean distances as a measure of similarity was used. HCA was done for the evaluation of spatial and temporal similarities between parameters for different sampling stations and sampling periods. The results obtained from HCA were represented in the form of Dendrograms (Abdullah et al., 2015; Gazzaz et al., 2012c; Wang et al., 2013).

3.7.5.2 Principal Component Analysis (PCA)

PCA was used as an extraction method and varimax with Kaiser normalization as a rotation method in FA (Soo et al., 2017). PCA was used to identify pollution factors that affected water quality among 12 stations during dry and rainy seasons. Before PCA was performed, the water quality data were initially standardized by z-scale transformation to eliminate the effects of different measurement scales among individual variables and rendered the data dimensionless (Hua et al., 2016b; Ogwueleka, 2015). Kaiser–Meyer–Olkin (KMO) and Bartlett's sphericity tests were conducted on the parameter correlation matrix to measure the suitability of the sampling data for PCA. KMO is a measure of sampling adequacy that indicates the proportion of common variance that might be caused by underlying factors. A high value close to 1 generally indicates that the data is useful for PCA test. In the present study, the KMO value was interpreted according to the guideline of Kaiser (1974) (Table 3.13). For factor loadings interpretation, the terms 'strong', 'moderate' and 'weak' corresponding to absolute loading values of >0.75, 0.75-0.50, and 0.50- 0.30, respectively were applied (Barakat et al., 2016; Liu et al., 2003).

Table 3.13 Guiding rules for interpretation if the KMO test results

KMO value	Interpretation
0.90–1.00	Marvelous
0.80–0.89	Meritorious
0.70–0.79	Middling
0.60–0.69	Mediocre
0.50–0.59	Miserable
0.00–0.49	Unacceptable

Source: Kaiser (1974); [a] The degree of fit of the data to factor analysis.

3.7.6 Logistic Regression Model

Logistic regression is a type of probability models which usually used in the predictive analysis when the dependent variable is categorical in nature (binary and multinomial). The regression is used to describe data and to explain the relationship between one dependent binary variable and one or more nominal, ordinal, interval or ratio-level independent variables. At the center of the logistic regression analysis, the main task is estimating the log odds of an event. This regression assumes linearity of independent variables and logs odds. The logistic model describes that the log of the odds ratio is a linear function of exploratory variable and the slope coefficient gives the change in the log of the odds ratio per unit change in the independent or exploratory variables. Mathematically, logistic regression estimates multiple linear regression functions defined as following Equation (Eq. 3.6):

$$log \frac{p(x)}{1-p(x)} = \beta_0 + \beta_i X_i \quad 3.6$$

where,

$p(x)$ =1 if respondents awareness regarding willingness to participate in environmental management program is adequate aware

$p(x)$ = 0 for otherwise

X_i = Independent variables

β_0 = Constant term

β_i = Coefficient of independent variables

i = 1, 2, 3 --------- n

In the Equation 3.7 , $\beta_i X_i$ can be expressed as follows,

$$\beta_i X_i = \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \text{------------------} + \beta_n X_n \qquad 3.7$$

X_1 to X_n are independent variables for the model.

Numerous pseudo-R^2 values such as Cox and Snell R-square and Nagelkerke R-square have been developed for binary logistic regression (Chicas et al., 2016). These two R^2 have been interpreted with extreme caution as they have many computational issues which cause them to be artificially high or low. Hosmer-Lemeshow is a commonly used measure of goodness of fit based on the Chi-square test was applied as a better approach for the goodness of fit test. Moreover, classification table test was used to measure the ability of prediction rather than using pseudo- R^2.

In the present research, logistic regression analysis was applied to determine the factors influencing the communities' willingness to participate in local water environment management program as volunteer service.

CHAPTER 4

WATER QUALITY ASSESSMENT

4.1 Introduction

Surface water quality is very important and a sensitive issue as it plays a vital role in aquatic ecosystems and human health. Assessment of surface water quality and its pollution sources provide significant information for ecosystem sustainability and water resources management. Therefore, spatial and temporal variability study in water quality parameters along with its pollution sources has become an essential aspect due to the seasonal and regional characteristics of river water quality (Bu et al., 2010; Qadir et al., 2013; Wilbers et al., 2014).

Water quality is determined by comparing its physical, chemical and biological characteristics with water quality guidelines or standards. Any changes in its quality are the ultimate result of anthropogenic and natural inputs of point and non-point sources of pollutants. Anthropogenic changes like intensive agricultural development, lands clearing for agriculture, and excessive utilization of commercial inorganic fertilizers have become major nonpoint source issues that lead to increased erosion and nutrient additions (Bu et al., 2014; Carpenter et al., 1998; Glavan et al., 2013; Wu and Chen, 2013). Furthermore, urban and industrial developments with increased population and untreated domestic, municipal, and industrial waste discharge, as well as land development for infrastructure, are the major point sources of anthropogenic changes (Hu and Cheng, 2013; Xue et al., 2015) In addition to human activities, landscape characteristics and natural inputs, including hydrological variables, climatic variables, erosion, weathering and dissolution of geological crustal materials, play an important role in spatial and temporal variation of water quality (Ai et al., 2015; Hubbard et al., 2011; Li and Zhang, 2010; Wang et al., 2012). As all the changes seriously degrade the aquatic environments, accurate assessment of water quality conditions is prerequisite to achieving sustainable management as well as remediation degradation.

The study area, Bertam River Catchment covers the major urban areas and agricultural activities of Cameron Highlands, which hosts most of its social and economic activities. It is drained by the main Bertam River and its tributaries influenced by a hilly and undulating terrain system. The river system is the major source of potable water supply for the local residents as well as the commercial utilization of the Highlands. More importantly, the area act as a headwater catchment provides water supply to the rest of Malaysian living further downward. However, as a result of rapid uncontrolled development within the area, the water quality of the river system has been deteriorated over time through the inclusion of increased point and nonpoint pollution loads. Untreated domestic wastewater discharge, as well as agricultural runoff, significantly influenced the water quality. Poor agricultural practices and development activities at slope areas also affected the water quality within the catchment (Aminuddin et al., 2005; Eisakhani and Malakahmad, 2009; Gasim et al., 2009a). All these anthropogenic activities significantly influenced the water quality of Bertam River and its tributaries, leading to adverse effects on the aquatic environment of the entire catchment. However, previous studies have focused only on Upper Bertam River (Aminu et al., 2015; Khalik et al., 2013). No detailed study has focused on the water quality of the entire Bertam Catchment.

In the present chapter, the whole Bertam Catchment's water quality has been evaluated with special emphasis on spatio-temporal variations due to anthropogenic activities occurring in the catchment vicinity. A number of physico-chemical parameters of water samples have been analyzed to evaluate their spatio-temporal variability. The hydrological and climatic variables have also been studied to observe the climatic and seasonal changes and their impacts on water quality.

4.2 Hydrological Status

Hydrological variables have potential influences on water resources (Hubbard et al., 2011; Zhou et al., 2012). It is important to have background knowledge hydrological characteristics of the study area to interpret the water quality appropriately.

The hydrological analysis was carried out to evaluate the water level characteristics of the main river and its tributaries within the catchment. Hydrological variables are mainly used to determine the season variation of rainfall and stream flow.

4.2.1 Seasonal Variation in Rainfall

During the study period, sampling program was conducted to collect water samples from January 2014 to February 2015. Based on the historical average monthly rainfall and streamflow pattern, sampling program was classified seasonally as the dry/ average low flow and rainy season/high flow. The water sampling in the month of January'14, March'14, June'14 and February'15 were considered as dry season while that of in the month September'14 and October'14 as rainy season. However, the scenario of rainfall during the sampling day is portrayed in Figure 4.1.

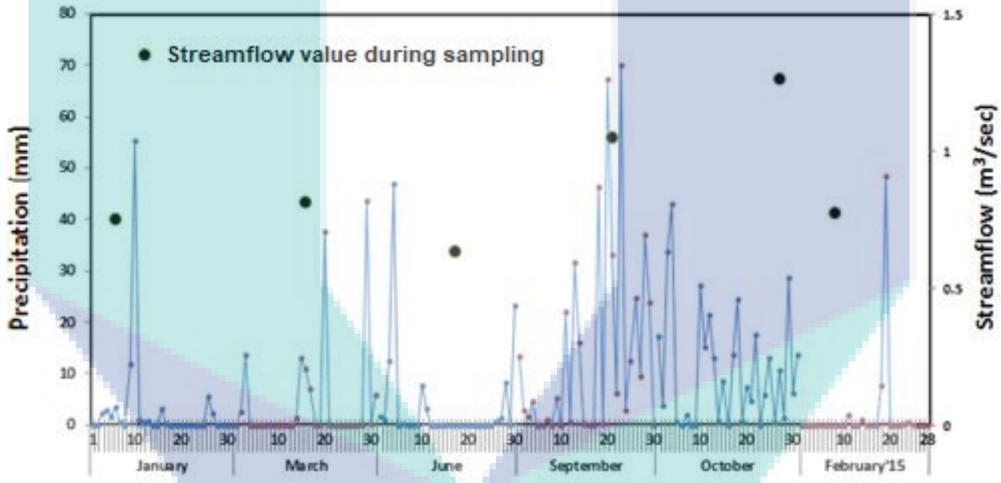

Figure 4.1 Rainfall and streamflow during the time of water sampling

4.2.2 Seasonal Variation in Streamflow

The streamflow at different stations in the catchment depends mainly on the rainfall pattern of the area. The high flow was observed during the sampling days in September and October 2014 and the low flow was measured during the sampling days in January, March, May 2014 and February 2015. The low and high flow distributions during the sampling periods are shown in Figure 4.2.

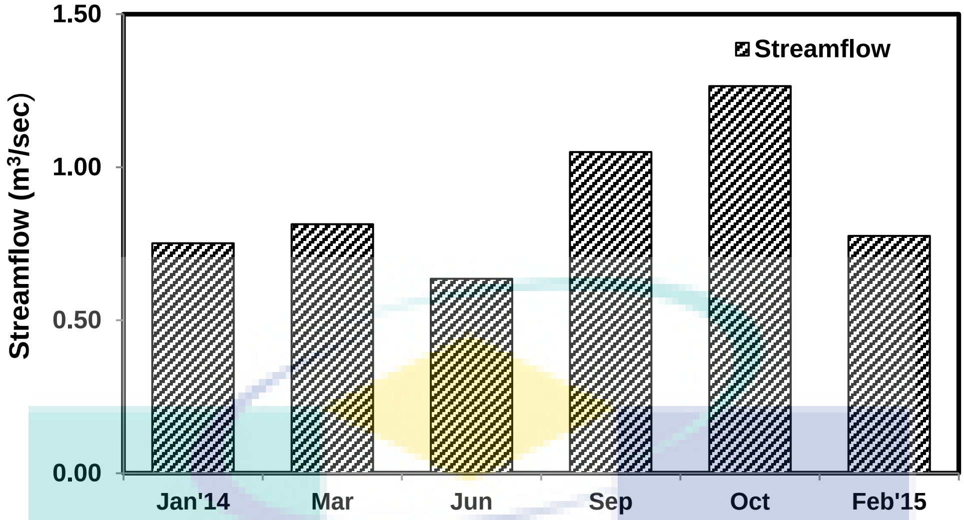

Figure 4.2 The measured average streamflow in the catchment during the sampling periods

The measured streamflow of different sampling stations is represented in Figure 4.3,. According to the observed data, the streamflow ranged from 0.04 to 4.80 m3/s with an average of 0.74 m3/s in the dry season and 0.11 to 6.44 m3/s with an average of 1.16 m3/s in the rainy season.

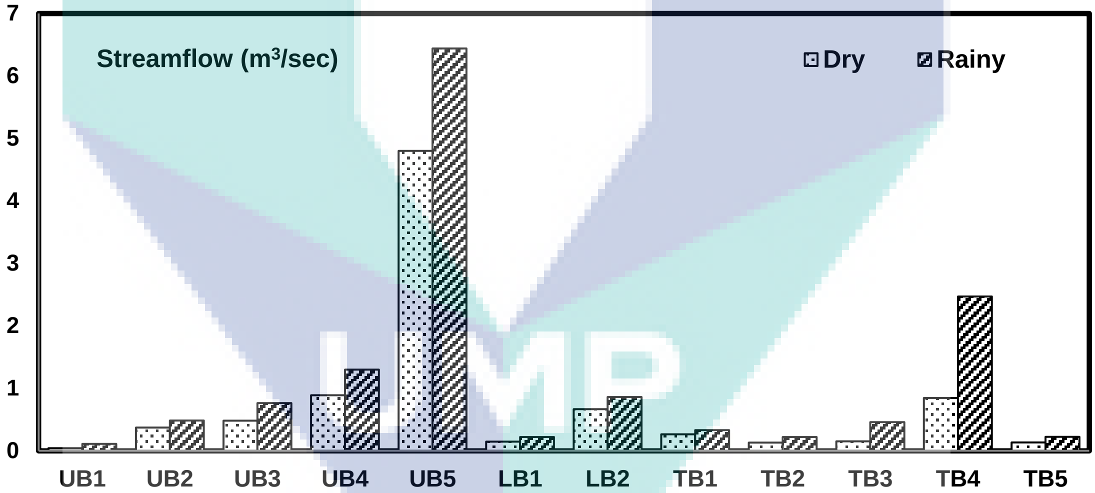

Figure 4.3 Average streamflow distribution at different sampling stations during the dry and rainy periods along the Bertam Catchment

The lowest and the highest streamflows were observed at stations UB1 and UB5 along the main Bertam in both seasons. Among the tributaries, the Batu Pipih showed the higher flow (0.85 m3/s in dry and 2.47 m3/s in rainy) compared to others. The average streamflow of Upper Bertam (0.81 m3/s in dry and 1.28 m3/s in rainy) was considerably higher than that of the Lower Bertam (0.41 m3/s in dry and 0.54 m3/s in rainy).The observed reduction of streamflow at Lower Bertam was mainly a result of water storage and regulation in the upstream Ringlet Reservoir (Jaafar et al., 2010).

4.3 Results and Discussions of Water Quality Parameters

The measured values of physico-chemical parameters were mainly applied to assess the spatial and temporal variation of water quality in the Bertam Catchment. The data were used to classify the water quality class and status as well as to identify their source pollutants. Finally, the data was applied to prepare the contaminant maps of the catchment. The results from all these analyses were discussed below in sequence.

4.3.1 Descriptive Analysis

The descriptive statistics including minimum values (min), maximum values (max), mean values (mean), and standard deviation of each water quality parameter was calculated for the study of water quality. The statistical summary of physical and chemical parameters for all sampling stations along the Bertam River and its main tributaries are presented in Table 4.1 and Table 4.2, respectively**.** The results showed that the average concentrations of turbidity (195.15 NTU), TSS (321.59 mg/L), BOD (8.95 mg/L), NH_3-N (1.32mg/L), and PO_4-P (0.74 mg/L) exceeded the Malaysian National Water Quality Standards (NWQS) level for Class I, Class IIA, and Class IIB that necessitate conventional treatment (DOE, 2010). High standard deviation of data in most of the measured parameters indicates a strong spreading variability of the composition.

4.3.2 Nonparametric Test

Results from the non-parametric Kruskil Walis test are shown in Table 4.3. The result exhibited significant spatial differences for all parameters ($p<0.05$) at the twelve sampling stations. Results also displayed significant temporal variability for temp, DO, COD Turbidity, TSS, NO_3-N, PO_4-P and TP ($p<0.05$) within six sampling times over the study period (January 2014 to February 2015). Such spatial and seasonal variability of water quality parameters is related to heterogeneous characteristics of the watershed in respect of space and season (Ai et al., 2015; Pratt and Chang, 2012; Wilbers et al., 2014).

Table 4.1 Statistical Summary of Physical Parameters for Surface Water Samples in the Bertam Catchment Area

Station		Temp (°C)	pH	DO (mg/L)	EC (µS/cm)	TDS (mg/L)	Turbidity (NTU)	TSS (mg/L)
Main River								
UB-1	Range	16.00-17.33	5.46-7.91	7.34-7.88	6.00-17.00	5.00-11.00	0.00-0.05	2.00-11.00
	Mean ± SD	16.62±0.49	6.49±0.68	7.54±0.18	12.50±3.54	8.89±2.03	0.02±0.02	4.89±2.63
UB-2	Range	17.38-20.30	5.42-8.06	6.82-8.22	36.00-91.00	24.00-59.00	6.80-56.10	11.00-86.00
	Mean ± SD	18.61±.94	6.88±0.83	7.30±0.44	73.17±3.55	47.89±9.11	20.12±17.13	31.94±24.28
UB-3	Range	17.89-20.17	5.71-7.12	6.54-8.10	32.00-70.00	30.00-53.00	28.60-560.20	55.00-560.00
	Mean ± SD	18.80±0.71	6.55±0.50	7.13±0.47	58.61±11.31	41.39±5.63	170.70±178.94	255.94±188.51
UB-4	Range	18.66-20.33	5.83-7.94	6.21-8.02	57.00-75.00	23.00-53.00	33.70-280.50	50.00-334.00
	Mean ± SD	19.61±0.54	6.75±0.71	6.60±0.54	66.39±5.45	43.83±6.48	113.26±83.82	149.44±90.26
UB-5	Range	19.05-20.94	5.60-7.50	7.85-9.33	46.00-71.00	33.00-45.00	78.20-950.00	39.00-1299.00
	Mean ± SD	20.22±0.62	6.39±0.60	8.39±0.42	57.89±7.53	38.50±3.94	304.63±295.32	430.39±380.48
LB-1	Range	22.47-26.92	6.39-8.17	5.05-6.42	98.00-202.00	61.00-131.00	56.00-817.90	77.00-830.00
	Mean ± SD	25.29±1.49	7.17±0.44	5.68±0.45	164.89±23.99	109.33±17.19	303.42±277.47	340.44±274.23
LB-2	Range	22.66-24.81	5.96-7.01	7.15-7.97	69.00-163.00	48.00-106.00	55.40-1292.20	94.00-2084.00
	Mean ± SD	23.88±0.74	6.58±0.30	7.34±0.28	121.94±20.50	81.11±14.34	377.60±433.59	550.39±687.60
Tributaries								
TB-1	Range	17.00-20.29	5.41-8.12	7.13-8.17	35.00-73.00	22.00-47.00	5.00-87.20	12.00-132.00
	Mean ± SD	18.01±1.11	6.88±0.84	7.53±0.27	59.83±10.40	40.06±6.71	23.00±28.15	39.33±38.39
TB-2	Range	17.79-18.94	5.65-8.96	7.19-8.02	18.00-51.00	15.00-38.00	19.30-1242.70	32.00-4780.00
	Mean ± SD	18.41±0.38	6.99±1.08	7.42±0.26	34.56±10.69	27.28±6.91	588.86±506.29	1326.61±1497.62
TB-3	Range	19.16-20.61	5.90-7.70	4.57-6.22	40.00-119.00	30.00-70.00	29.50-200.20	11.00-349.00
	Mean ± SD	20.06±0.51	6.56±0.43	5.59±0.45	73.17±24.13	51.11±13.76	82.85±41.29	129.28±96.54
TB-4	Range	20.09-21.75	5.91-7.82	7.63-8.59	35.00-67.00	28.00-43.00	10.60-1267.70	20.00-2152.00
	Mean ± SD	21.18±0.61	6.75±0.60	7.83±0.32	50.50±9.12	35.00±4.70	242.11±471.08	443.83±776.17
TB-5	Range	19.89-21.64	5.63-7.48	7.45-8.49	44.00-67.00	28.00-43.00	8.30-657.20	4.00-840.00
	Mean ± SD	20.85±0.70	6.50±0.53	7.76±0.34	54.94±7.20	36.56±5.20	127.23±242.68	156.56±309.58
	Guide level	Normal (I)	6.5-8.5 (I)	7.00 (I)	1000.00 (I)	500.00 (I)	5.00 (I)	25.00 (I)
	(DoE)	Normal+2(IIB)	6-9 (IIB)	5.0-7.0 IIB)	1000.00 (IIB)	1000.00 (IIB)	50.00 (IIB)	50.00 (IIB)
All	Average	20.13	6.70	7.18	69.03	46.65	195.15	321.59

Table 4.2 Statistical Summary of Chemical Parameters for Surface Water Samples in the Bertam Catchment Area

Station		COD (mg/L)	BOD (mg/L)	TN (mg/L)	NH_3-N (mg/L)	NO_3-N (mg/L)	PO_4-P (mg/L)	TP (mg/L)
Main River								
UB-1	Range	5.00-19.00	0.35-5.95	0.20-1.00	0.01-0.17	0.08-0.20	0.10-0.22	0.12-0.40
	Mean± SD	11.33±4.73	2.79±1.63	0.47±0.25	0.06±0.04	0.12±0.04	0.14±0.03	0.26±0.07
UB-2	Range	16.00-44.00	2.90-24.80	1.90-4.20	0.61-2.12	0.30-0.90	0.48-1.39	0.63-2.01
	Mean± SD	26.33±11.28	10.22±4.86	2.96±0.68	1.14±0.51	0.66±0.18	0.83±0.23	1.13±0.32
UB-3	Range	8.00-50.00	5.50-12.15	1.80-3.20	0.70-2.20	0.30-0.70	0.21-1.25	0.50-1.62
	Mean± SD	22.67±11.98	9.29±2.04	2.64±0.36	1.18±0.47	0.49±0.14	0.72±0.28	1.01±0.36
UB-4	Range	5.00-55.00	0.90-19.15	2.00-4.80	0.53-1.36	0.30-1.20	0.24-0.92	0.45-1.98
	Mean± SD	21.39±13.49	8.94±5.09	3.31±0.74	0.89±0.29	0.69±0.21	0.52±0.20	0.96±0.38
UB-5	Range	8.00-40.00	1.25-10.45	1.60-4.50	0.11-1.94	0.50-1.20	0.30-1.67	0.56-2.10
	Mean± SD	20.67±12.21	5.83±2.83	3.24±0.73	0.80±0.57	0.88±0.18	0.89±0.35	1.43±0.50
LB-1	Range	9.00-47.00	1.56-21.45	3.80-10.90	0.85-2.04	1.20-3.30	0.53-1.54	1.00-2.80
	Mean± SD	28.06±11.52	11.54±4.02	5.99±1.74	1.38±0.41	2.44±0.45	1.02±0.29	1.71±0.67
LB-2	Range	4.00-41.00	2.10-10.60	3.20-6.90	0.28-1.23	1.80-3.70	0.60-2.22	0.58-1.98
	Mean± SD	17.50±10.12	5.83±2.56	5.04±1.16	0.66±0.28	2.75±0.58	1.34±0.45	1.15±0.49
Tributaries								
TB-1	Range	13.00-46.00	1.90-19.20	1.40-4.00	0.29-1.08	0.30-1.20	0.36-1.51	0.58-1.89
	Mean± SD	21.33±10.80	9.09±5.69	2.68±0.71	0.70±0.25	0.79±0.25	0.77±0.27	1.15±0.49
TB-2	Range	10.00-59.00	0.45-13.05	1.30-4.40	0.50-3.72	0.1-0.30	0.10-0.69	0.38-1.37
	Mean± SD	27.11±18.50	6.48±3.83	2.43±0.99	1.36±0.83	0.17±0.07	0.34±0.19	0.68±0.31
TB-3	Range	19.00-64.00	11.20-35.50	2.20-5.50	0.63-3.38	0.10-0.70	0.21-0.87	0.40-1.89
	Mean± SD	40.72±16.17	22.01±9.77	4.07±0.89	2.10±0.86	0.33±0.19	0.54±0.21	1.04±0.48
TB-4	Range	7.00-40.00	0.40-10.10	1.50-3.70	0.05-0.38	0.50-1.20	0.27-1.26	0.53-1.87
	Mean± SD	16.17±10.12	4.50±3.76	2.59±0.70	0.23±0.09	0.77±0.22	0.66±0.32	1.05±0.39
TB-5	Range	7.00-40.00	0.90-10.15	0.50-4.80	0.06-0.35	0.40-0.80	0.32-2.20	0.58-3.20
	Mean± SD	16.89±10.03	4.83±3.30	2.53±0.98	0.15±0.08	0.58±0.13	1.06±0.57	1.41±0.83
	Guide level (DoE)	10.00 (I) 25.00 (IIB)	1.00 (I) 3.00 (IIB)		0.10 (I) 0.30 (IIB)		0.1(IIB)	
All	Average	**22.51**	**8.95**	**3.16**	**1.32**	**0.89**	**0.74**	**1.14**

No. of Samples: **216.**

Table 4.3 Result of Kruskal-Wallis Test

Parameters	**Independent Sample Kruskal-Wallis Test**	
	Temporal	**Spatial**
Temperature	**.013**	**.000**
pH	.975	**.000**
EC	.085	**.000**
DO	**.003**	**.000**
BOD	.323	**.000**
COD	**.000**	**.000**
TDS	.216	**.000**
Turbidity	**.000**	**.000**
TSS	**.000**	**.000**
NO3-N	**.040**	**.000**
NH3-N	.559	**.000**
TN	.113	**.000**
PO4-P	**.000**	**.000**

Bold parameters are significant at $p<0.05$

4.3.3 Correlation Matrix

All the 14 water quality parameters were analyzed to determine the relationship among water quality parameters Table 4.4. Results of the correlation analysis showed a strong positive correlation between EC and TDS (r=0.965) along with all nutrients. It showed mutual correlations for NH_3-N (EC=0.429 and TDS=0.502), NO_3-N (EC=0.646 and TDS=0.621), TN (EC=0.698 and TDS=0.724), PO_4-P (EC=0.546 and TDS=0.530), TP (EC=0.551 and TDS=0.569) and DO (EC=0.466 and TDS=0.538) respectively.

The strong to moderate correlations between EC and all nutrients reveals that the high EC could be attributed to the discharge of domestic sewage as well as agricultural runoff which introduce a significant amount of ions into the river system (Kozaki et al., 2016). The positive correlation between COD and BOD with NH_3-N (r=0.534 and r=0.482, respectively) reflects inhibition of nitrification by low DO impose through high oxygen demand. As a result, DO was negatively correlated with NH_3-N (r=-0.566) and BOD (r=-0.541). The positive association of TN with NO_3-N (r=0.598) and NH_3-N (r=0.485) indicates that NO_3-N was a relatively higher contributor to TN than NH_3-N. Conversely, the strong correlation between TP and PO_4-P (r=0.792) indicates that PO_4-P was the highest contributor to TP.

Table 4.4 Spearman's Correlation Coefficient for Water Quality Parameter in the Bertam Catchment Area[a]

	Temp	pH	EC	TDS	Turbidity	TSS	DO	BOD	COD	NH_3-N	NO_2-N	NO_3-N	TN	PO_4-P	TP
Temp	1.000														
pH	-0.008	1.000													
EC	**0.574****	0.283**	1.000												
TDS	**0.565****	0.334**	**0.965****	1.000											
Turbidity	**0.467****	0.101	0.331**	0.336**	1.000										
TSS	**0.442****	0.062	0.256**	0.260**	**0.951****	1.000									
DO	-0.231**	-0.229**	**-0.466****	**-0.538****	-0.143*	-0.099	1.000								
BOD	0.192**	-0.190**	0.269**	0.293**	0.177**	0.165*	**-0.541****	1.000							
COD	-0.074	0.032	0.194**	0.238**	0.067	0.064	-0.111	0.193**	1.000						
NH_3-N	0.060	0.271**	**0.429****	**0.502****	0.413**	0.372**	**-0.566****	**0.482****	**0.534****	1.000					
NO_2-N	0.134*	0.049	**0.376****	**0.413****	0.004	-0.043	-0.267**	0.303**	0.370**	**0.420****	1.000				
NO_3-N	**0.686****	0.080	**0.646****	**0.621****	0.324**	0.330**	-0.119	0.115	-0.070	0.065	0.230**	1.000			
TN	**0.632****	0.228**	**0.698****	**0.724****	0.500**	0.435**	**-0.407****	**0.284****	**0.263****	**0.485****	0.299**	**0.598****	1.000		
PO_4-P	**0.582****	0.070	**0.546****	**0.530****	0.313**	0.282**	-0.144*	0.183**	-0.129	0.051	0.052	**0.632****	**0.470****	1.000	
TP	**0.641****	0.075	**0.551****	**0.569****	0.436**	.388**	-0.195**	0.218**	-0.045	0.145*	0.104	**0.624****	**0.522****	**0.792****	1.000

* Correlation is significant at the 0.05 level (2-tailed).** Correlation is significant at the 0.01 level (2-tailed).

Abbreviations for the water quality variables are mentioned in the methodology section

[a]The bold-faced numerical values indicate a significant relationship at a level of $p < 0.01$.

Correlation matrix showed a strong positive correlation (r=0.95) between turbidity and TSS (r=0.951) infer that the turbidity is greatly affected by higher soil erosion and sedimentation from the farms cultivated on hill slopes (overland eroded areas) (Zerga, 2015)

4.3.4 Water Quality Status

A total of 14 (fourteen) physico-chemical parameters of collected samples were analyzed to evaluate the spatio-temporal variability of surface water quality of Bertam River Catchment. Temporal variations of the parameters are narrated on the basis of month and season. The level of variability under different stations and seasons are represented by comparing their ranged values using box and whisker plots in following sections. All results obtained from the analyses are shown in Appendix D.

4.3.5 Spatio-temporal Variation of Physical Parameters

A total of six (6) physical parameters were analyzed to assess the spatial and temporal variations of surface water quality of Bertam River and its tributaries. However, the detailed results of individual parameters are discussed as follows.

4.3.5.1 Temperature

Surface water temperature of Bertam River Catchment was recorded during the sampling periods and analyzed to identify the spatial and temporal variations.

Spatial variation of temperature among the stations

Surface water temperature ranged from 16.00 °C to 26.92 °C with a mean value of 20.13 °C and was found within the acceptable limit of Malaysian Standard (DOE, 2010). The values generally showed an increasing trend followed by the elevation toward downstream, except station LB1 and TB4 (). Sampling time and decreased flow with low depth might cause such exception at these two stations (Shuhaimi-Othman et al., 2007). The highest temperature was recorded at LB-1, followed by TB-4, while the lowest was at UB-1. The present data of temperature is more or less similar to the atmospheric condition of Cameron Highlands (Eisakhani and Malakahmad, 2009).

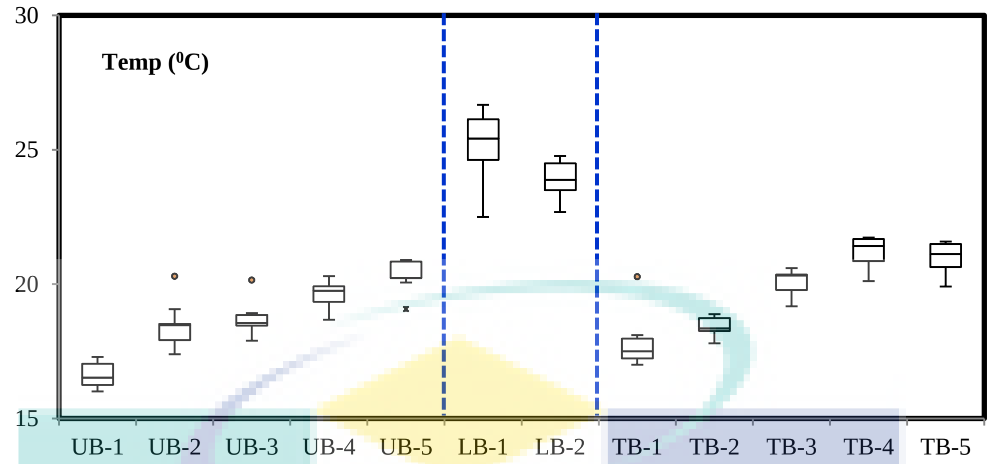

Figure 4.4 Spatial distribution of temperature among the sampling stations

Temporal variation of temperature among the periods and stations

The temporal variation of temperature and its average values during dry and rainy seasons at different stations are presented in Figure 4.5. The mean highest temperature was recorded in September 2014 while the mean lowest temperature was observed in March 2014. The range of temperature, my month, was reasonably different during the study period. Temperature showed higher values in the months of September and October while those values were lower in the months of January, February, and March. Thus, temperature showed a general increasing trend of variation from dry to rainy season. The comparatively higher temperature in the rainy season resulted from the specific climatic conditions during this period (Chen et al., 2014).

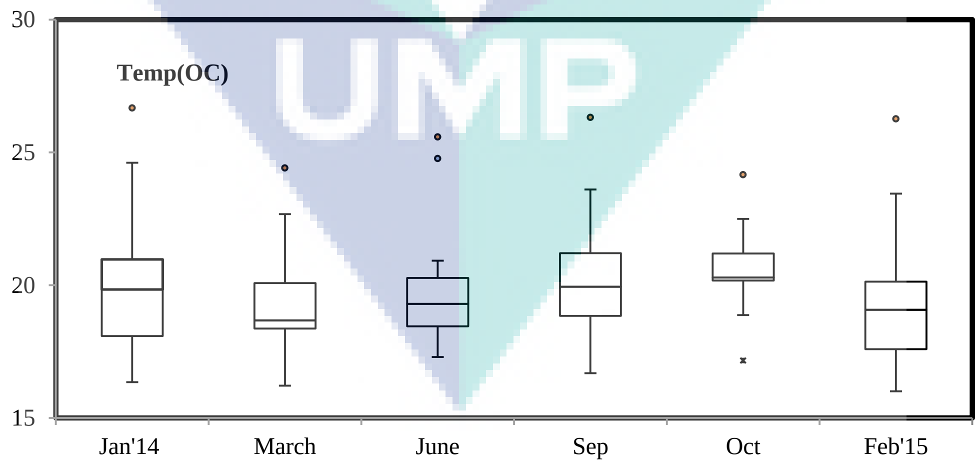

Figure 4.5 Temporal distribution of temperature within the sampling periods

Seasonally, the ranges of temperature varied all around the year and did not show any significant trend of variation. The average lower temperatures of water were observed during the months of the dry season while the higher at the months of the rainy season (Figure 4.5). Moreover, most of the stations showed higher temperature in the rainy season than dry season (Figure 4.6). Sampling time, location impact along with seasonal condition are general factors for such variations in temperature (Chen and Lu, 2014; Shuhaimi-Othman et al., 2007).

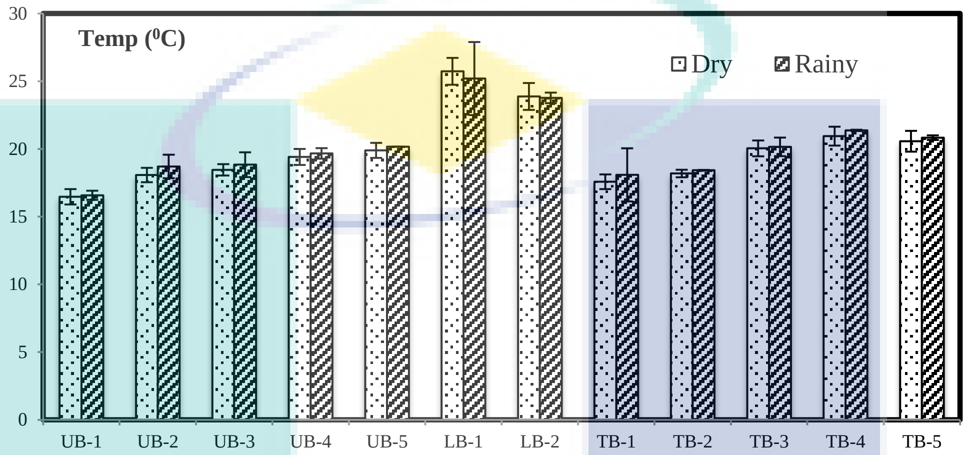

Figure 4.6 Seasonal distribution of temperature among the sampling stations

4.3.5.2 pH

The pH values of all stations were recorded during the sampling periods and their spatial and temporal variation are shown in Figure 4.7, Figure 4.8 and Figure 4.9.

Spatial variation of pH among the stations

The pH values in the catchment showed variation at all stations ranged from 5.41 to 8.96 with an average of 6.70 that falls within the permissible range of NWQS of Malaysia. The measured values among the stations varied widely but did not show any significant trend of variation (Figure 4.7).). Along the Bertam River, the lowest mean value (6.39) was recorded at station UB-1 located at the mountainous forest area in the Upper Bertam, while the highest pH (7.11) was found at station LB-1 in Lower Bertam. Among the tributaries, Sungai Jasar (TB-3) showed the lowest pH value (6.61) followed by Sungai Uluh (TB-5) and Sungai Batuh Pipih (TB-4) with pH values of 6.65 and 6.88, respectively. The highest pH value was observed at Sungai Ruil (TB-2).

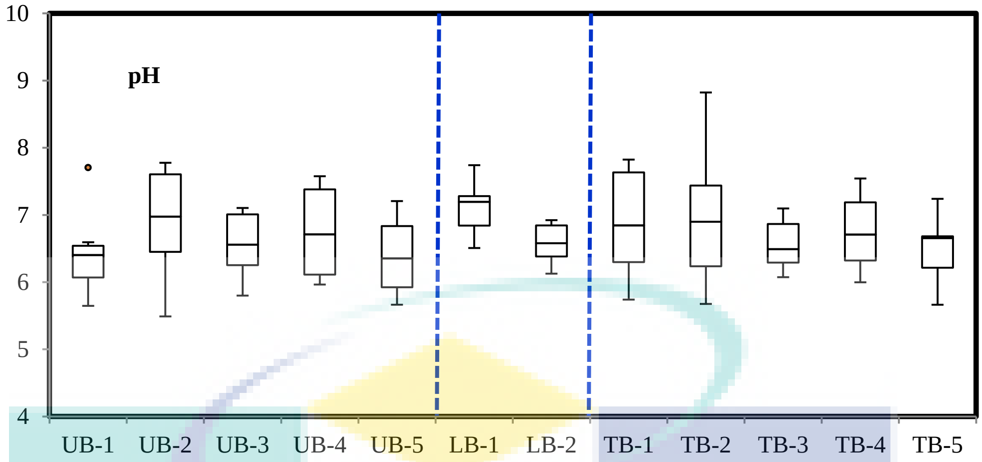

Figure 4.7 Spatial distribution of pH among the sampling stations

Temporal variation of pH among the periods and stations

An increasing trend of pH values observed during the months of January, February, and March in dry season while the highest value was observed in the month of September in the rainy season. With a higher amount of rainfall in the month of October, the values of pH dropped a little bit in October in the studied catchment. The reason might be due to dilution effect because of continuous rainfall within Catchment.

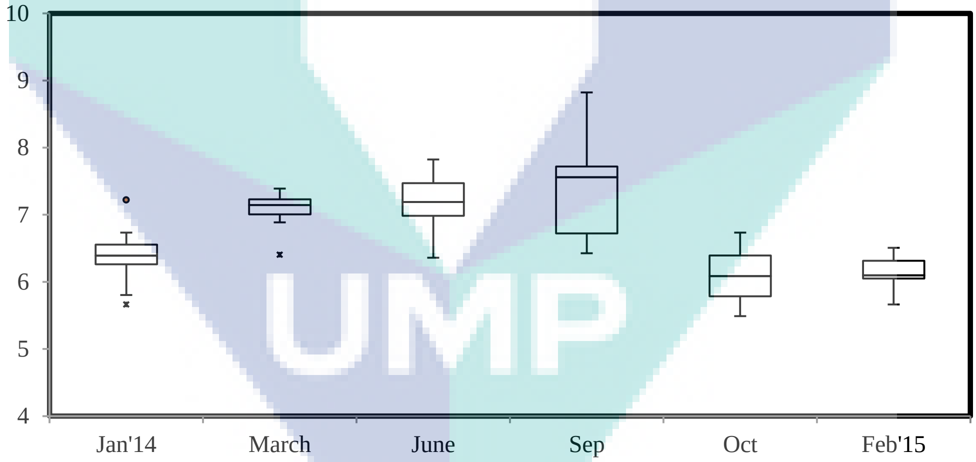

Figure 4.8 Temporal distribution of temperature within the sampling periods

Seasonally pH values showed a little bit increasing trend during the dry season while the highest values observed in the rainy season. The values are gradually decreased with constant rainfall. In the rainy season, the pH showed lower values at most of the stations in Upper Bertam except station UB-1 and TB-2. However, in the Lower Bertam, the values showed higher in all stations during the same season.

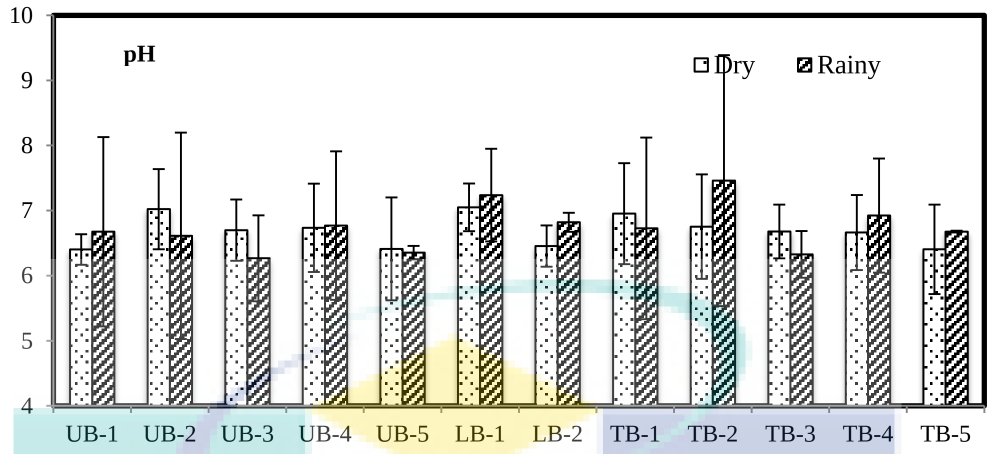

Figure 4.9 Seasonal distribution of pH among the sampling stations

4.3.5.3 Electrical Conductivity

Measurement of electrical conductivity (EC) values was done during the sampling periods from all collected water samples and their spatial and temporal variations are shown in, Figure 4.11, and Figure 4.12.

Spatial variation of EC among the stations

EC values displayed a wide range of variation among the sampling stations with a range of 6.00 to 202.00µS/cm respectively (Figure 4.10). The low value of EC was recorded at station UB1, which is the source point of the Bertam River located at the undisturbed mountainous forest and free from the influences of human activities (Singh and Mishra, 2014). Low value also occurs in the source water originated from local precipitation. The composition of the granitic bank could be another reason for the low EC value. The highest mean values of EC at station LB1 (164.89µS/cm) was mainly caused by the combined effect of point and nonpoint sources of domestic discharge from Ringlet town and agricultural activities along Lower Bertam Valley. Among the tributaries, Jasar River exhibited the highest mean EC value (73.17µS/cm) due to the direct discharge of untreated municipal wastewater from the Tanah Rata town and from a water resources recovery facility. The high EC could be attributed to the discharge of domestic sewage as well as agricultural runoff that introduces a significant amount of ions into the river system. Results of correlation analysis in Table 4.4 showed significant positive correlations between EC and all nutrient parameters. Such relations might reflect in the variations of EC concentrations within the catchment.

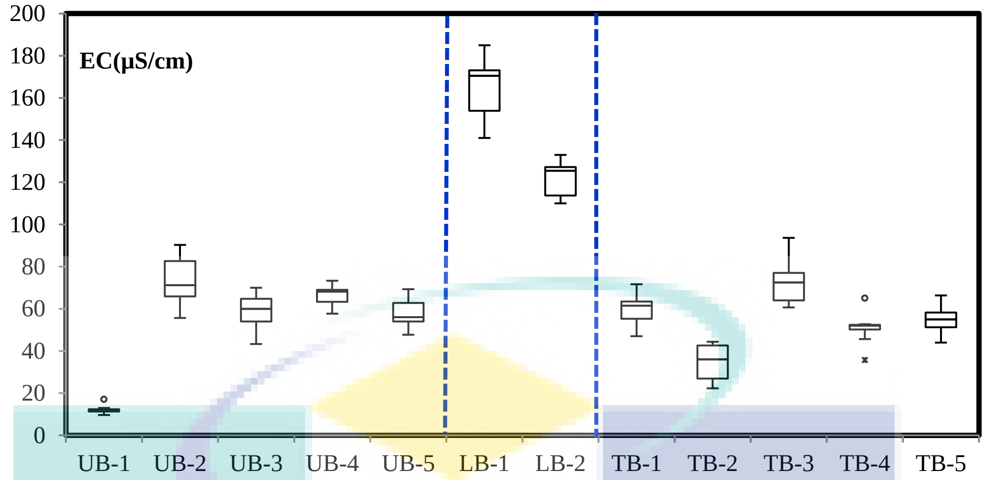

Figure 4.10 Spatial distribution of EC among the sampling stations

Temporal variation of EC among the periods and stations

In the catchment, the average highest concentration of EC was observed in the month of September while the lowest was recorded in January. From the Figure 4.11, an increasing trend in EC values was seen in the months of January, March, June, and September during the sampling periods. However, with increasing amount of rainfall in the month of October, the average concentration of EC dropped a little bit in the studied catchment. The reason might be due to dilution effect because of continuous rainfall within Catchment (Yu et al., 2016).

The seasonal variation of EC from the Figure 4.12 showed that higher concentrations of EC observed at all stations in Upper Bertam and most of its tributaries during the rainy season. Conversely, the stations of lower Bertam and TB-3 showed higher values during the dry season. Rain shelter farming practice in the lower Bertam valley might be the reason behind the lower concentration of EC during the rainy season (Aminuddin et al., 2005). Another reason could be dilution effect as a result of higher precipitation (Yu et al., 2016).

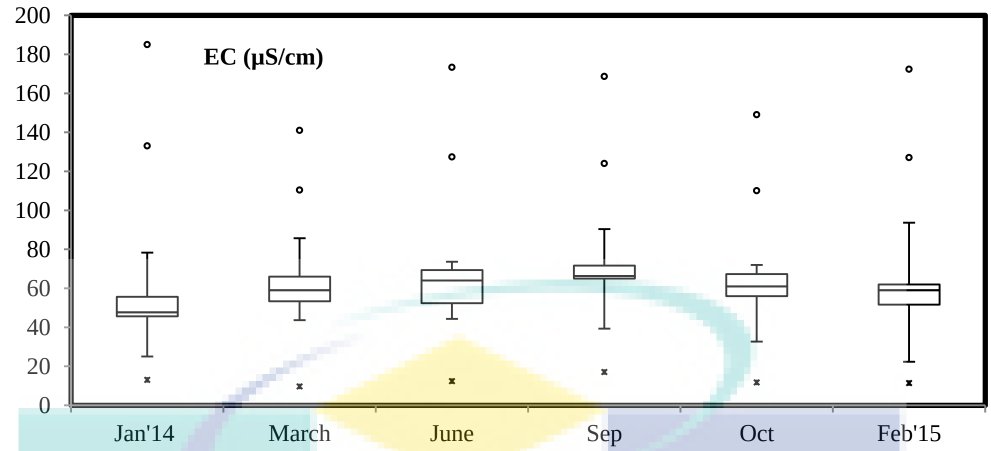

Figure 4.11 Temporal distribution of conductivity among the sampling stations

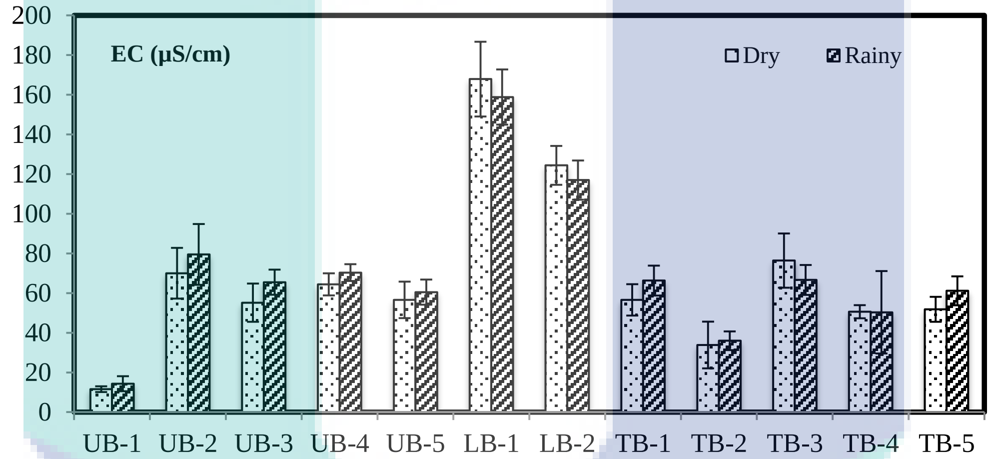

Figure 4.12 Seasonal distribution of EC within the sampling stations

4.3.5.4 Total Dissolved Solid (TDS)

TDS refers to all kinds of solids (organic and inorganic) that are dissolved in water. The TDS concentrations were recorded from all monitoring stations. The data were used for spatio-temporal variations of Bertam River and its tributaries.

Spatial variation of TDS among the stations

The measured values of TDS varied in between 5.00 mg/L to 131.00 mg/L with an average mean value of 46.65 mg/L. The mean value was found beyond the acceptable limit of Malaysian Standard (DOE, 2010). The highest mean value of TDS (109.33 mg/L) was recorded at station LB-1 while the lowest mean value of TDS (8.89 mg/L) was at station UB-1.

As the station UB-1 is located in the mountainous forest, the water displayed a very low value of TDS (8.89 mg/L). The reason is mainly due to the origin of the water from rainwater (Van der Ent and Termeer, 2005). From this station to downward, addition of domestic wastewater from residential area increased the TDS values at station UB-2 (Bu et al., 2010). Further downward, the values decreased successively at station UB-3, UB-4, and UB-5 in the Upper Bertam due to the influence of tributaries (Figure 4.13). Eisakhani and Malakahmad (2009) obtained the similar trend in the values of TDS in the Upper Bertam. Among the tributaries, the lowest mean TDS value (27.28 mg/L) was observed in TB-2 (Sungai Ruil) followed by TB-4 (Sungai Batu Pipih) and TB-5 (Sungai Uluh) with TDS values of 35.00 mg/L and 36.56 mg/L respectively. Conversely, the highest TDS value (51.11mg/L) was observed in TB-3 (Sg. Jasar). Among the stations of lower Bertam, LB-1 and LB-2 showed higher values of TDS compared to others. Moreover, correlation matrix showed a strong positive correlation among TDS, EC and nutrients variables (Table 4.4).

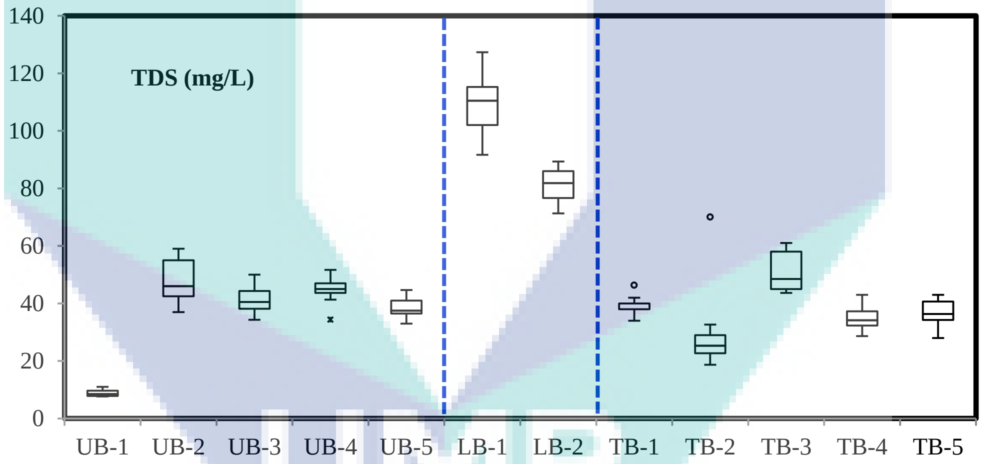

Figure 4.13 Spatial distribution of TDS among the sampling stations

Temporal variation of TDS among the periods and stations

In the catchment, the average highest concentration of TDS was observed in the month of September while the lowest was recorded in January. From the Figure 4.14, an increasing trend in TDS values was seen in the months of January, March, June, and September during the sampling periods. However, with increasing amount of rainfall in the month of October, the average concentration of TDS dropped a little bit in the studied catchment. The reason might be due to dilution effect because of continuous rainfall within Catchment (Yu et al., 2016).

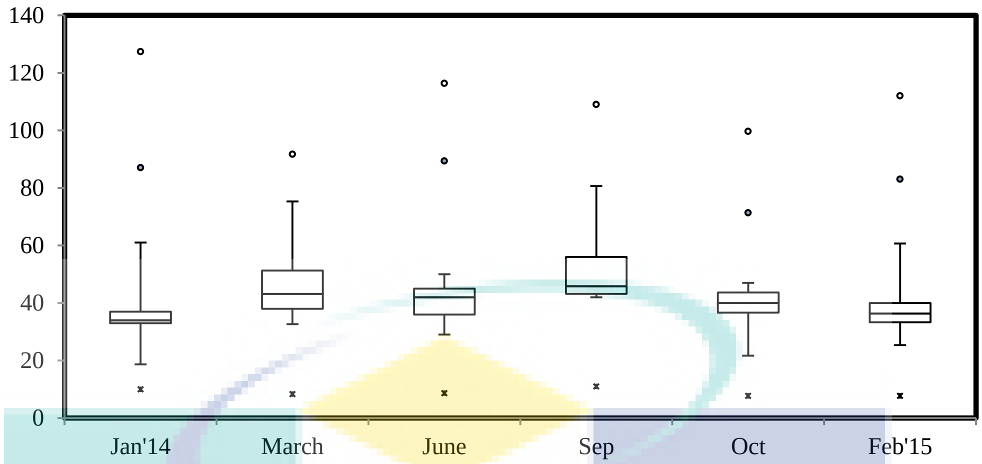

Figure 4.14 Temporal distribution of TDS among the sampling periods.

From the Figure 4.15, it can be observed that most of the stations in the catchment except TB3, LB1, and LB2 showed a higher concentration of TDS during the rainy season. Conversely, in the Lower Bertam, a higher concentration of TDS was found during the dry season. Rain shelter farming practice in the lower Bertam valley might be the reason behind the lower concentration of TDS during the rainy season (Aminuddin et al., 2005). Another reason could be dilution effect as a result of higher precipitation (Yu et al., 2016).

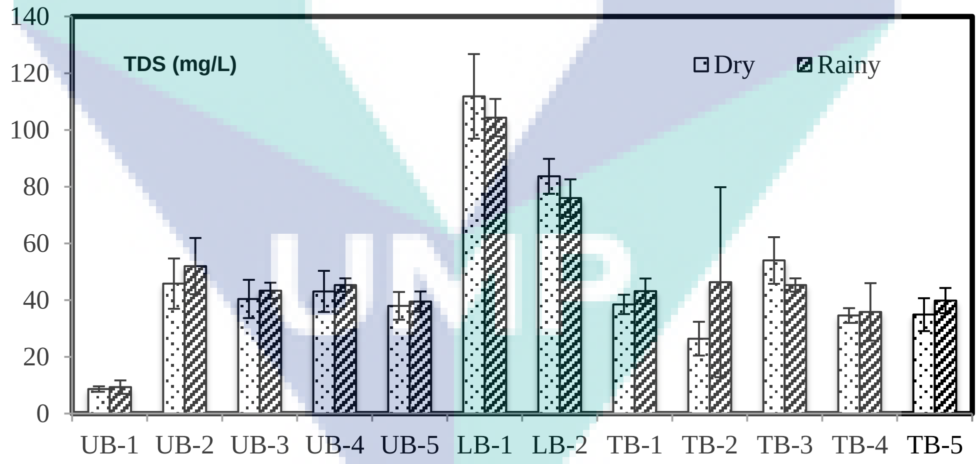

Figure 4.15 Seasonal distribution of TDS among the sampling stations

4.3.5.5 Turbidity

Turbidity is a visual property of water that indicates the lack of clarity and the extent of interfering with the straight lie transmission of light into the water. In the present study, turbidity was measured and the observed data was analyzed to know the spatial and temporal variation. The results of analyses were presented in the Figure 4.16, Figure 4.17, and Figure 4.18.

Spatial variation of turbidity among the stations

Regarding water clarity, the turbidity ranged from 0.02 to 588.86 NTU with a mean value of 195.15 NTU. The turbidity showed a wide range of spatial variations among all the stations. Along the main river, the highest values of turbidity (304.63 NTU) was found at station UB-5 located at the downward of Upper Bertam, while the lowest values of turbidity (0.02 NTU) was recorded at station UB-1 towards upward of Upper Bertam near the forest area. Among the turbidities, station TB-2 (Sungai.Ruil) showed the highest concentrations (588.86 NTU) while station TB-1 (Sungai Burung) showed the lowest values of turbidity (23.00 NTU) during the study period. The values of turbidity at most of the stations of Bertam River and its tributaries showed higher values than the limit (> 5 NTU) of Malaysian standard (Figure 4.16). Correlation matrix showed a strong positive correlation (r=0.89) between TSS and turbidity (Table 4.4). It is actually the proxy of TSS and confirmed the higher TSS as a result of higher turbidity (Rügner et al., 2013).

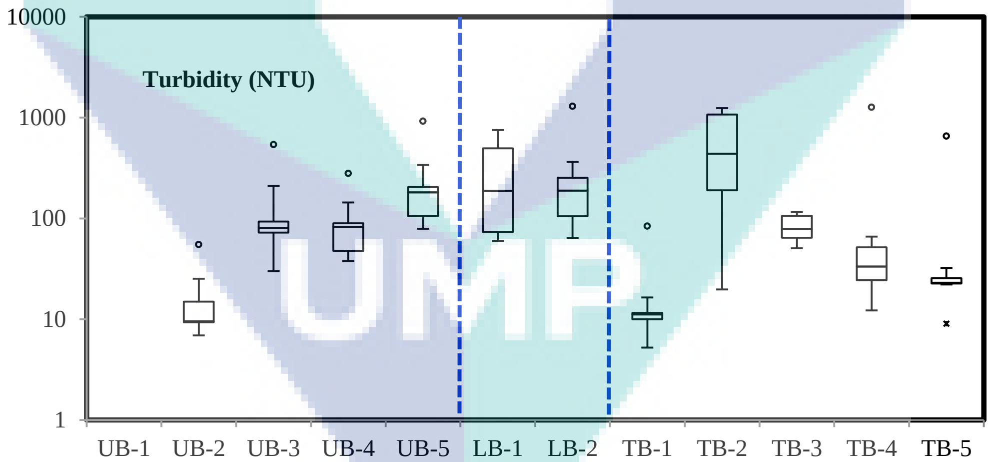

Figure 4.16 Spatial distribution of turbidity among the sampling stations

Temporal variation of turbidity among the periods and stations

The values of turbidity showed a significant variation for each sampling period. Turbidity showed higher values in the months of September and October, while those values were lower in the months of January, February, and March. Seasonally, the ranges of turbidity varied widely all around the year and showed a significant increasing trend of the pattern from dry to the rainy season (Figure 4.17).

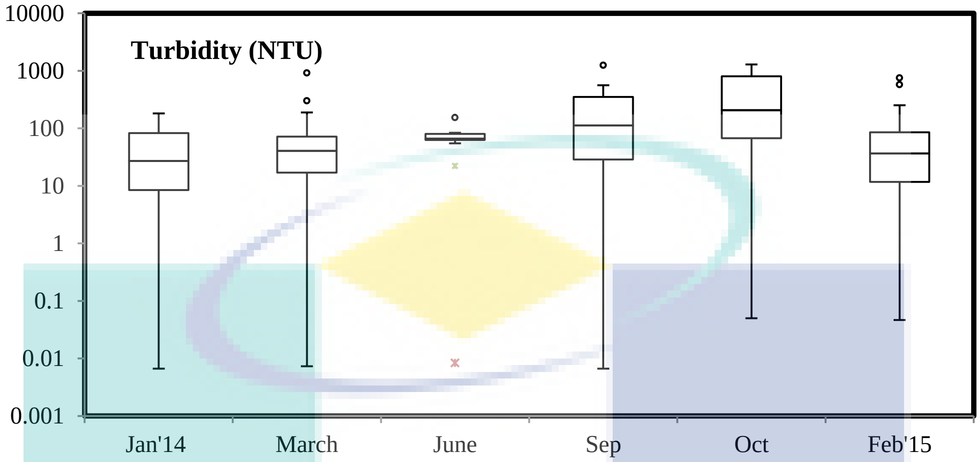

Figure 4.17 Temporal distribution of turbidity among the sampling periods

Higher values were recorded at most of the stations during the rainy season (Figure 4.18).

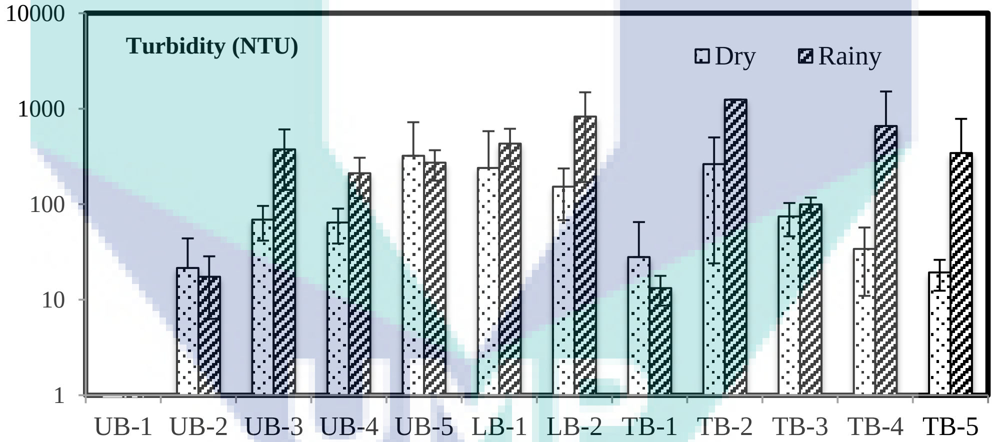

Figure 4.18 Seasonal distribution of turbidity among the sampling stations

4.3.5.6 Total Suspended Solids (TSS)

TSS includes all particle suspended in water which cannot pass through a filter. TSS was measured from all sampling stations during the sampling periods. The analyzed results are displayed in Figure 4.19, Figure 4.20, and Figure 4.21 to assess their spatial, temporal and seasonal variations. The mean value of TSS showed higher turbidity than the Malaysian limit of the standard.

Spatial variation of TSS among the stations

The concentration of TSS was found within a range of 2.00 to 4780.00 mg/L and displayed a wide range of spatial variation. Along the Bertam River, the highest mean values of TSS (550.39 mg/L) was recorded toward the downward station at LB2, whereas the lowest mean values of TSS (4.89 mg/L) was found near the origin, at station UB1. Among the tributaries, station TB2 (Ruil River) showed the highest concentrations (1326.61 mg/L), while station TB1 (Burung River) showed the lowest values of TSS (23.00 mg/L). Moreover, the values of TSS at most of the stations of the Bertam River and its tributaries showed higher values than the limit (> 25 mg/L) of Malaysian standard (Figure 4.19). A correlation matrix also showed a strong positive correlation (r=0.95) between TSS and turbidity (Table 4.4). The higher soil erosion and sediment transport from overland eroded area significantly increased the TSS concentrations at most of the stations of Bertam River and its tributaries due to the steep gradient (Toriman et al., 2010). Present agricultural activities on steep and gentle slopes, hilltops, and the valley floor, as well as construction activities, were the main reasons for such increments during the study period (Aminuddin et al., 2005). Other studies have focused on similar results, stating that agricultural activities and land pattern development strongly influenced the total suspended solids and sediments in the river water (Duan et al., 2013; Glavan et al., 2013; Mouri et al., 2013).

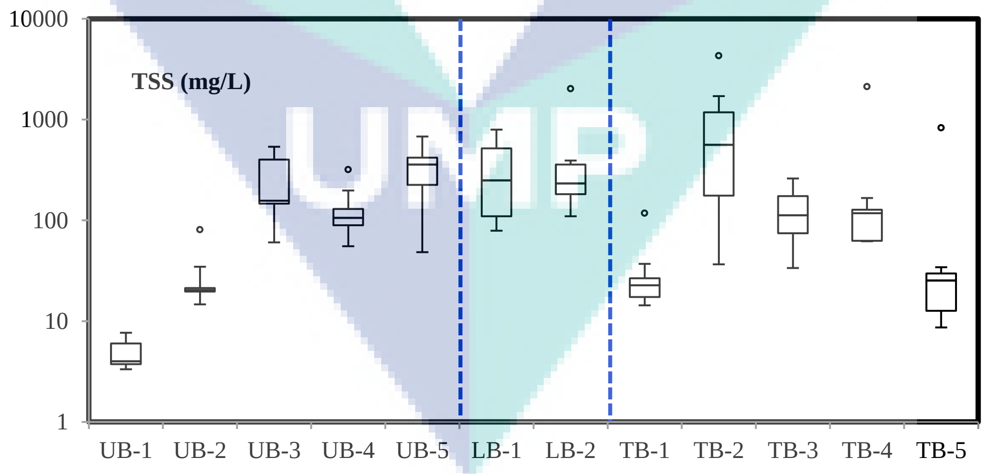

Figure 4.19 Spatial distribution of TSS among the sampling stations

Temporal variation of TSS among the periods and stations

The values of TSS showed a significant variation for each sampling period. TSS showed higher values in the months of September and October, while those values were lower in the months of January, February, and March. Seasonally, the ranges of TSS varied widely all around the year and showed a significant increasing trend of the pattern from dry to the rainy season (Duan et al., 2013; Mustapha et al., 2012) (Figure 4.20).

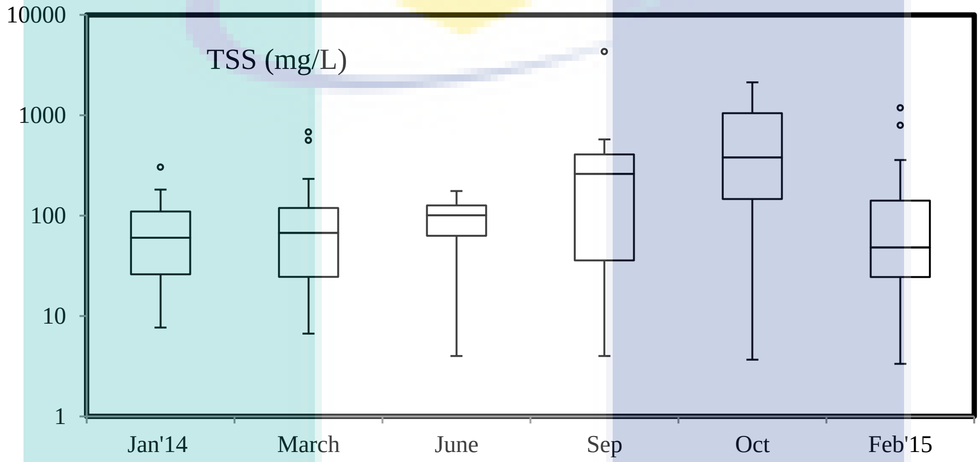

Figure 4.20 Temporal distribution of TSS among the sampling periods

Higher values were recorded at most of the stations during the rainy season (Figure 4.21).

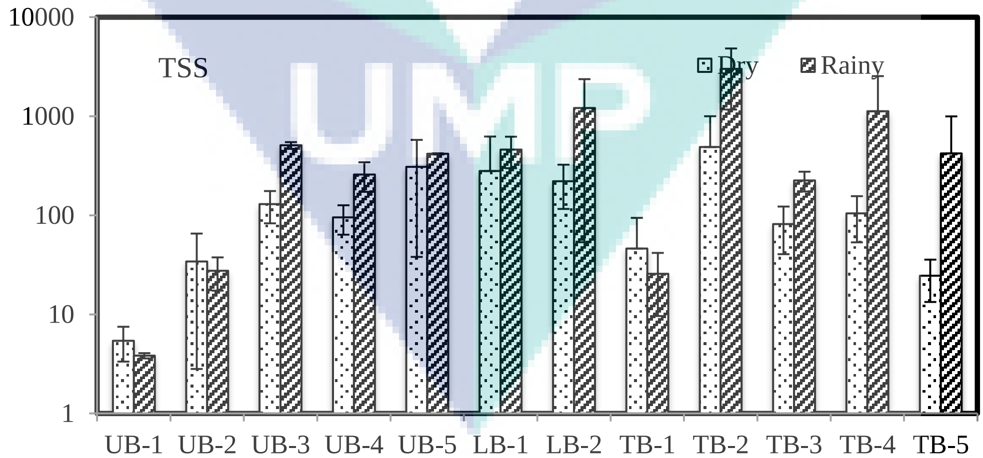

Figure 4.21 Seasonal distribution of TSS among the sampling stations

4.3.5.7 Similar Trends among the parameters

Among the physical parameters, EC and TDS values displayed a similar spatial trend among the sampling stations in the Bertam Catchment (Figure 4.22 A). Similarly, A similar pattern of spatial variation was observed in between TSS and turbidity among the sampling stations in the studied area (Figure 4.22 B)

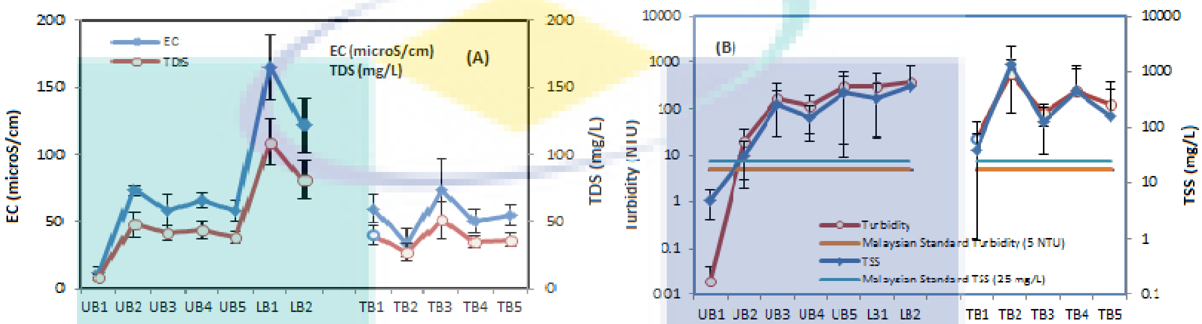

Figure 4.22 Trend of EC and TDS (A) and TSS and turbidity in the study area (B)

4.3.6 Spatio-temporal Variation of Chemical Parameters

A total of eight chemical parameters were analyzed to assess the spatial and temporal variations of surface water quality of Bertam River and its tributaries. The detailed results of individual parameters are discussed in the next sub-sections

4.3.6.1 Dissolved Oxygen (DO)

Spatial variation of DO among the stations

The mean DO values ranged from 5.59 mg/L to 8.39 mg/L with an average of 7.18 mg/L. From the Figure 4.23, it can be seen that in the main Bertam River, the average highest DO concentration (8.39 mg/L) was recorded at UB-5 followed by UB-1 with a concentration of 7.56 mg/L; while the lowest (5.68 mg/L) concentration was recorded at station LB-1. Among the tributaries, lowest concentration (5.59 mg/L) was observed at Sungai Jasar (TB-3) while the highest concentration (7.83 mg/L) was found at Sungai Batuh Pipih (TB-4). The average lower concentration of DO observed at station LB1 (5.68mg/L) and at TB3 (5.59mg/L) might be due to the discharge of domestic wastewater into the river stream from the two main towns, Tanah Rata and Ringlet of Bertam Catchment (Perrin et al., 2014). DO values mainly decrease due to decomposition of organic matter and nitrification of ammonia introduced from human and industrial wastes (Bailey and Ahmadi, 2014).

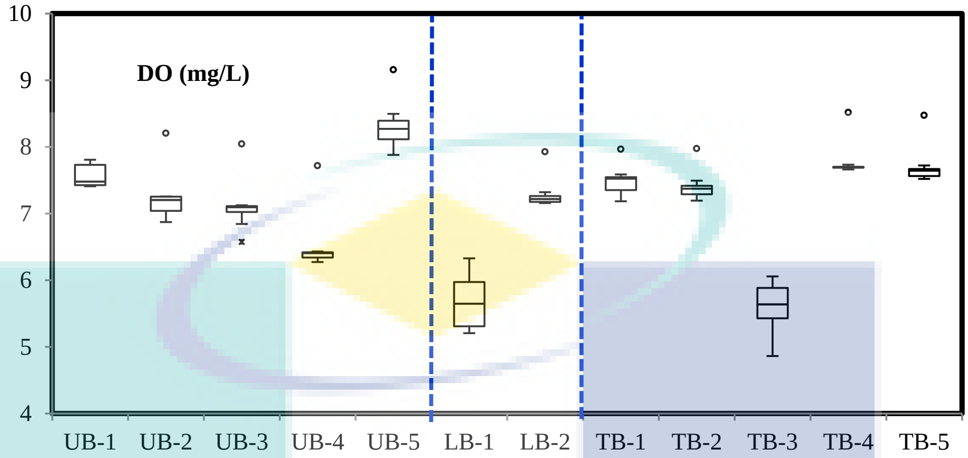

Figure 4.23 Spatial distribution of DO among the sampling stations

Temporal variation of DO among the periods and stations

Temporally the DO showed higher values in January and February and lower values in September and October (Figure 4.24). The DO values showed a decreasing trend toward the rainy season caused by decomposition of organic compounds (Ai et al., 2015).

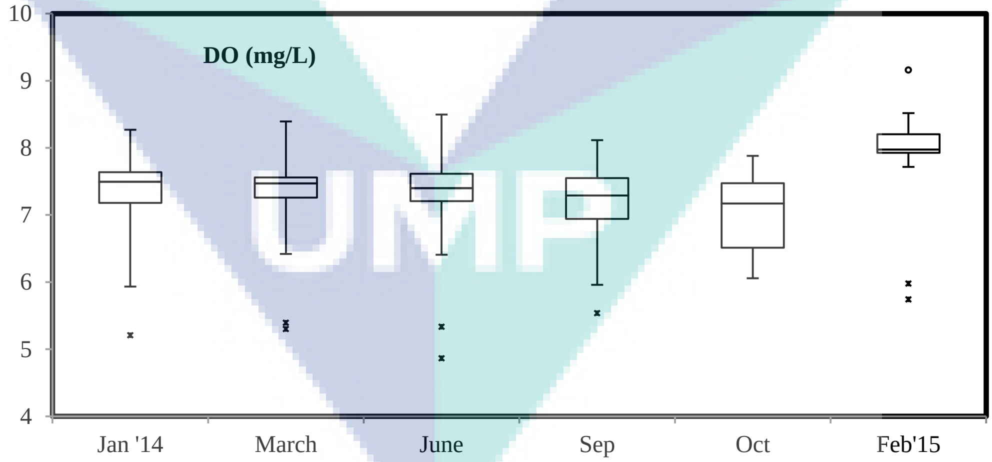

Figure 4.24 Temporal distribution of DO among the sampling periods

From the Figure 4.25, as can be seen, that all the sampling stations of the study area showed average higher values in the dry season than in rainy season (Yu et al., 2016).

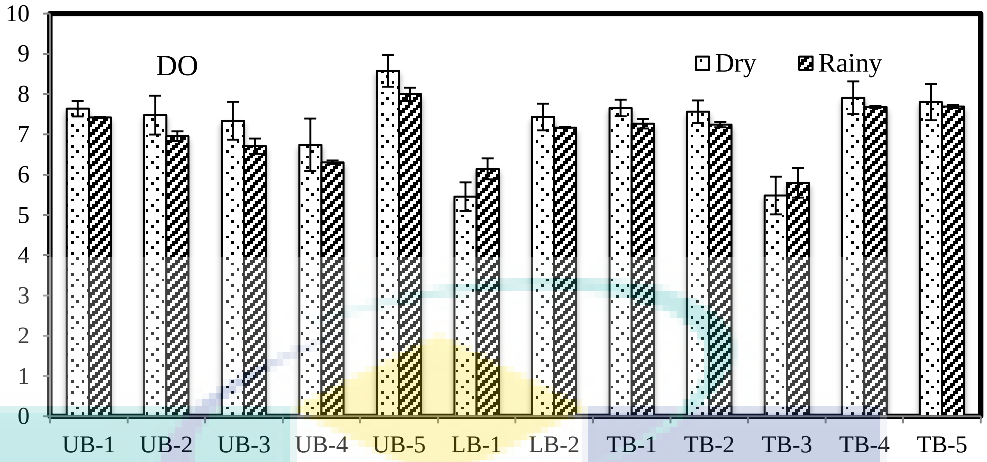

Figure 4.25 Seasonal distribution of DO among the sampling stations

4.3.6.2 Biological Oxygen Demand (BOD)

Spatial variation of BOD among the stations

Biological oxygen demand is an important parameter to analyze the organic contamination of the study area. The concentrations of BOD ranged from 0.35 to 35.50 mg/L with a mean of 8.95 mg/L (Figure 4.26). The average concentration showed higher values than the acceptable limit (> 10mg/L) for NWQS at stations UB2, TB2, TB3, and LB1 within the catchment. The average values of BOD showed a wide range of spatial variation among the stations without following any specific trend. In the Bertam River, the highest BOD was found at station LB1 (11.54 mg/L), while the lowest of that was recorded at station UB1 (2.79 mg/L). Among the tributaries, the highest BOD value (22.01 mg/L) was recorded at station TB3 (Jasar River), while the lowest value (4.50 mg/L) was found at station TB4 (Batu Pipih River). The higher values of BOD at stations UB2 (10.22 mg/L), TB3 (22.01 mg/L), and LB1 (11.54 mg/L) might be attributed to domestic wastewater discharged into the river stream from residential areas of Brinchang, Tanah Rata, and Ringlet towns. A number of researchers have mentioned that high BOD values indicate water quality deterioration caused by the discharges of municipal wastewater (Mei et al., 2014; Mouri et al., 2011; Ogwueleka, 2015).

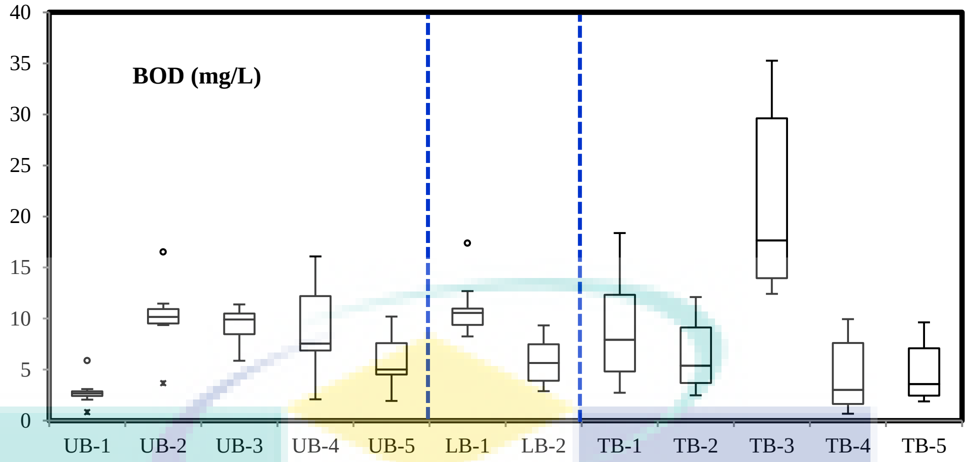

Figure 4.26 Spatial distribution of BOD among the sampling stations

Temporal variation of BOD among the periods and stations

By months, the ranges of BOD varied widely all around the year without showing any significant trend of variation. The average concentrations gradually decrease from January to June till the onset of rainy season. With increasing rainfall, the average concentration of BOD increased in the month of October during the rainy season. However, the concentration further dropped toward the month of February 2015 in the dry season (Figure 4.27).

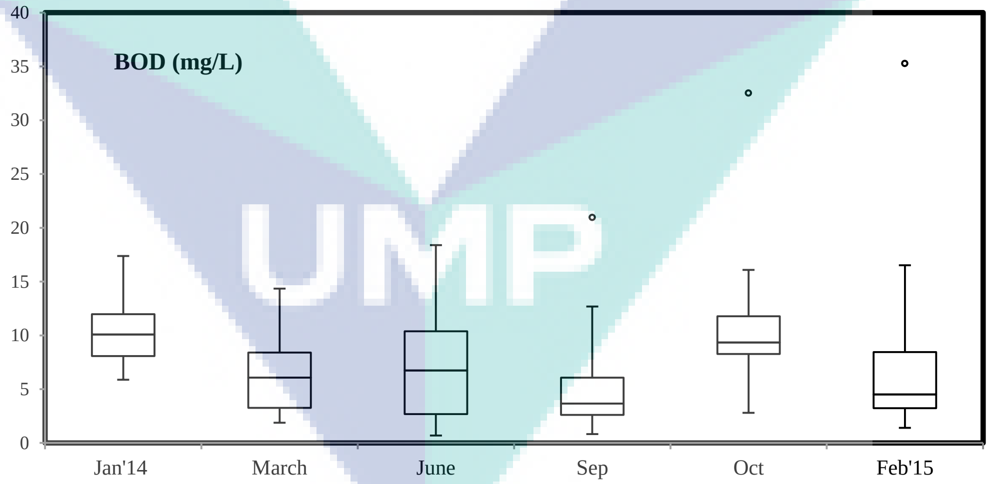

Figure 4.27 Temporal distribution of BOD among the sampling periods

From the analytical data, it found that the average concentration of BOD was higher during the rainy season than dry season. The seasonal distributions of BOD showed higher values in most of the station during the rainy season (Figure 4.28).

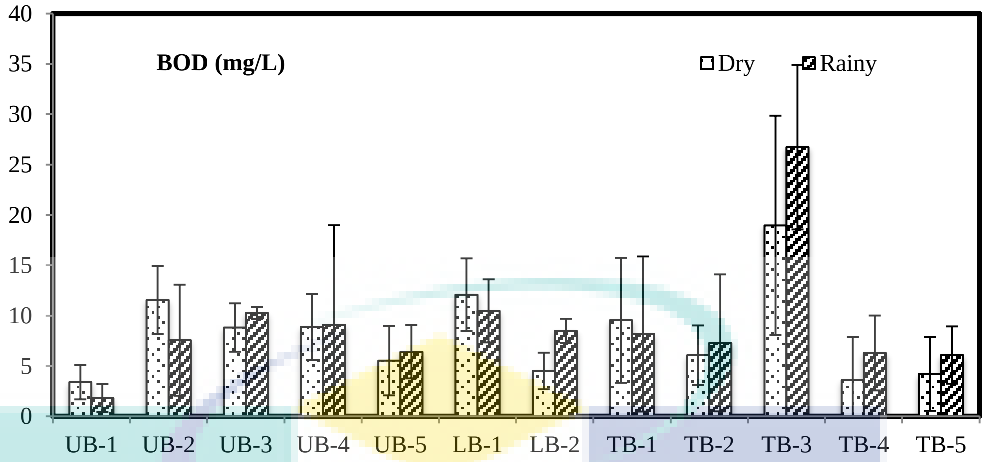

Figure 4.28 Seasonal distribution of BOD among the sampling stations

4.3.6.3 Chemical Oxygen Demand (COD)

Spatial variation of COD among the stations

The concentration of COD ranged from 5.00 to 64.00 mg/L with a mean average of 22.51 mg/L Figure 4.29 Spatial distribution of COD among the sampling stations(Figure 4.29). The values of COD showed a wide range of variation among the stations without following any specific trend. Similar to BOD, the mean concentration showed higher values than the acceptable limit (> 25 mg/L) for NWQS at stations UB2, TB2, TB3, and LB1 within the catchment. Along the Bertam River, the highest mean value of COD was found at station LB1 (28.06 mg/L), while the lowest of that was recorded at station UB1 (11.33 mg/L). Among the tributaries, the mean highest COD value (40.72) was recorded at station TB3 (Jasar River), while the lowest value (16.16 mg/L) was found at station TB4 (Batu Pipih River). The higher values of COD at stations UB2 (28.06 mg/L), TB2(27.11 mg/L), TB3 (40.72 mg/L), and LB1(28.06 mg/L) might be attributed to domestic wastewater discharged into the river stream from residential areas of Brinchang, Taman Sedia, Tanah Rata, and Ringlet towns ((Rasul, 2016). A number of researchers have mentioned that high COD values indicate water quality deterioration caused by the discharges of municipal wastewater (Kibena et al., 2014b; Kozaki et al., 2016; Mei et al., 2014).

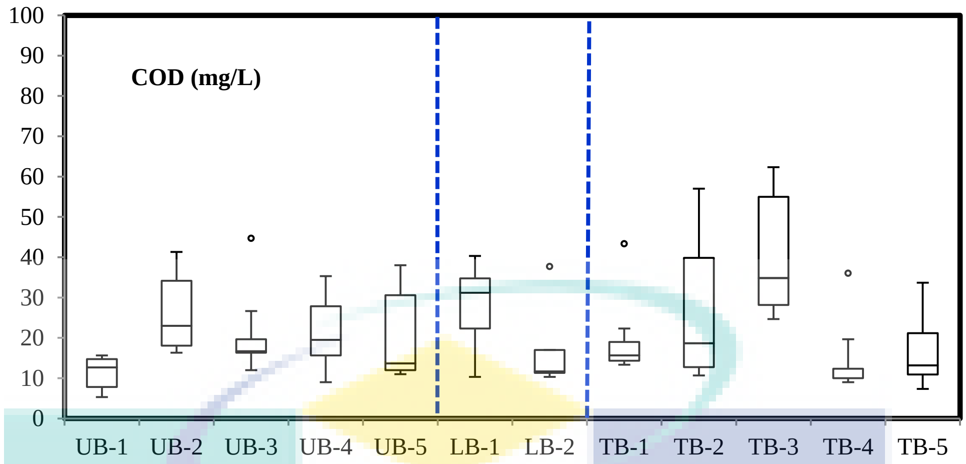

Figure 4.29 Spatial distribution of COD among the sampling stations

Temporal variation of COD among the periods and stations

By months, COD showed an inconsistent variation in the study area. However, a higher concentration of COD was observed during the months of January'14, February'15 and March'14 in the dry season. Conversely, the lower concentration was found during the months of September and October in the rainy season. The height means concentration was recorded in February'15 while the lowest was seen in October'14 (Figure 4.30).

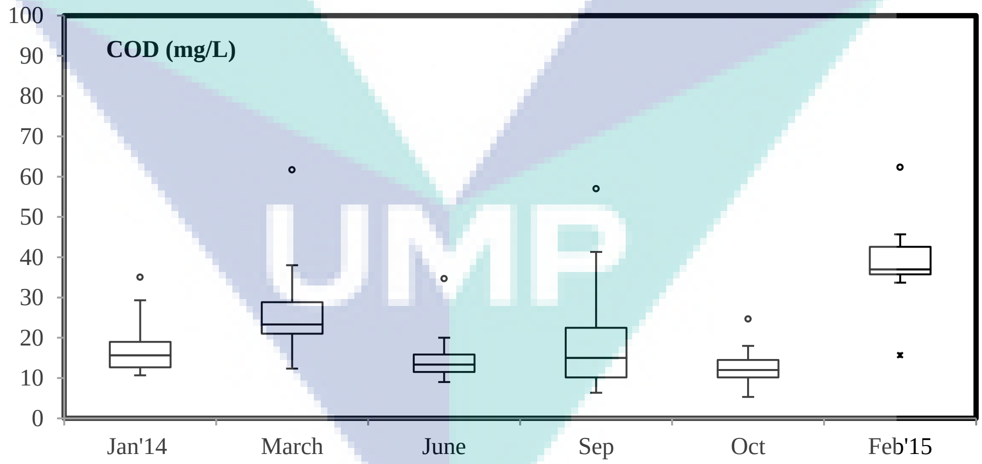

Figure 4.30 Temporal distribution of COD among the sampling periods

Seasonally, the average concentration values of COD showed higher in the dry season than a rainy season (Mei et al., 2014; Mustapha et al., 2012). From the seasonal observation, it showed that the concentrations of COD were higher in most of the stations during the dry season (Figure 4.31).

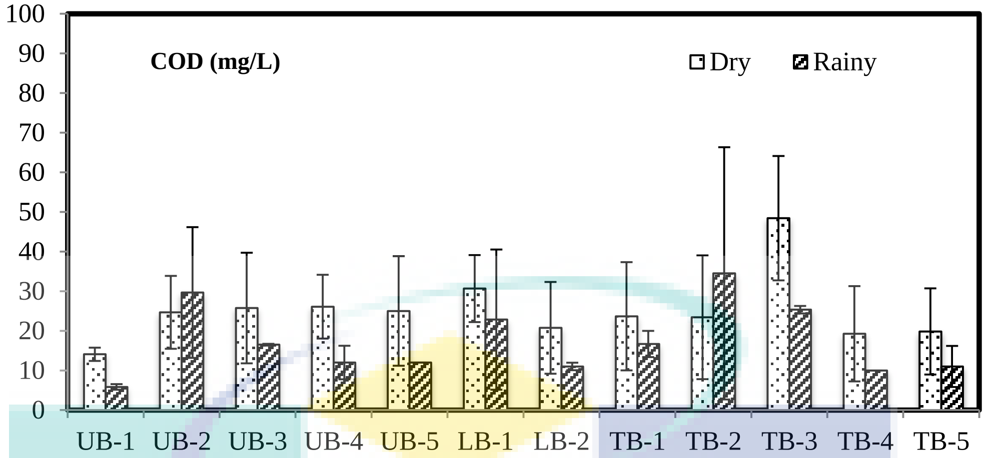

Figure 4.31 Seasonal distribution of COD among the sampling stations

4.3.6.4 Nitrate- nitrogen (NO_3-N)

Nitrate-nitrogen concentration was measured from 12 (Twelve) monitoring stations for 6 (Six) times and the data obtained were analyzed to know the spatio-temporal and seasonal distribution among the stations. The average concentrations are presented in Figure 4.32, Figure 4.33 and Figure 4.34 that show the spatial, temporal and seasonal variations.

Spatial variation of NO_3-N among the stations

In the catchment, the concentrations of NO_3-N ranged from 0.08 to 3.70 mg/L with a mean concentration of 0.89 mg/L among the stations. In the Figure 4.32, the NO_3-N values showed higher concentrations at sampled stations of Lower Bertam than that of Upper Bertam along the River. Thus, a spatial increasing trend was observed toward downstream with a little variation by the influences of its tributaries. The average highest NO_3-N was observed at station LB-2 (2.75 mg/L) followed by station LB-1 (2.44 mg/L). The lowest NO_3-N was recorded at station UB-1 (0.12 mg/L) which is the point of origin of the Bertam River located in the mountainous area. The lowest concentration of NO_3-N at this point was mainly due to lack of human activities. In the Lower Bertam, a higher concentration of NO_3-N was found at the stations LB1 and LB2. These might be attributed to agricultural runoff containing nitrogenous fertilizers from vegetable farming areas around the Lower Bertam Valley (Huang et al., 2010; Shrestha and Kazama, 2007), as well as runoff from upward eroded land (Bu et al., 2010). Ammonification and slower nitrification might also be taken place as well, which was evidenced by increased NO_3-N and lower dissolved oxygen concentrations in the lower region (Angyal et al., 2016). Among the tributaries, higher concentrations of NO_3-N was observed at stations TB1 (Burong River), TB4 (Batu Pipih River), and TB5 (Uluh River) located around the agricultural areas with their concentrations of 0.79 mg/L, 0.77mg/L, and 0.58 mg/L, respectively. Agricultural runoff containing fertilizers could be the major cause for such concentrations in these regions (Mouri et al., 2013; Wu et al., 2009).

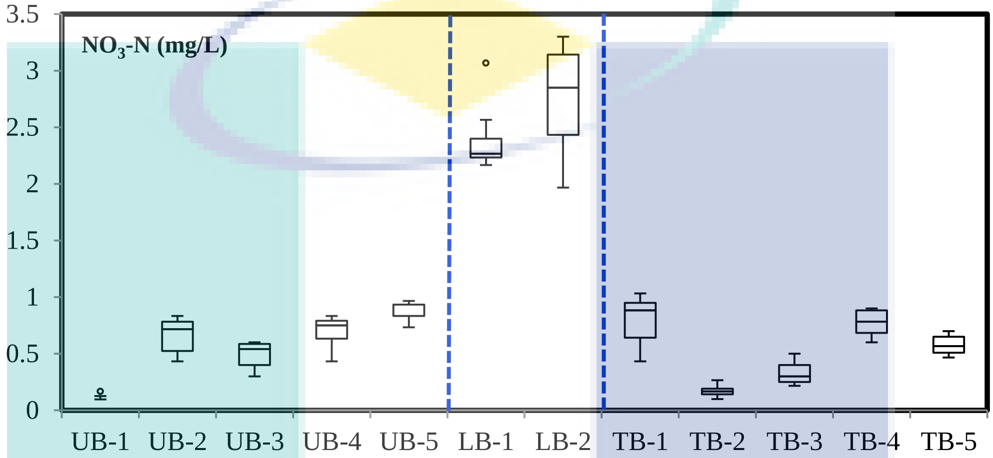

Figure 4.32 Spatial distribution of NO_3-N among the ssampling stations

Temporal variation of NO_3-N among the periods and stations

From the Figure 4.33 it can be seen that the highest concentration was recorded in the month of October during the higher amount of rainfall while the lowest was found in February. Rising effect of rainfall gradually increased the NO_3-N concentrations within the soil by overland flow and subsurface lateral flow as precipitation during the rainy season (Park et al., 2010; Wu and Chen, 2013). The farming practices, application of fertilizer and the rapid increased in overland runoff from agricultural areas was suspected for the variation in the average concentration of NO_3-N in the study area (Vega et al., 1998; Wu and Chen, 2013)

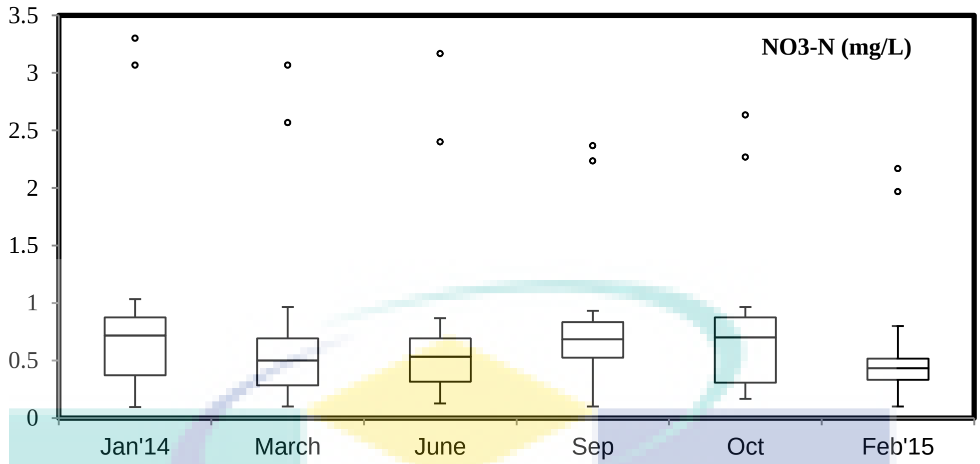

Figure 4.33 Temporal distribution NO_3-N among the sampling periods

Seasonally, a slightly increasing trend of NO_3-N value was observed from dry to rainy season with a very little exception in the month of January. From the seasonal distribution of NO_3-N concentrations, it can be seen that the NO_3-N showed higher values in almost all of the stations in rainy season except lower Bertam area where the values of stations were higher in the dry season (Figure 4.34). The present agricultural practices under close farming on steep and gentle slopes, hilltops or valley floor in the Lower Bertam region might be the reason for such variations (Aminuddin et al., 2005).

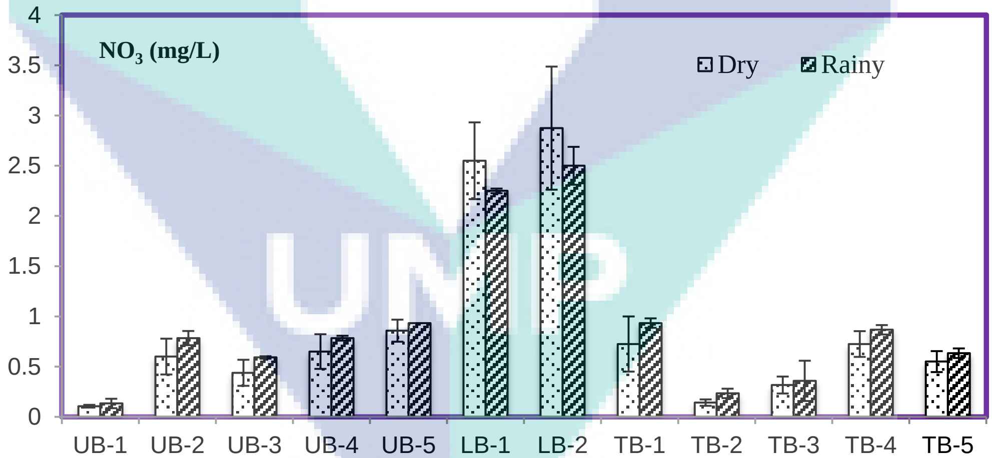

Figure 4.34 Seasonal distribution of NO_3-N among the sampling stations

4.3.6.5 Ammoniacal-nitrogen (NH_3-N)

NH_3-N concentration was measured from 12 (Twelve) monitoring stations for 6 (Six) times and the data obtained were analyzed to know the spatial-temporal and seasonal distribution among the stations. The average concentrations are presented in

Figure 4.35, Figure 4.36 and Figure 4.37 that shows the spatial, temporal and seasonal variations.

Spatial variation of Ammonia Nitrogen (NH_3-N) among the stations

In the studied catchment, the concentrations of NH_3-N ranged from 0.01 to 3.38 mg/L among the sampling stations. The mean concentration of NH_3-N (1.32 mg/L) showed a higher value than the guided value (> 0.30 mg/L) of NQWS of Malaysia. Spatially, the NH_3-N showed higher concentrations at sampled stations of Lower Bertam than that of Upper Bertam along the Bertam River. In the Upper Bertam, like other physical parameters, the lowest value of NH_3-N was observed at mountainous station UB1(Abildtrup et al., 2013). Ye et al. (2009) found that a similar forest-dominated region in Xiangxi Basin, China, had a low concentration of nutrient variables. Next, to UB1, the stations UB2 and UB3 showed increased concentrations of NH_3-N. These pollutants could originate from the decomposition of nitrogen-containing organic compounds as well as detergents occurring in municipal wastewater discharges from Brinchang town and the residential area of Taman Sedia in the study area (Angyal et al., 2016).

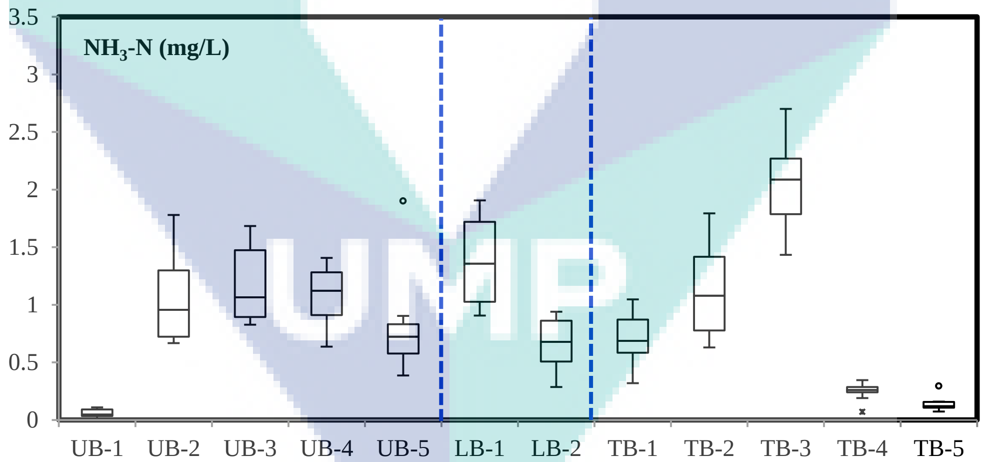

Figure 4.35 Spatial distribution of NH_3-N among the sampling stations

The higher concentration could also be due to influences of the Burong and Ruil tributaries as well as these two tributaries joined just before the stations. In the Lower Bertam, a high concentration of NH_3-N was found at the stations LB1 could be the reason for direct discharge of wastewater from the Ringlet town. Among the tributaries, the higher concentration of NH_3-N was observed at stations TB3 (Jasar River) and TB2 (Ruil River) amounting 2.10 mg/L and 1.36 mg/L, respectively. The discharge of untreated domestic sewage to the river from Tanah Rata town and small Ruil villages might be the reason behind such increment (Zhang et al., 2015). NH_3–N was mainly from the relatively constant municipal PS pollution loads in the studied area.

Temporal Variation of NH_3-N among the periods and stations

Temporarily, the ranges of NH_3-N varied all around the year but did not show any significant trend of variation. From the Figure 4.36, the average highest concentration was observed in the month of March followed by January, February, and June during dry season while the lowest was recorded in October during the rainy season.

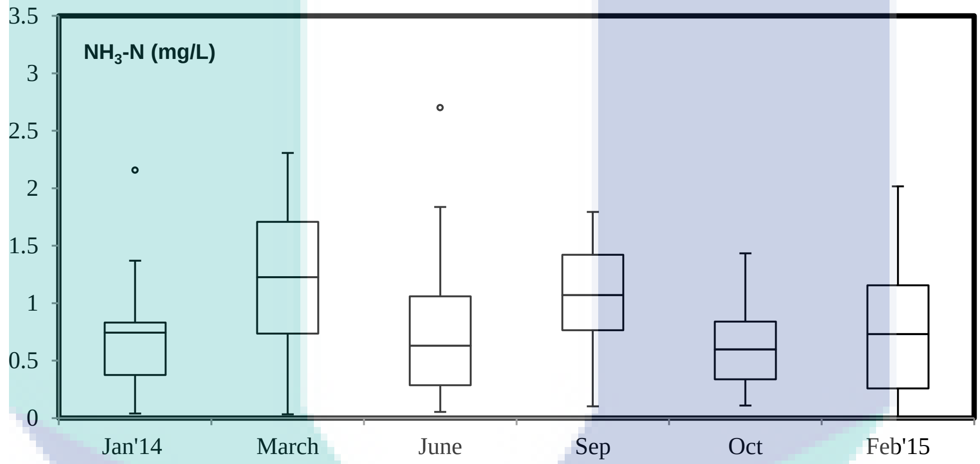

Figure 4.36 Temporal distribution of NH_3-N among the sampling periods

Seasonally, NH_3-N showed average higher concentration duSring the dry season than rainy season. The concentration decreased in the rainy season probably due to the dilution effect of heavy rainfall as well as the influence of streamflow. Wu and Chen (2013) found that low streamflow increased the concentration of NH_3-N in the dry season while high streamflow decreased the concentration in the rainy season in East River (Dongjiang) in South China. However, in the studied catchment, the concentration of NH_3-N showed higher values especially the stations around the urban areas in the dry season and those of around agricultural areas in the rainy season (Figure 4.37). Mei et al. (2014) showed the similar impact of TN influenced by tributaries at Wen-Rui Tang River watershed of eastern China

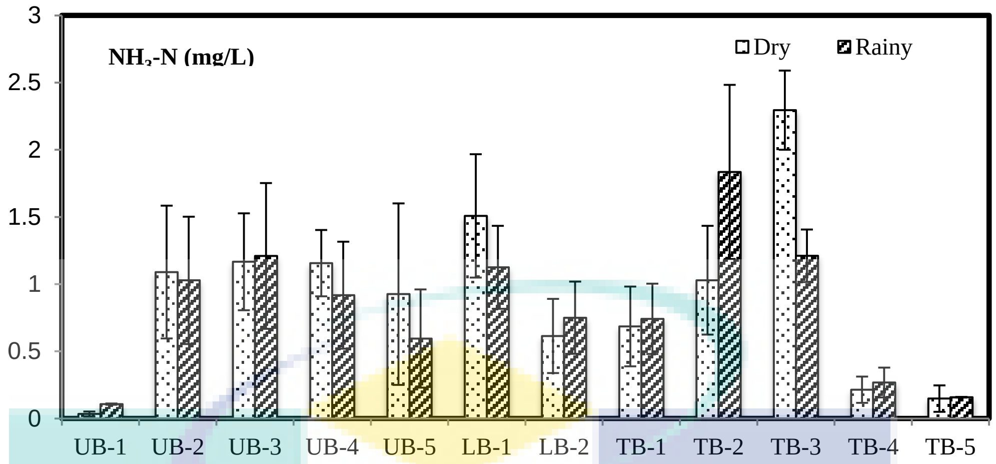

Figure 4.37 Seasonal distribution of NH_3-N among the sampling stations

4.3.6.6 Total Nitrogen (TN)

Spatial variation of Total Nitrogen (TN) among the stations

In the studied catchment, the concentrations of total nitrogen (TN) ranged from 0.20 to 10.90 mg/L with a mean concentration of 3.16 mg/L. From the Figure 4.38, it can be seen that the highest concentration was observed in the station LB1 (5.99 mg/L) while the lowest was at station UB1 (0.47 mg/L). Moreover, the stations of Lower Bertam showed a higher concentration of TN than that of Upper Bertam.In the Upper Bertam, higher TN values were observed at stations UB4 (3.31 mg/L) and UB5 (3.24 mg/L) due to the combined effect of point and nonpoint sources of Brinchang town and the residential area of Taman Sedia as well as agricultural activities. Another reason could be the influenced by Jasar (TB3), Batu Pipih (TB4), and Uluh (TB5) tributaries. Mei et al. (2014) showed the similar impact of TN influenced by tributaries at Wen-Rui Tang River watershed of Eastern China. In the Lower Bertam, higher concentrations TN were found at the stations LB1 and LB2 could occur as a result of the combined effect of point and nonpoint sources from the aforementioned agricultural farming areas and residential wastewater around the Lower Bertam Valley. Similar findings were reported by many researchers that the diversification of the agriculture practices, involving the use of fertilizers as well as the residential wastewater and a poor sewage system, was the potential sources of high nitrogen concentrations (Kibena et al., 2014b; Kilonzo et al., 2014). Among the tributaries, the highest value of TN was recorded at station TB-3 (Sungai Jasar) (4.07 mg/l) followed by station TB-1 (Sungai Burong) and station TB-4 (Sungai Batu Pipih), relating to their higher concentrations of NH_3-N and NO_3-N respectively.

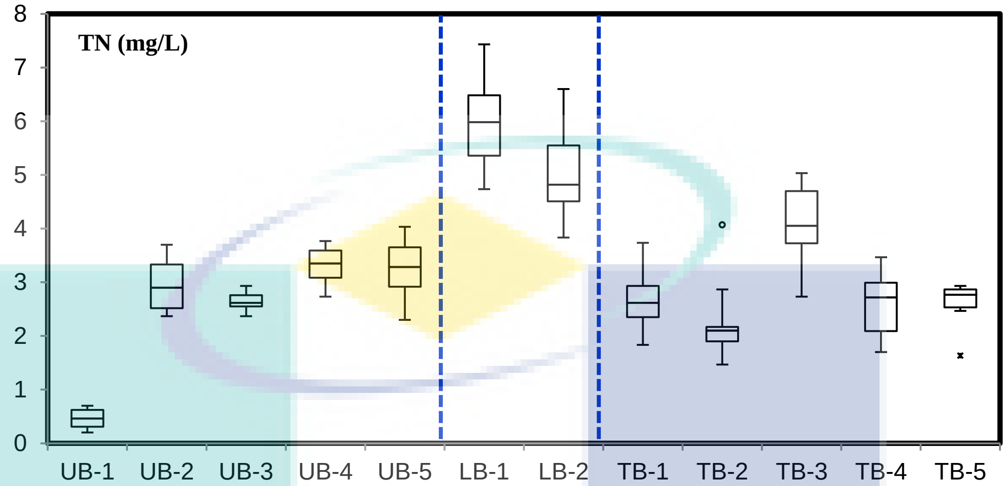

Figure 4.38 Spatial distribution of TN among the sampling stations

Temporal Variation of TN among the periods and stations

An increasing trend of TN values was observed during the months of the dry season till the onset phase of the rainy season. With higher rainfall in the month of October, the trend of TN declines widely in the study area. Higher precipitation is the main reason for the dilution effect as well as the changing trend during the rainy season (Figure 4.39).

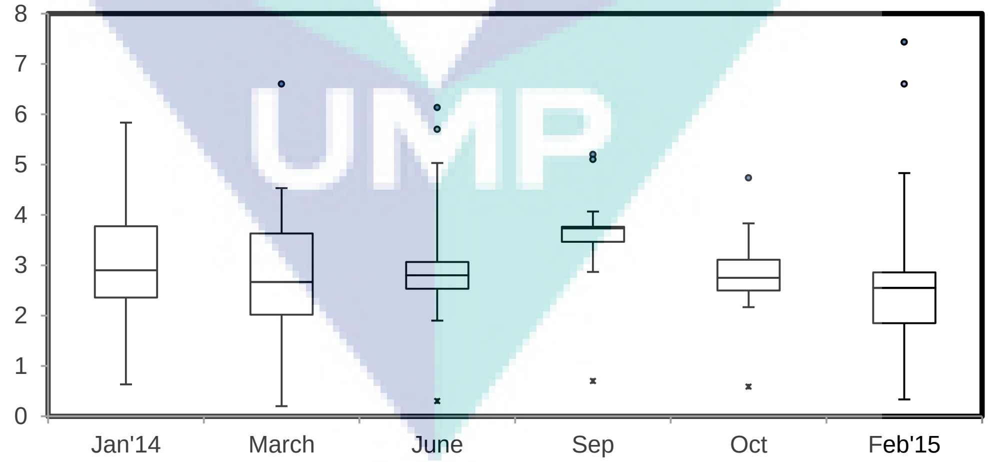

Figure 4.39 Temporal distribution of TN among the sampling periods

Besides, the concentration of TN showed higher values especially the stations (UB-2, LB-1, lB-2, and TB-3) around the urban areas in the dry season and those of around the agricultural areas in the rainy season (Figure 4.40).).

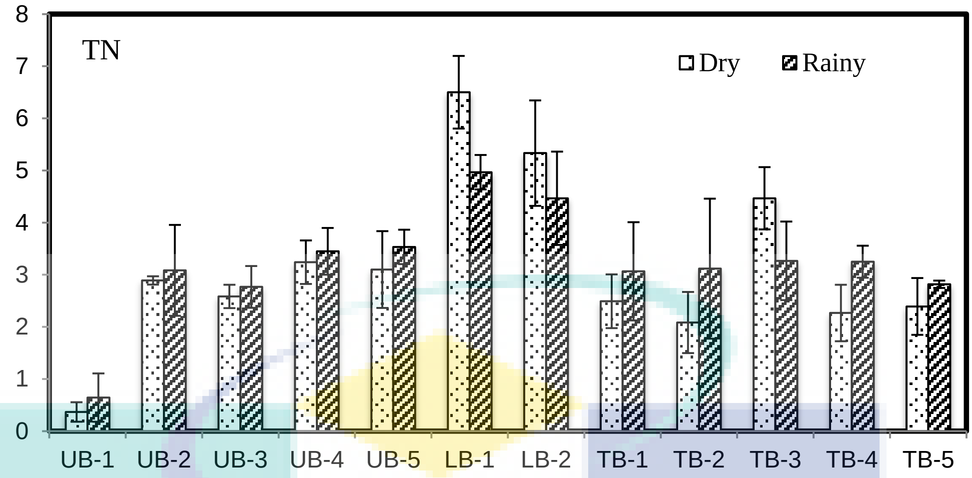

Figure 4.40 Seasonal distribution of TN among the sampling stations

4.3.6.7 Phosphate-phosphorous (PO_4-P)

Spatial Variation of PO_4-P among the stations

In the studied catchment, the concentrations of phosphate phosphorous (PO_4-P) was recorded within the ranges of 0.10 to 2.22 mg/L. The mean concentrations of PO_4-P (0.74 mg/L) showed a higher value than the guiding value of NQWS of Malaysia. The average lowest concentration (0.15 mg/L) was observed at its origin at station UB-1 while the highest average concentration (1.34 mg/l) was recorded in the Lower Bertam at station LB-2. From theFigure 4.41, the higher concentrations of PO_4-P were observed at sampled stations of Lower Bertam than that of Upper Bertam along the Bertam River. In the Upper Bertam, like other parameters, the lowest value (0.15 mg/L) of PO_4-P was observed at mountainous station UB1. Next, to UB1, the stations UB2 and UB3 showed increased concentrations of PO_4-P. The higher concentrations could originate from domestic and municipal wastewater discharges from Brinchang town and the residential area of Taman Sedia in the study area (Ai et al., 2015; Vega et al., 1998). Another reason could be due to the influences of the Burong (TB-1) and Ruil (TB-2) tributaries as well. In the Lower Bertam, a high concentration of PO_4-P was found at the stations LB1 and LB2. These might be attributed to agricultural runoff containing phosphorous fertilizers from vegetable farming areas around the Lower Bertam Valley (Huang et al., 2010), as well as runoff from upward eroded land (Bu et al., 2010). Among the tributaries, higher concentrations of NO_3-N, PO_4-P, and TP were observed at stations TB1 (Burong River), TB4 (Batu Pipih River), and TB5 (Uluh River) located around the agricultural areas (Figure 2I, K, L). Agricultural runoff containing fertilizers could be the major cause for such concentrations (Mouri et al., 2013).

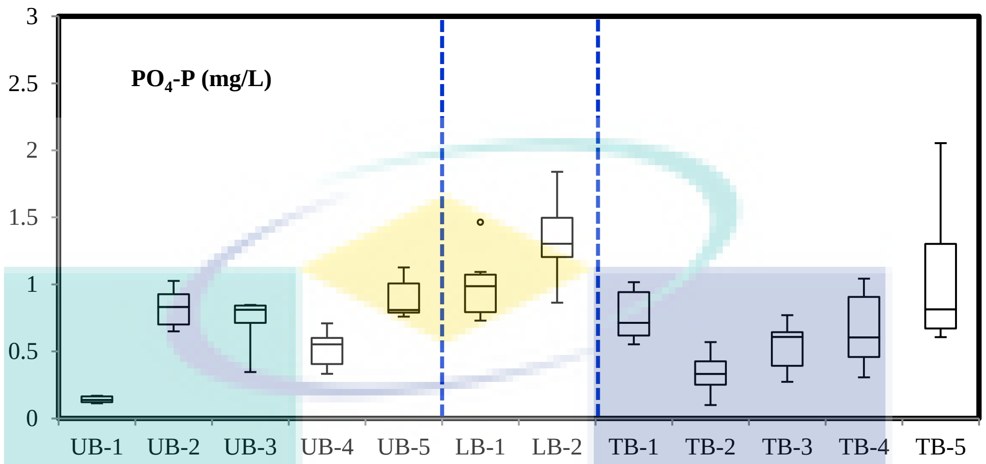

Figure 4.41 Spatial distribution of PO_4-P among the sampling stations

Temporal Variation of PO_4-P among the periods and stations

By months, the average PO_4-P value showed a wide range of variation during the study period. The average higher values were observed during the months of September and November during rainy season while the lower values were in January, February, March, and June during the dry season. From the Figure 4.42, the average highest concentration was observed in the month October, while the lowest concentration was on February'15.

Seasonally, the concentration of PO_4-P values showed an increasing trend of variation from dry to rainy season. The overland runoff from agricultural and urban areas was suspected to have caused such temporal variation in the concentration of PO4-P within the catchment (Wu et al., 2009). The active and stable mineral P can only be transported by surface runoff when attaching to sediments (Wu and Chen, 2013). However, from the Figure 4.43, it can be seen that most of the stations showed higher value during the rainy season due to the influence of the agricultural activities.

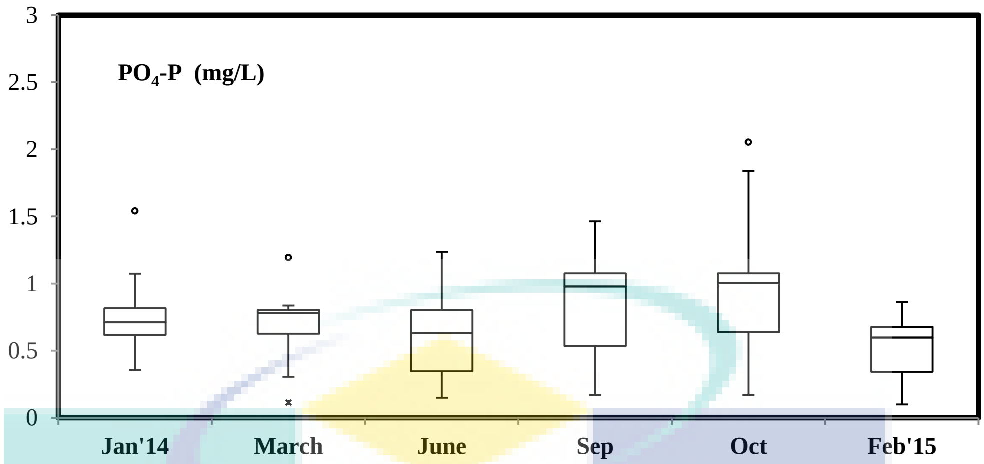

Figure 4.42 Temporal distribution of PO_4-P among the sampling periods

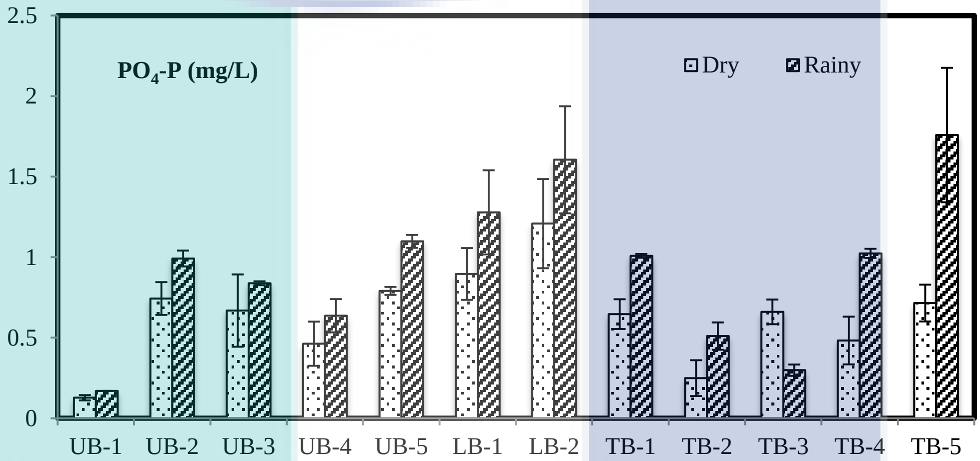

Figure 4.43 Seasonal distribution of PO_4-P among the sampling stations

4.3.6.8 Total phosphorous (TP)

Spatial Variation of TP among the stations

The concentrations of total phosphorous (TP) were recorded within the ranges of 0.12 to 2.80 mg/L with a mean concentration of 1.14 mg/L. In the catchment, the spatial variation of TP showed the similar trend of the pattern as PO4-P. Along the Bertam River, TP showed an increasing trend toward downward with a little variation at stations UB2 and UB3. The variation of TP concentrations at these two stations could be found due to the influences of the Burong (TB-1) and Ruil (TB-2) tributaries. The highest concentration of TP (1.15 mg/L) was observed in station LB-2, while the lowest was at station UB-1 (0.26 mg/L). Spatially, TP showed higher concentrations at sampled stations of Lower Bertam than that of Upper Bertam (Figure 4.44). In the Lower Bertam, high concentrations of TP were found at the stations LB1 and LB2. Among the tributaries, higher concentrations of TP was observed at stations TB1

(Burong River), TB4 (Batu Pipih River), and TB5 (Uluh River) located around the agricultural areas. Higher concentration of TP at stations LB-2 (1.15 mg/L), LB-1 (1.71 mg/L), TB-1 (1.15 mg/L), TB-4 (1.05 mg/L) and TB-5 (1.41 mg/L) indicated that agricultural runoff containing fertilizers were probably the major causes for concentration of PO4-P (Mouri et al., 2013) On the other hand, the concentration at UB-2 and UB-3 may be due to the residential and municipal wastewater discharges (Ai et al., 2015) as well as the influence of Burong and Ruil tributaries (Bu et al., 2010).

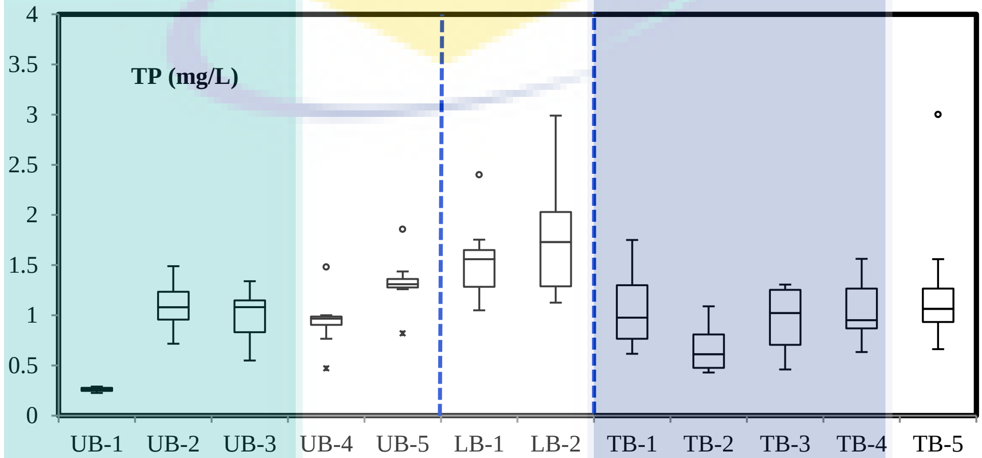

Figure 4.44 Spatial distribution of total TP among the sampling stations

Temporal Variation of TP among the periods and stations

In the catchment, the average concentration of TP showed a wide range of variation during the study period. From the Figure 4.45, the highest concentration of TP was observed in September 2014 while the lowest was found in February 2015. The average higher values were observed in the months of September and October during the rainy season than the months of January, March, June, and February during the dry season (Duan et al., 2013). The rainfall washed TP out of the eroded sediments and discharged into the water body, causing the differences in TP concentration between the dry and rainy seasons.

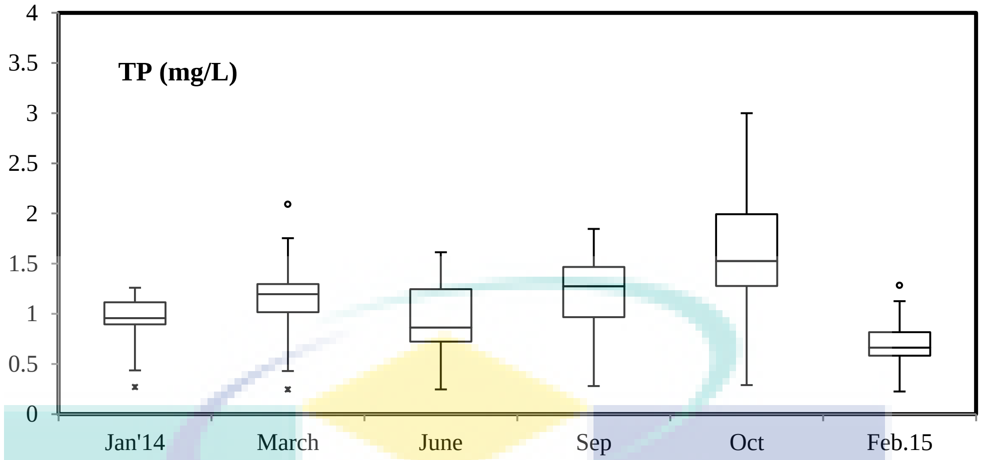

Figure 4.45 Temporal distribution of TP among the sampling periods

Seasonally the TP concentrations showed an increasing trend from dry season to rainy season. From the Figure 4.46, the seasonal variations of TP concentrations showed higher values at most of the stations during the rainy season. The overland runoff from agricultural and urban areas was suspected to have caused such temporal variation in the concentration of these nutrients within the catchment (Lu et al., 2011).

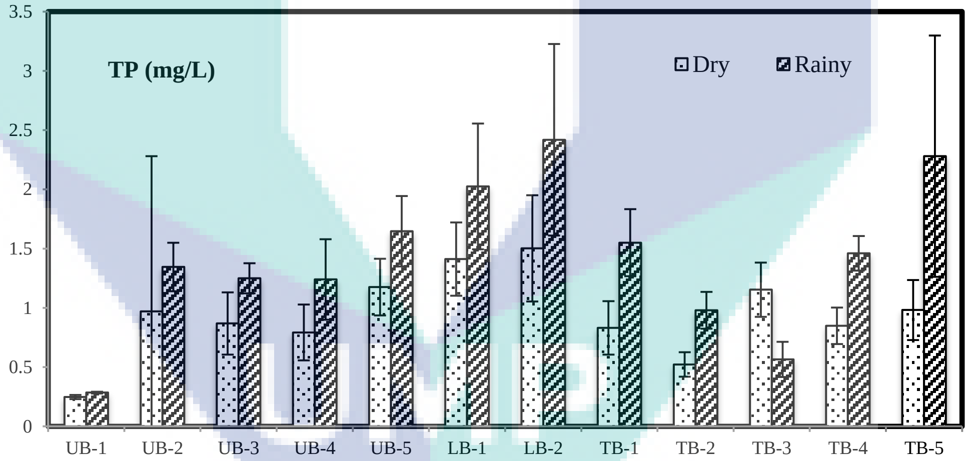

Figure 4.46 Seasonal distribution of TP among the sampling stations

4.3.7 Pollution Zones and Sources Identification

Different multivariate statistical techniques as HCA and PCA were performed to investigate the grouping of the sampling stations and periods and to identify the main pollution factors and sources. HCA grouped all the sampling stations into three different clusters and all the sampling periods into two groups. PCA identified three major factors for sources of pollutions.

4.3.7.1 Hierarchical Cluster Analysis (HCA)

A dendrogram was used to interpret the result of the cluster analysis. This dendrogram used the correlation between variables to identify the similarities of variables. The cluster was statistically significant at complete linkage similarities within 46.49% and the number of clusters was decided by the practicality of the results.

Based on the 14 water quality variables, cluster analysis classified the 12 sampling sites into three distinct clusters, represented as clean to less pollution, moderate pollution, and high pollution levels (Figure 4.47). Cluster 1 was formed by sites UB1, UB2, and TB1 while cluster 3 was composed by sites LB1, LB2, TB4, and TB5. The other five sites were attributed to cluster 2. The sampling sites of cluster1were located at the upper part of the catchment. Among the sites of cluster 1, UB1 was located at the source point of the river system in a mountainous area and free from all human activities. Thus, the station was clean. However, UB2 and TB1 included in this cluster were not clean as UB1 but less polluted compared to others.

In cluster 2, the stations, UB3, UB4, TB2 and TB3 were located at upper to middle part of the river that experienced the influences of untreated domestic sewage discharge and poor waste treatment facilities from the two main towns, namely Tanah Rata, Ringlet, and small settlement areas that include a dense population of the Highlands. Thus, the water quality found to be moderately polluted by the influence of urban activities.

Stations LB1, LB2, TB4 and TB5 were grouped in cluster 3 located in lower part of the river system. Within the catchment, the lowest-quality water was observed at stations LB1 and LB2 in Lower Bertam. The water quality was mainly influenced by agricultural runoff as well as untreated domestic sewage discharge of Ringlet town and the settlement of Bertam Valley. Approximately 68% of market gardening areas (vegetables and flowers) are located at Ringlet and Bertam Valley region in the Lower Catchment. Moreover, the water quality of TB4 and TB5, two tributaries of Bertam River in the lower catchment were also influenced by the agricultural activities surrounding the sampling area.

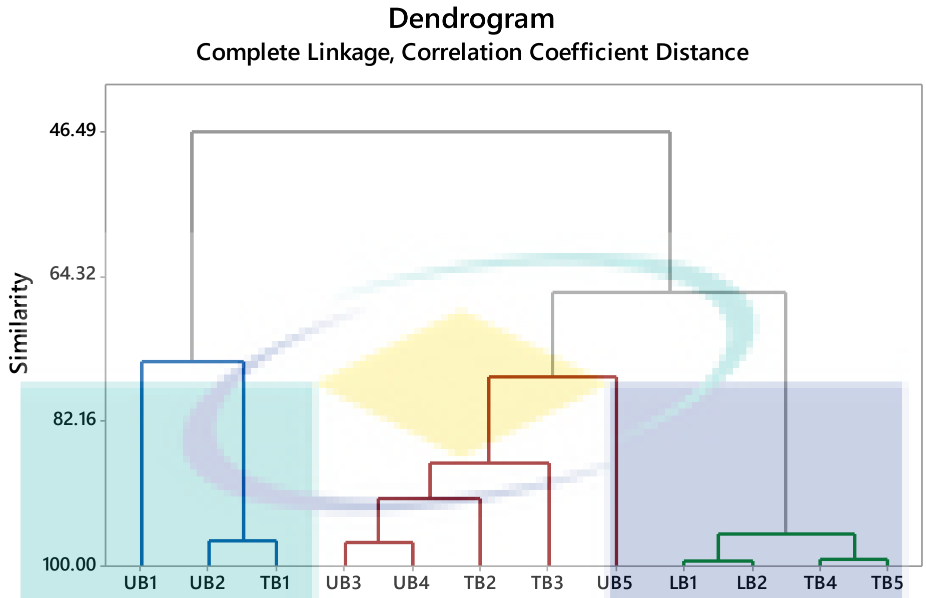

Figure 4.47 Dendrogram showing spatial cluster analysis of sampling stations
Cluster 1: UB1 UB2 TB1; **Cluster 2:** UB3 UB4 UB5 TB2 TB3; **Cluster 3:** LB1 LB2 TB4 TB5

Temporal variations generated a dendrogram depicting the six months sampling periods into two distinct clusters within 93.66% linkage similarities (Figure 4.48). Cluster 1 is composed of the sampling months, January, February March, and June corresponding to low flow periods. Cluster 2 is grouped by September and October corresponding to low flow periods. From the cluster analysis, it is clearly showed that the sampling periods are classified as distinct dry and d rainy seasons. Moreover, the characteristics of temporal variation in the water quality of the catchment were greatly determined by hydrological conditions and local climate characteristics in Cameron Highlands.

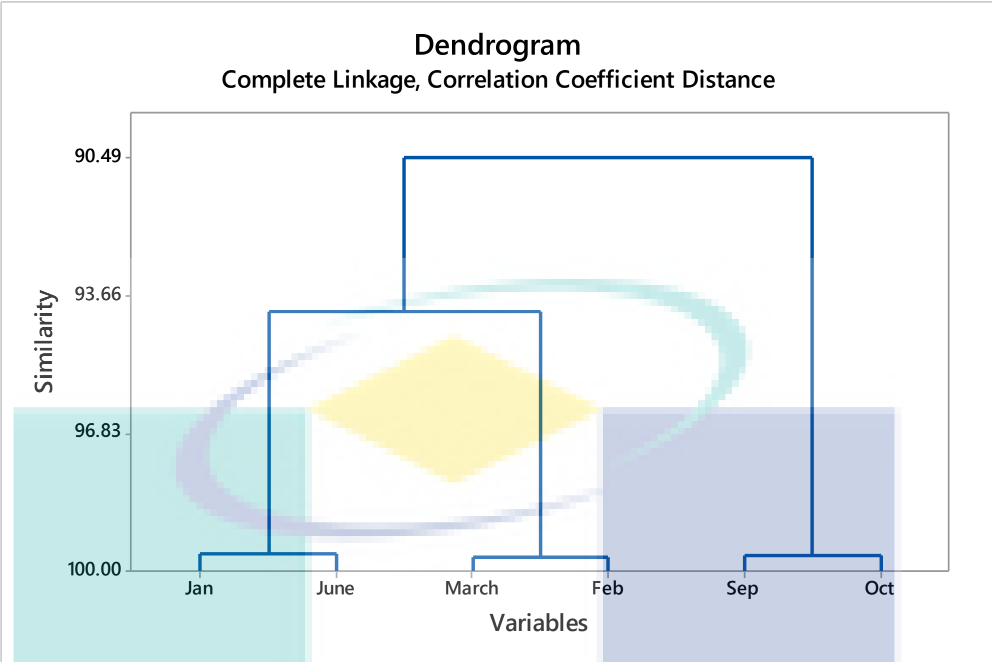

Figure 4.48 Dendrogram showing temporal clustering of sampling periods

4.3.7.2 Principal Component Analysis (PCA)

In the present study, the KMO value was found to be 0.828, indicating that the variables were correlated enough for appropriate PCA and interpreted as meritorious according to the guideline of Kaiser (1974). Similarly, Bartlett's test of sphericity in this study showed significant level .000 ($p<0.01$) confirmed that PCA can be applicable for source apportionment (Table 4.5).

Table 4.5 KMO and Bartlett's Test for water quality parameters

KMO and Bartlett's Test		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy		.828
Bartlett's Test of Sphericity	Approx. Chi-Square	2443.517
	df	105
	Sig.	.000

Based on the correlation matrix of parameters, the results of PCA showed that the first three rotated components with an eigenvalue greater than 1 were extracted and explained 70.92% of the total variance (Table 4.6 and Table 4.7). The three principal components are considered three major factors of source pollutions that deteriorated the water quality of the Bertam River Catchment (Table 4.8). Factor 1, designated as a nutrient factor, accounting for 48.30% of the total variance, was highly correlated with major physicochemical variables (EC and TDS) and nutrients (NO_3, PO_4, and TP) (Bu et al., 2010). These variables are attributed to the discharge of domestic sewage as well as agricultural runoff which introduce a significant amount of ions into the river system. Factor 2, named as the erosion factor, accounted for 13.02% of the total variance and was strongly correlated with turbidity, TSS and streamflow infer that the turbidity is greatly affected by higher soil erosion and sedimentation from the farms cultivated on hill slopes. It is also influenced by the rate of streamflow as well as the concentration of TSS changed by seasons (Mustapha et al., 2012). Factor 3 accounted for 9.60 % of the total variance and was highly associated with negative DO and positive BOD, COD, and NH_3 indicating decomposition of organic matter and nitrification of ammonia (Chen and Lu, 2014; Mustapha et al., 2012). The highest values of BOD and COD were recorded at sampling sites around urban areas where water quality is influenced by wastewater discharge of domestic and municipal waste as well as a poor sewage system.

Table 4.6 Factor loadings of the 15 variables on VARIMAX rotation in the Bertam Catchment

Total Variance Explained

Component	Initial Eigenvalues			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	7.245	48.298	48.298	5.270	35.135	35.135
2	1.954	13.028	61.327	2.633	17.554	52.690
3	1.439	9.591	70.918	2.498	16.652	69.341
4	1.170	7.802	78.720	1.407	9.378	78.720

Table 4.7 Rotated Component Matrix of sixteen variables

Rotated Component Matrix				
Parameters	Component			
	1	2	3	4
Temp	.831	.129	.041	.097
pH	.050	.119	-.081	.914
EC	.824	.314	.288	.184
TDS	.811	.326	.324	.209
Turbidity	.439	.807	.226	.099
TSS	.251	.839	.112	.102
DO	-.338	.239	-.644	-.479
BOD	.214	-.015	.817	-.080
COD	-.151	.254	.633	-.096
NH_3N	.255	.573	.633	.290
NO_2N	.600	.169	.545	.007
NO_3N	.907	.168	-.050	-.048
PO_4P	.835	.166	.101	-.007
TP	.799	.325	.146	-.007
Flow	.466	.635	-.151	-.364

- Bold values represent strong loadings.

Table 4.8 List of significant latent pollution sources in the catchment

Factor	% of the variance	Name of the factor	Pollution
PC1	48.30%	Nutrient factor	Nutrients Pollution
PC2	13.02%	Erosion factor	Soil erosion Pollution
PC3	9.60%	Organic decomposition factor	Organic pollution

4.3.8 Water Quality Classification based on DOE-WQI

The Water Quality Index (WQI) value of different stations of Bertam River and its tributaries was calculated based on six parameters namely DO, BOD, COD, SS, NH3-N and pH and their sub-indices value. Measured concentrations of selected parameters were summarized for each station on a seasonal basis to analyze the temporal variability of DOE-WQI values. The statistical summary of indicator parameters is shown in Table 4.9 and the average results of WQI, their status, and their corresponding water class is presented in Table 4.10. The result showed that all the calculated WQI values were ranged from 57 to 95 indicating clean to polluted water quality status of the Bertam River and its tributaries within the catchment. The overall water quality status of the Bertam Catchment is classified as "**Slightly Polluted**" and falls under **class III** category.

4.3.8.1 Spatio-temporal Variation of Water Quality Status based on DOE-WQI

The WQI value of station UB-1 is 93 in the dry season and 95 in rainy seasons, respectively. The water at this station falls underwater class I, all around the year. According to DOE-WQI, the status is clean. No treatment is necessary except disinfection and boiling only for water supply purpose. The reason behind the cleanliness is the location of the station. It is located at the source of Bertam River in Mountain Brinchang wherein it flows through the forest with no human influence. Due to its natural flow and intact stream banks, the level of suspended solids is very low.

The station UB-2 is located just after the Brinchang town and confluence of Sg. Burong and main river course. WQI value of the station is 75 in the dry season and 77 in the rainy season, respectively. Thus, the water at this station falls under the water class III in the dry season and class II in the rainy season. Direct discharge of domestic wastewater and agricultural runoff are the responsible for the high concentration of BOD, COD, and NH3-N as well as the main reason for low WQI at this station. According to DOE-WQI, the water at this station is slightly polluted all around the year and is suitable only for recreational use with body contact.

The WQI values of station UB-3, UB-4, and UB-5 are ranked as 73, 69 and 73 in the dry season and 66, 72 and 74 in the rainy season, respectively. Low sub-index value of ammoniacal nitrogen and suspended solids are mainly responsible for the lower value of WQI. Both the seasons, the water of these three stations falls under the water class III with slightly polluted status. According to DOE-WQI, the water in these regions is sensitive for aquatic species and only suitable for recreational use with body contact.

Among the tributaries, the Sungai Burung (station TB-1) joint first with the main course of Bertam River near at Golf course of Brinchang when it runs through the outer skirts of Brinchang town. The WQI values of the station are 77 in the dry season and 79 in the rainy season, respectively. The lower sub-index values of BOD and NH_3-N are responsible for the lower value of WQI. According to DOE-WQI, the water at this station is slightly polluted all around the year and is suitable only for recreational use with body contact. Sungai Ruil (TB-2) and Sungai Jasar (TB-3) joint with the main river course at village Taman Sedia and Tanah Rata town in the Upper Catchment. The results from the Table 00 showed that the water quality status at station TB-2 (Sungai Jasar) was polluted both dry and rainy seasons. The QWI value was 57 in both the seasons. Very low values of BOD, COD, AN and SS sub-indices were responsible for the pollution of water in the river. The water quality of Sungai Jasar found the most polluted status within the Bertam Catchment. According to DOE-WQI, the water at this station requires extensive treatment and it is threatened for sensitive species and common for tolerant species. On the other hand, Sungai Ruil found slightly polluted status in term of WQI values all around the year. Low SS sub-index is mainly responsible for the deterioration of water quality at this station. During the sampling periods, extensive development activities were observed at the upstream side as well as at surrounding areas of the Sungai. Such activities might increase the suspended sediment along the stream. Along the Lower Bertam, the other two tributaries namely, Sungai Batu Pipih (TB-4) and Sungai Uluh (TB-5) show clean status in their quality. WQI value of Sungai Uluh falls under class I in both the seasons. However, the WQI value for Sungai Batu Pipih turns to slightly polluted status in the rainy season due to lower sub-index value of TSS.

In the Lower Catchment, The WQI values of station LB-1 and LB-2 are found as 63 and 77 in the dry season and 66 and 68 in the rainy season, respectively. Low sub-index value of ammoniacal nitrogen and suspended solids are mainly responsible for the lower value of WQI. Both the seasons, the water of these two stations falls under slightly polluted status with class III for LB-1, class II and III for LB-2. According to DOE-WQI, the water in these regions is sensitive for aquatic species and only suitable for recreational use with body contact.

Table 4.9 Statistical Summary of Indicator parameters for Water Quality Index (WQI) in Bertam Catchment

Station		**Dry Season**						**Rainy Season**					
		pH	DO (mg/L)	BOD (mg/L)	COD (mg/L)	NH_3-N (mg/L)	TSS (mg/L)	pH	DO (mg/L)	BOD (mg/L)	COD (mg/L)	NH_3-N (mg/L)	TSS (mg/L)
Main River													
UB-1	Mean	6.40	7.64	3.39	14.08	0.03	3.83	6.68	7.42	1.81	5.83	0.11	5.42
	SD	0.24	0.19	1.71	1.66	0.02	2.08	1.45	0.02	1.39	0.71	0.00	0.24
UB-2	Mean	7.02	7.48	11.55	24.67	1.09	34.17	6.61	6.96	7.57	29.67	1.03	27.50
	SD	0.61	0.48	3.37	9.21	0.49	31.35	1.59	0.12	5.51	16.50	0.47	10.14
UB-3	Mean	6.70	7.34	8.81	25.75	1.17	129.50	6.27	6.71	10.26	16.50	1.21	508.83
	SD	0.47	0.47	2.40	13.96	0.36	46.62	0.66	0.19	0.58	0.24	0.54	39.36
UB-4	Mean	6.73	6.74	8.88	26.08	1.16	95.08	6.77	6.31	9.08	12.00	0.92	258.17
	SD	0.68	0.65	3.27	8.05	0.25	31.33	1.44	0.05	1.90	4.24	0.40	85.56
UB-5	Mean	6.41	8.58	5.53	25.00	0.93	307.50	6.35	8.00	6.41	12.00	0.65	417.17
	SD	0.79	0.40	3.45	13.81	0.68	269.44	0.10	0.16	2.65	0.00	0.37	5.89
LB-1	Mean	7.05	5.45	12.08	30.67	1.51	280.17	7.24	6.14	10.47	22.83	1.13	461.00
	SD	0.37	0.35	3.60	8.45	0.46	343.77	0.71	0.26	3.13	17.68	0.31	161.69
LB-2	Mean	6.45	7.43	4.50	20.75	0.61	220.50	6.82	7.17	8.84	11.00	0.75	1210.17
	SD	0.32	0.33	1.82	11.59	0.28	104.45	0.15	0.01	1.21	0.94	0.27	1156.59
Tributaries													
TB-1	Mean	6.95	7.66	7.04	23.67	0.61	46.17	6.73	7.27	8.18	16.67	0.74	25.67
	SD	0.78	0.21	2.12	13.65	0.30	48.04	1.40	0.12	7.70	3.30	0.26	16.03
TB-2	Mean	6.75	7.56	6.06	23.42	1.03	488.83	7.46	7.24	7.29	34.50	1.34	3003.17
	SD	0.80	0.28	2.95	15.60	0.41	512.58	1.93	0.07	6.80	31.82	0.65	1834.47
TB-3	Mean	6.68	5.48	18.96	48.42	2.30	81.58	6.33	5.80	20.73	25.33	1.57	224.67
	SD	0.41	0.47	10.90	15.69	0.29	41.10	0.36	0.37	3.18	0.94	0.20	50.91
TB-4	Mean	6.66	7.91	3.60	19.25	0.21	104.67	6.92	7.68	6.29	10.00	0.27	1122.17
	SD	0.58	0.41	4.29	12.02	0.10	51.37	0.88	0.03	3.71	0.00	0.11	1420.58
TB-5	Mean	6.41	7.80	4.21	19.83	0.15	24.50	6.68	7.69	6.08	11.00	0.16	420.67
	SD	0.69	0.45	3.65	10.87	0.10	11.18	0.01	0.04	2.85	5.19	0.00	577.00
	Min	6.40	5.45	3.39	14.08	0.03	3.83	6.27	5.80	1.81	5.83	0.11	5.42
Overall	Max	7.05	8.58	18.96	48.42	2.30	488.83	7.46	8.00	26.73	34.50	1.57	3003.17
	Average	6.68	7.76	7.88	25.13	0.90	151.15	6.74	7.03	9.08	17.28	0.82	640.25

Table 4.10 WQI and sub-index parameter values and overall water status during the dry and rainy season of all monitoring stations in Bertam Catchment.

Location	Station	Dry Season									Rainy Season								
		Sub-Index of Parameters						Water Quality Index			Sub-Index of Parameters						Water Quality Index		
		DO SI	BOD SI	COD SI	AN SI	SS SI	pH SI	WQI	CLASS	WQ STATUS	DO SI	BOD SI	COD SI	AN SI	SS SI	pH SI	WQI	CLASS	WQ STATUS
Main River																			
Upper Bertam	UB-1	100	86	80	97	94	96	93	I	C	100	93	91	89	95	98	95	I	C
	UB-2	100	56	69	46	79	99	75	III	SP	98	70	63	47	82	98	77	II	SP
	UB-3	100	66	68	44	56	98	73	III	SP	95	60	77	43	24	95	66	III	SP
	UB-4	93	63	68	45	49	96	69	III	SP	92	66	77	46	48	99	72	III	SP
	UB-5	100	79	69	50	39	96	73	III	SP	100	78	73	56	37	94	74	III	SP
Lower Bertam	LB-1	85	54	62	37	41	99	63	III	SP	92	60	71	45	27	98	66	III	SP
	LB-2	100	81	74	59	47	97	77	II	SP	100	67	84	55	0	99	68	III	SP
Tributaries																			
Burang	TB-1	100	63	70	57	74	100	77	II	SP	100	65	73	56	77	99	79	II	SP
Ruil	TB-2	100	77	70	47	25	99	71	III	SP	100	75	66	45	0	100	66	III	SP
Jasar	TB-3	81	36	46	24	60	98	57	III	P	82	31	53	29	56	97	57	III	P
Batu Pipih	TB-4	100	85	73	78	58	98	83	II	C	100	81	78	76	28	99	78	II	SP
Uluh	TB-5	100	83	73	85	84	96	87	II	C	100	80	77	85	53	97	82	II	C
	Overall	100	68	68	51	53	98	74	III	SP	100	65	75	52	17	99	69	III	SP

***C**=Clean, **SP**=Slightly Polluted, **P**=Polluted

* SIBOD range: 91-100=C, 80-90=SP, 0-79=P; SIAN range: 92-100=C, 71-91=SP, 0-70=P; SISS range: 76-100=C, 70-75=SP, 0-69=P and WQI range: 81-100=C, 60-80=SP, 0-59=P (DOE, 2010)

4.3.8.2 Water Quality Mapping

The distributions of mean concentrations of contaminants and WQI values were mapped within ArcGIS 9.3 to understand the seasonal variations among the sampling sites within the Bertam River Catchment (Pratt and Chang, 2012; Jha et al., 2015; Sponseller et al., 2014, Ai et al, 2015). The spatial and seasonal variations in average water quality parameters were presented in Figure 4.49 while that of WQI was shown in Figure 4.50.As can be seen from the Figure 4.49, the pH concentrations remained more or less similar condition in both rainy and dry seasons. The concentration of DO was higher in the dry season than that of the rainy season (Ai et al., 2015; Yu et al., 2016). Similarly, COD showed a decreasing trend in its concentration towards the rainy season (Mei et al., 2014; Mustapha et al., 2012). However, BOD concentrations were higher in the rainy season than that of the dry season. BOD displayed an opposite trend to DO and COD in the studied catchment. The concentration of NH_3N in the area followed the same trend as DO and COD. The concentration of NH_3N was higher in the dry season than that of the rainy season (Mei et al., 2014; Wu and Chen, 2013). TSS concentration showed an extremely high rate of deposition in the river system in rainy season except in the source area. The overall spatial and seasonal variations of river water quality parameters are related to the fact that catchment characteristics are heterogeneous in space and season (Ai et al., 2015; Pratt and Chang, 2012).

From the water quality mapping, it can be concluded that higher concentrations of COD and NH_3N in the dry season as a result of domestic and municipal wastewater discharge and are associated with the urban land area (Zhou et al., 2012). TSS is tremendously high in the catchment area in rainy season depicted the strong influences of rainfall and streamflow (Duan et al., 2013; Khoi and Suetsugi, 2014). Moreover, upland soil erosion as a result of agricultural practice in slope valley could another important factor for such sedimentation in the study area.

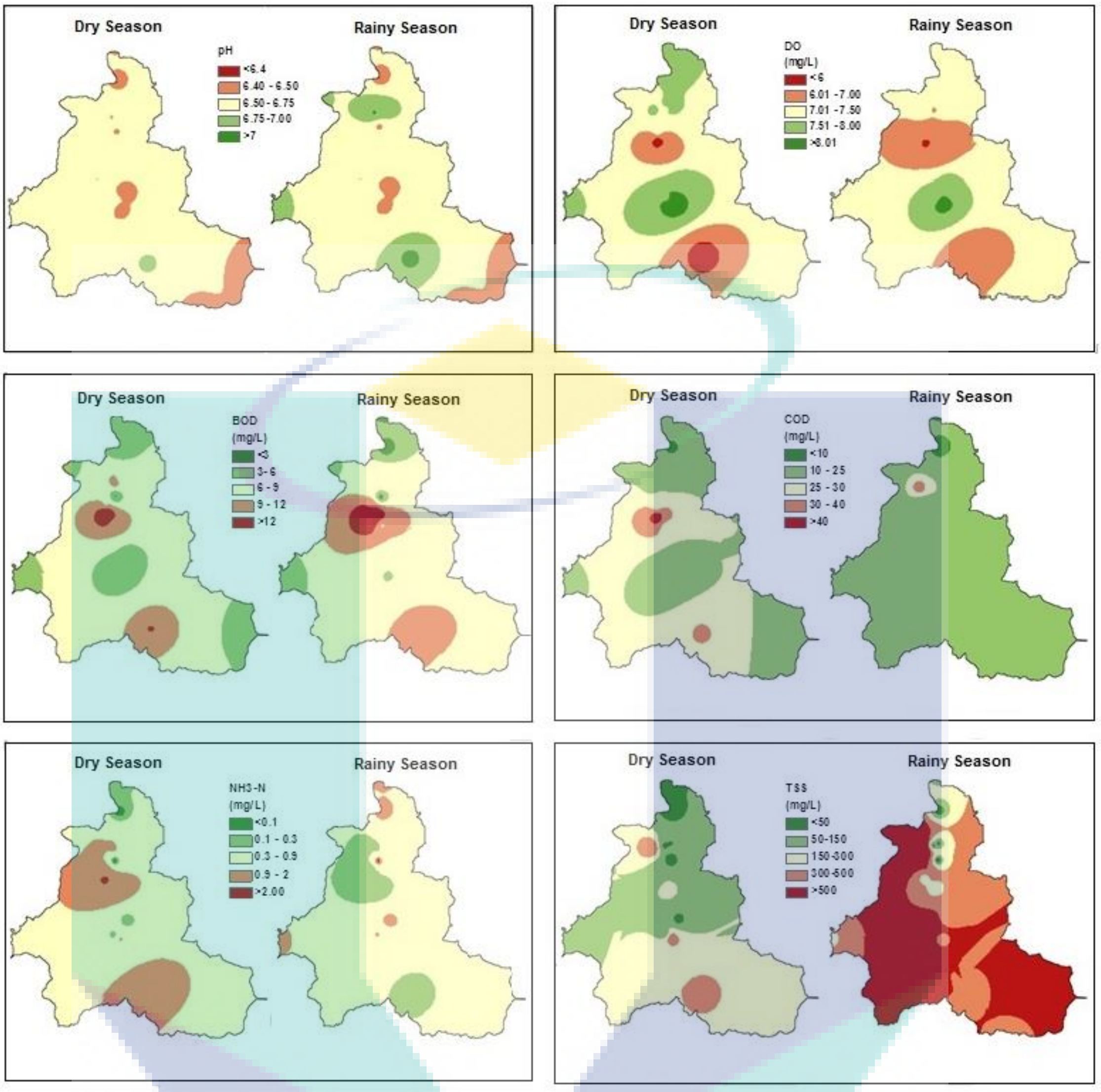

Figure 4.49 Water quality mapping showing the spatio-temporal variations of WQI parameters.

The analytical result showed that the minimum and maximum values of WQI during dry season were 57.38 and 92.76 and during rainy season were 57.32 and 94.97 respectively (Figure 4.50). The lower value of WQI during the dry and rainy season is an indication that point/ non-point sources of pollution have a great impact on water quality (Jha et al., 2015). Lower values are mainly observed among the sampling stations associated with the urban area in both the seasons.

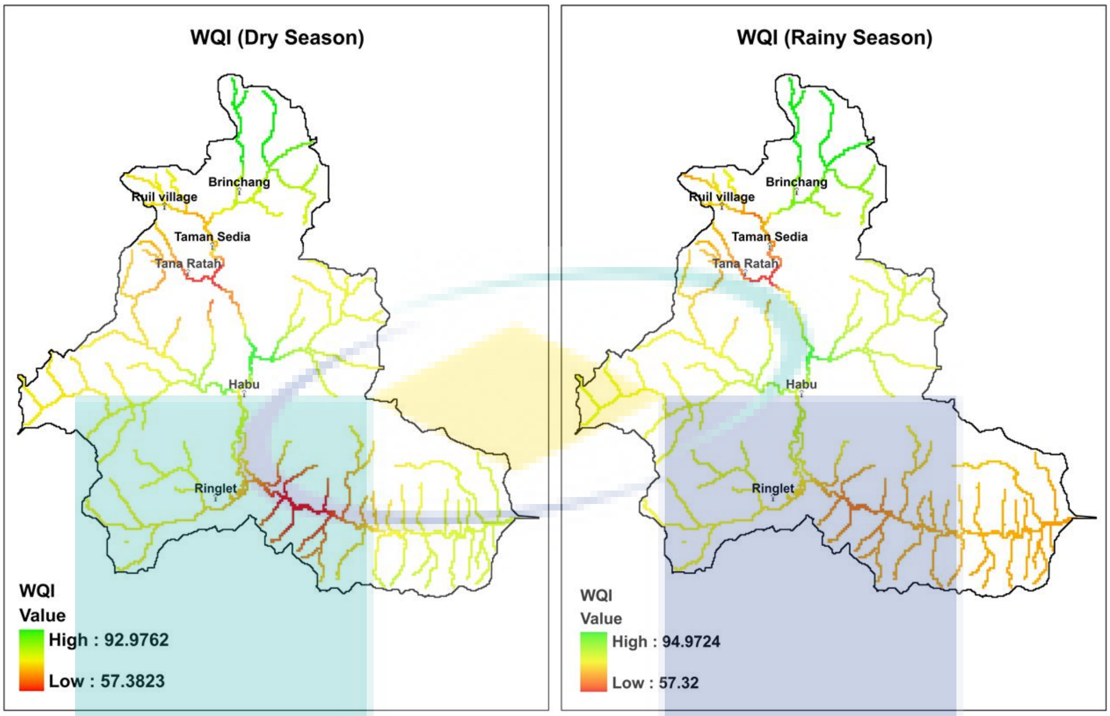

Figure 4.50 WQI map showing spatio-temporal variations of WQI values along the Bertam Catchment.

4.3.9 Summary

For the assessment of water quality variability and source identification, water samples were collected from twelve sampling stations at six times during dry (January, March, June'14 and February'15) and rainy (September and October'14) season. A fourteen number (six physical and eight chemical) of water quality parameters have been assessed and interpreted to evaluate their spatial and temporal variations. Hydrological measurements (water velocity, depth, and width of the river) were also carried out to determine the specific streamflow values of the main river and its tributaries at different stations and seasons.

Water quality assessment revealed that average concentrations of turbidity and TSS exceeded the Malaysian National Water Quality Standards (NWQS) level for IIB while BOD, COD, NH_3-N, and PO_4-P exceeded that of level for Class I, Class IIA and IIB. Nonparametric statistical analysis showed significant spatial differences for all parameters ($p<0.05$). It also revealed significant temporal variability for temp, DO, COD Turbidity, TSS, NO_3-N, PO_4-P and TP ($p<0.05$) Except for DO and COD, all other parameters displayed higher values in the rainy season. Results of correlation analysis showed positive correlations between EC and TDS and among all nutrient parameters. It also showed strong positive correlation (r=0.95) between TSS and turbidity. The multivariate statistical analysis as HCA showed that 12 sampling sites were grouped into three distinct clusters, represented as clean to less pollution, moderately pollution, and high pollution levels. PCA analysis identified that nutrients, organic matter, and soil erosion are the main pollution sources for water quality deterioration within the studied catchment.

The results of spatial variation showed that the lowest values of all parameters were found at the mountainous forest area in the Upper Bertam region. The lower-quality water was observed in Lower Bertam as most of the parameters showed high values. Considering the pollution sources, the high concentrations of BOD, COD, and NH_3-N were observed at stations located around the urban areas. The results demonstrated the influence of untreated domestic sewage discharge and wastewater plant from the three main towns, namely Brinchang, Tanah Rata, Ringlet, and small settlement areas that include most of the population of the Highlands. On the other hand, the high concentrations of the nutrient variables (NO_3-N, TN, PO_4-P, and TP) were mainly observed at stations around Burong, Batuh Pipih, Ulu River, Ringlet, and Lower Bertam Valley. These concentrations are influenced mainly by agricultural runoff. The values of TSS and turbidity at most of the stations showed higher values than the limit of Malaysian standard. The higher soil erosion and sediment transport from overland eroded area significantly increased the TSS concentrations at most of the stations of Bertam River and its tributaries due to steep gradient. The results also revealed that tributaries played an important role in spatial changes of water quality in the main course of Bertam River.

Results of seasonal variation exhibited that the values of temperature, pH, turbidity, and TSS were higher at almost all stations during the rainy season. However, DO show the opposite trend. In turn, EC and TDS displayed higher values at all stations of Upper Bertam and most of its tributaries during the rainy season, while higher values of those at Lower Bertam were observed during the dry season. The NO_3-N showed higher values in almost all of the stations in the rainy season, except the stations of Lower Bertam where the values showed higher in the dry season. The close farming (rain shelter) on steep, gentle slopes and the valley floor in the Lower Bertam Valley might decrease the NO_3-N concentration in the runoff during the rainy season. On the other hand, TN and NH_3-N showed higher values at stations around urban areas in dry season and agricultural areas in rainy season. Most of the stations showed higher PO_4-P and TP values during the rainy season due to the influence of agricultural activities. Seasonally, the concentrations of BOD showed higher values at most of the stations during rainy season while that of COD showed in the dry season because of dilution and decomposition of organic matter in the rainy season. Moreover, the results of DoE-WQI showed that all the calculated WQI values between 57 to 95, which indicates the clean to polluted water quality status in different stations of Bertam River and its tributaries during rainy and dry seasons. The overall water quality status of the Bertam Catchment was classified as "Slightly Polluted" and fall under class III category. Similar to spatial variation, the tributaries have potential influences in temporal variation of water quality in the main course of Bertam River.

The main purpose of this chapter was to undertake a comprehensive examination of the temporal and spatial variation of the water quality across the selected Bertam River Catchment. The overall results indicated the spatial and seasonal variation was apparent in most of the water quality parameters measured. The findings also revealed a strong relationship between land use type and water quality. The finds of this chapter could recognize the general ideas about the impacts of landuse on water quality and support to determine the land use types controlling the different water quality variables. In addition, the seasonal and spatial patterns of water quality in Bertam River Catchment depicted the pollutant sources and contaminated areas. The results of this study provide a basis for protection of river environments and ecological restoration in mountainous Bertam Catchment.

CHAPTER 5

LANDUSE CLASSIFICATION AND IMPACTS ON WATER QUALITY

5.1 Introduction

Landuse change is a general term to identify the human modification of Earth's terrestrial surface. The usage of land is mainly controlled by the socio-economic demand coupled with growing population. The increasing trend of these factors gives rise to unplanned and uncontrolled changes in usage practices. These changes mostly include deforestation, agricultural intensification and urban sprawl at local, regional and global scales. Such changes ultimately create major impacts on natural environmental processes and ecosystems. Many researchers have reported the impact of such changes on biodiversity loss, soil quality, soil erosion and sedimentation, surface runoff and sediment yields, water flow, and water quality and subsequently climate changes (Amin et al., 2014; Moyo and Rapatsa, 2016; Zaiha et al., 2015; Zhang et al., 2009; Zhou et al., 2012). For the evaluation of any environmental changes and their consequence assessment, an accurate and up-to-date understanding of land usage activity and its changes is therefore essential. It is also vital for planning, utilization of regional resources and environment management (Zhao et al., 2013b). Measuring land use types within watersheds/catchments can be a convenient, indirect method of projecting human activities and can allow for cautious generalizations of the relationships between land use and water quality. Land-use activities have a significant effect on water quality, both spatially and temporally (Ai et al., 2015; Bu et al., 2014).

The study area, Bertam River Catchment, is the core area of socioeconomic activities in Cameron Highlands, Malaysia mainly focused on agricultural and tourism economies. Unfortunately, the area has undergone remarkable changes over the last few decades as a result of rapid development leading to negative effects on the environment

(Chan, 2006). Anthropogenic activities like agriculture, urbanization, infrastructure development and deforestation are the prime factors for environmental problems in the study area and contribute to accelerate the degradation of the highlands environment by soil degradation, upland soil erosion and sedimentation, water quality deterioration as well as micro-climate change (Aminuddin et al., 2005; Barrow et al., 2009; Fortuin, 2006; Hashim et al., 2006; Ismail et al., 2014; Midmore et al., 1996; Teh, 2011; Toriman et al., 2010). However, though the noticeable pattern of land alteration is significant over time, there has not been any in-depth study on land pattern changes that can help to ensure better management of landuse conservation as well as to protect the further deterioration of the water resources along with the environment of the study area.

In the present study, different land types and their distribution, land use change and their changing trends were analyzed over time (1984-2010) within the catchment. The distribution of land types according to slope classes was also investigated. The impacts of landuse changes towards the water quality on the studied Bertam River Catchment have been evaluated through all of these assessments.

5.2 Landuse Types Distribution

The overall landuse was categorized into 10 types based on the usage, economic significance, and practices. These are – (i) forest, (ii) urban, (iii) market (iv) gardening, (v) orchard, (vi) horticulture, (vii) floriculture, (viii) tea, (ix) scrub, (x) open land, and water body. Among the land types, 'market gardening' is the commercial production of vegetables and fruits and 'floriculture' is of flowers. Horticulture comprises ornamental plants garden serving as aesthetic as well as production purpose. The scrub is characterized by vegetation dominated by shrubs including grasses and herbs. The urban area under study constitutes the combined of the urban and associated area, recreational area, estate building, power station, roads, and agricultural station. The area is mostly located in three main towns namely Brinchang, Tanah Rata and Ringlet under the study area. The tea land type covers the tea plantation in the study area.

The coverage of each landuse category in 1984, 1997, 2004 and 2010 including the area, percentage area and change between the four time periods for the Bertam River Catchment was calculated and shown in Table 5.1. The spatio-temporal distributions of these land types are also shown in Figure 5.1. Considering a total area of 97.36 km^2, the maximum 71.80 km^2 area of the catchment was covered by forest land (73.75%) in the year 1984. The forest land type was successively followed by tea (13.89%), scrub (6.12%), market gardening (2.39%), urban (1.70%), horticulture (1.36%) and water body (0.81%) (Table 5.1 and Figure 5.1). The individual land types analyzed in the catchment area over the time periods are described as follows.

5.2.1 Forest

Analysis of landuse changes in Bertam River Catchment revealed a considerable decrease in forest area over the study period. It is the mainland type comprising 73.75% of the total study area during 1984 and successively decreased over time. In terms of area, the forest area was 71.80 km^2 during 1884 which decreased subsequently to 55.09 km^2 in 1997, 50.70 km^2 in 2004 and 48.95 km^2 in 2010. A net total of 22.85 km^2 (23.47%) forest area was reduced during the study period in the study area. Rising demands of agro-products in the study area and long mismanagement in land use planning has resulted in a significant (23.47%) reduction in the forest during the period under study.

5.2.2 Market Gardening

The market gardening under the study area is mostly used for vegetable growth and the chief products are tomato, onion, veg-cabbage, lettuce etc. They suitable weather makes the area favorable for producing vegetables. As a result, the percentage increment of this land type increased consistently over time. The total area occupied by this category was 2.33 km^2 in 1984 which has increased to 15.09 km^2, 18.52 km^2 and 18.70 km^2 in 1997, 2004 and 2010 successively. A total of 16.37 km^2 (16.82%) market gardening area was increased during the study period in the study area.

The higher expansion of market gardening about 13.12% was observed during the time span of 1984 to 1997 compared to 1997-2004 (3.52%) and 2004-2010 (0.18%). Overall, it was observed as the third major land use category (2.33 km^2) in 1984 after forest (71.80 km^2) and tea garden (13.52 km^2); however, became second major land use category (15.09 km^2) in 1997 after forest (55.09 km^2) and existed as same order of abundance among the land types till 2010.

Table 5.1 Area, percentage area and change in each landuse category in 1984, 1997, 2004 and 2010 for the Bertam river catchment area

Landuse Category	**Area in Km^2**				**Percentage of total area**				**Change in Km^2**			**Change in %**		
	1984	1997	2004	2010	1984	1997	2004	2010	1984-1997	1997-2004	2004-2010	1984-1997	1997-2004	2004-2010
Forest	71.80	55.09	50.70	48.95	73.75	56.58	52.08	50.27	-16.71	-4.38	-1.76	-17.17	-4.50	-1.80
Urban	1.65	4.81	5.52	5.80	1.70	4.94	5.67	5.95	3.15	0.71	0.28	3.24	0.73	0.28
Market Gardening	2.33	15.09	18.52	18.70	2.39	15.50	19.02	19.21	12.77	3.43	0.18	13.12	3.52	0.18
Orchards	0.00	2.93	1.38	0.01	0.00	3.01	1.42	0.01	2.93	-1.55	-1.37	3.01	-1.59	-1.41
Horticulture	1.32	0.37	0.41	0.46	1.36	0.38	0.42	0.47	-0.95	0.04	0.05	-0.97	0.04	0.05
Floriculture	0.00	0.00	2.85	7.83	0.00	0.00	2.93	8.04	0.00	2.85	4.98	0.00	2.93	5.11
Tea	13.52	10.83	11.43	9.90	13.89	11.13	11.74	10.17	-2.69	0.60	-1.53	-2.76	0.61	-1.58
Scrub	5.96	6.92	5.23	4.82	6.12	7.11	5.38	4.95	0.96	-1.69	-0.42	0.99	-1.73	-0.43
Open Land	0.00	0.60	0.56	0.07	0.00	0.62	0.58	0.08	0.60	-0.04	-0.49	0.62	-0.04	-0.50
Water Body	0.79	0.72	0.74	0.83	0.81	0.74	0.76	0.85	-0.07	0.02	0.09	-0.07	0.02	0.09

5.2.3 Urban

During the study period, the overall increment of the urban area was 4.15 km^2 (4.26%) in the study area. In 1984, the area was just 1.65 km^2. With the passage of time, it changed to 4.81 km^2 in 1997, 5.52 km^2 in 2004 and 5.80 km^2 in 2010, respectively. The higher change of urban area observed during the time span of 1984 to 1997. The urban area of the catchment is now comprised of three main townships and four small settlements. The townships are Ringlet, Tanah Rata, and Brinchang, each plays different roles. Tanah Rata is the largest township consists of government and main facilities buildings and is the administrative center of the Highlands. Ringlet town plays a major role to commercialize vegetables and actively with transit activities. Brinchang town supports commercial facilities and hotels for the tourists. Other small settlements are Bertam Valley, Habu, Ruil and Taman Sedia.

5.2.4 Floriculture

Floriculture was not observed as a land type in landuse map of 1984 and 1997 of the study area. It came into being in 2004. The total amount of area was 2.85 km^2 (2.93%) in 2004 and was increased significantly in 2010 with an area amounting 7.83 km^2 (8.04%).

5.2.5 Tea

The study area is the most famous to produce tea in Malaysia. Most of the tea plantations were established in the 1930s, by planting tea seedlings on slopes (Othman, 2011). In 1984, the tea plantation was the second largest land type covering an area of about 13.52 km^2 followed by forest (71.80 km^2). According to the result of land pattern changes, the land area became 10.83 km^2 by decreasing its area of 2.69% from 1984 to 1997. Although tea garden area increased slightly in 2004, it was again reduced to an area of about 9.90 km^2 in the year 2010.

5.2.6 Scrub

Scrubland was the third largest land type in term of the area in 1984. During that time, it occupied an area of 5.96 km^2 followed by forest (71.80 km^2) and tea land area (13.52 km^2). Although the amount of scrubland area increased by 0.96 % in 1997, later it dropped subsequently to 1.69% in 2004 and 0.42% in 2010, respectively and finally covered its land area of 4.82 km^2 in 2010.

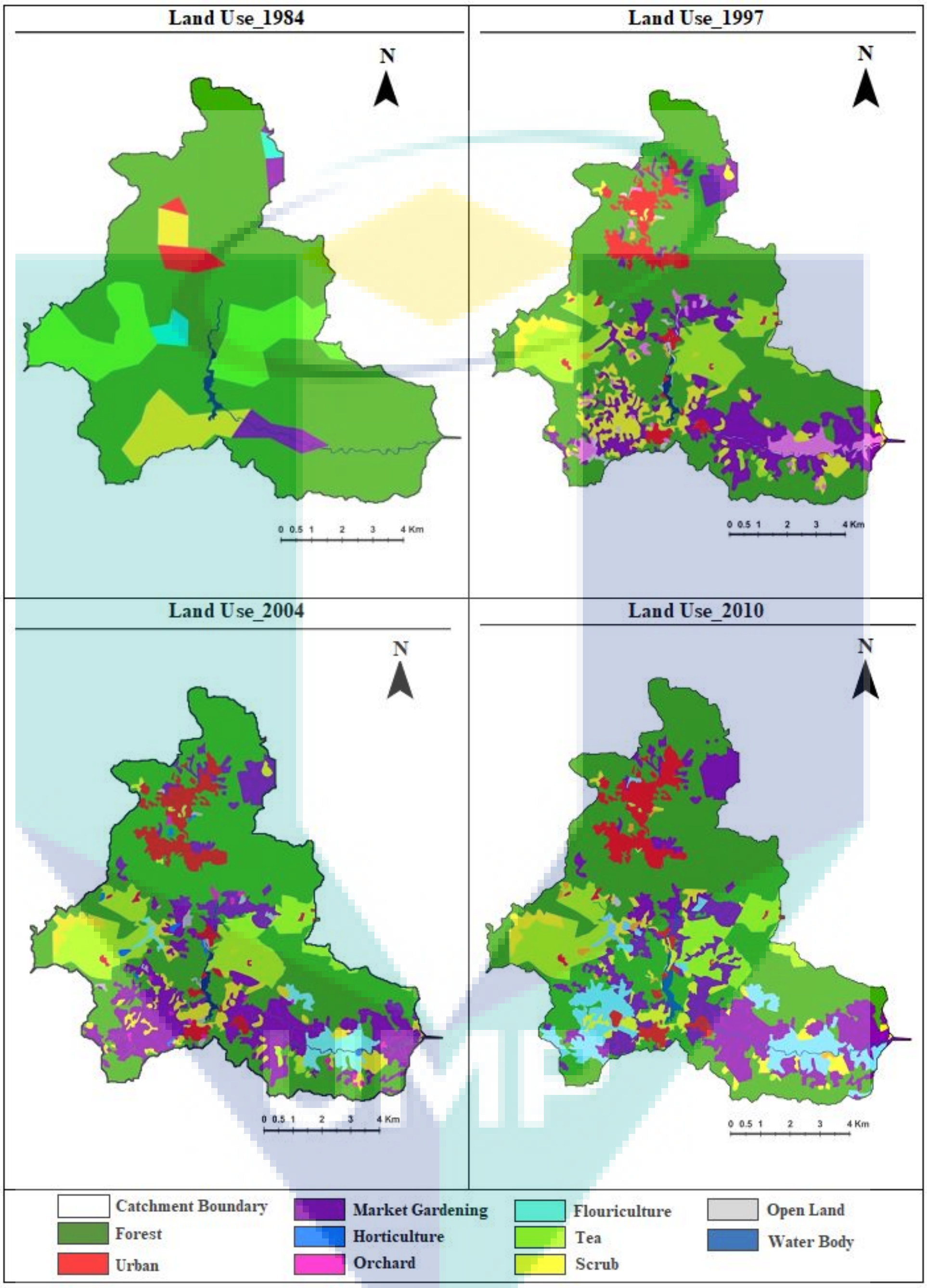

Figure 5.1 Land use maps of the study area (Bertam Catchment) in 1984, 1997, 2004 and 2010

5.2.7 Horticulture, Orchard, Open Land and Water Body

In 1984, the horticulture land type covered an aerial extent of 1.32 km^2 in the study area. With time, the area decreased to 0.37 km^2 in 1997 and 0.41 km^2 in 2004, respectively. Now, the land type got it shape with an area of 0.46 km^2. Concerning the orchard land type, this was not found in the study area in the year 1984. It introduced as a new landuse type in 1997 with an area of 2.93 km^2. However, over time, the land type decreased dramatically in the catchment area and became only 0.01 km^2 by 2010. The areal coverage of water body remained more or less similar throughout the study period.

5.3 Pattern Change of Land Area

During the year 1984, the forest covered 73.75% of the total catchment area followed by tea (13.89%), scrub (6.12%), market gardening (2.39%), urban (1.70%), horticulture (1.36%) and water body (0.81%) (Table 5.1 and Figure 5.1).

The landuse scenario became different in 1997 with a major increment of market gardening (13.12 %) and urban (3.24%) area as well as a reduction of forest (17.17%) and horticulture area (0.97%) with compare to 1984. Orchard introduced as a new landuse type in the study area with an area of 3.01% during that time. With these changes, a new order of abundance was observed in landuse types in 1997 where market gardening exceeded tea land type and followed the rank of order as forest (56.58%) > market gardening (15.50%) > tea (11.13%) > scrub (7.11%) > urban (4.94%) > orchard (3.01) > water body (0.74%) > open land (0.62) > horticulture (0.38%). It was clearly evident that the growth of market gardening area by 13.12% (16.20 km^2) and urban area 3.24 % (3.86 km^2) from 1984 to 1997 bears a positive relationship with the decreasing tendency of forest area and scrub area (Figure 5.2).

With a newly introduced floriculture area and a reduction of scrubland (1.73 %) further modified the landuse activities within the catchment by 2004. The changing trend of market gardening and the forest followed the similar changing pattern as 1984-1997. The orchard that was introduced as a new land type during 1997 was decreased by 1.59% in 2004.

In a span of 6 years, from 2004 to 2010, a major and significant land use change was the expansion of floricultural area and the reduction of orchard area. During the time, the land usage area of floriculture became 8.04% by increasing its area of 5.11% while the orchards area converted to 0.01% by transforming its area of 1.41%. Moreover, a decreasing trend in the forest (1.80%), tea (1.58%), open land (0.50%) and scrub (0.43%) was also observed during the time. A decreasing trend in the forest, tea, open land, and scrub was also observed during the time. The major changes in floriculture and orchards area turned the land use categories as its most recent situation and rank as forest (50.27%)> market gardening (19.21%) > tea (10.11%) > floriculture (8.04%) > urban (5.95%) > scrub (4.82%) > water body (0.85%) > horticulture (0.47%) > open land (0.08) > orchard (0.01%) in the catchment area (Figure 5.2).

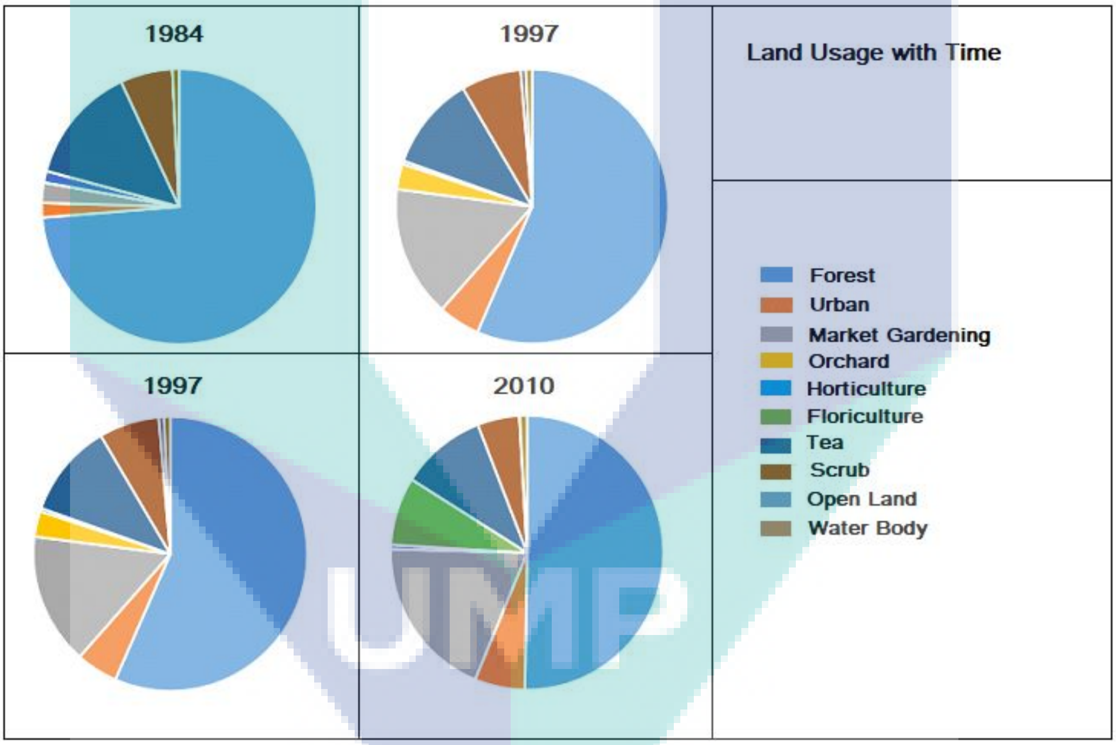

Figure 5.2 Land usage practice change along time within the catchment area

The changing trend of land usage clearly evident that the growth of market gardening (+16.20 km2) and urban area (+3.86 km2) from 1984 to 2004 bears a positive relationship with the decreasing tendency of forest (-21.09 km2) and scrub (-0.73 km2) land type area. The orchard that was introduced a new land type during 1997 was decreased by 1.59% in 2004. The expansion of floriculture (+ 5.11%) and the reduction of the orchard (-1.41%) were significant land use changes by 2010. A decreasing trend in the forest, tea, open land, and scrub was also observed during the time (Figure 5.3).

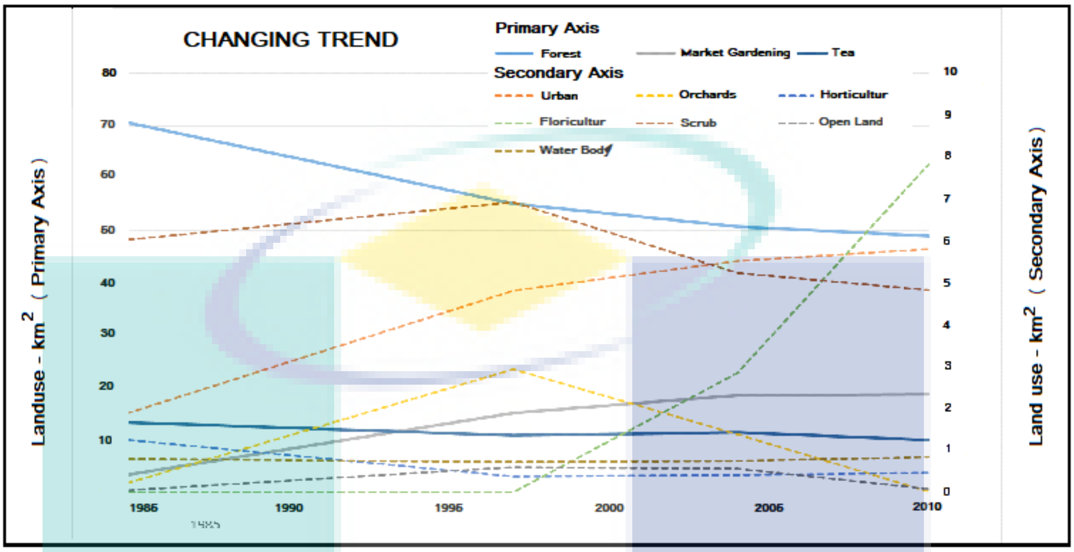

Figure 5.3 Changing trend of land patterns in the catchment area during 1984-2010

The distribution of different land-use types in the successive year of 1984, 1997, 2004 and 2010 has shown that the percentage positive change was higher for market gardening followed by floriculture and urban indicating an increasing trend over time. However, negative changes were marked by the forest, orchards, tea, scrub and open land showed more or less decreasing trend over time (Figure 5.4)

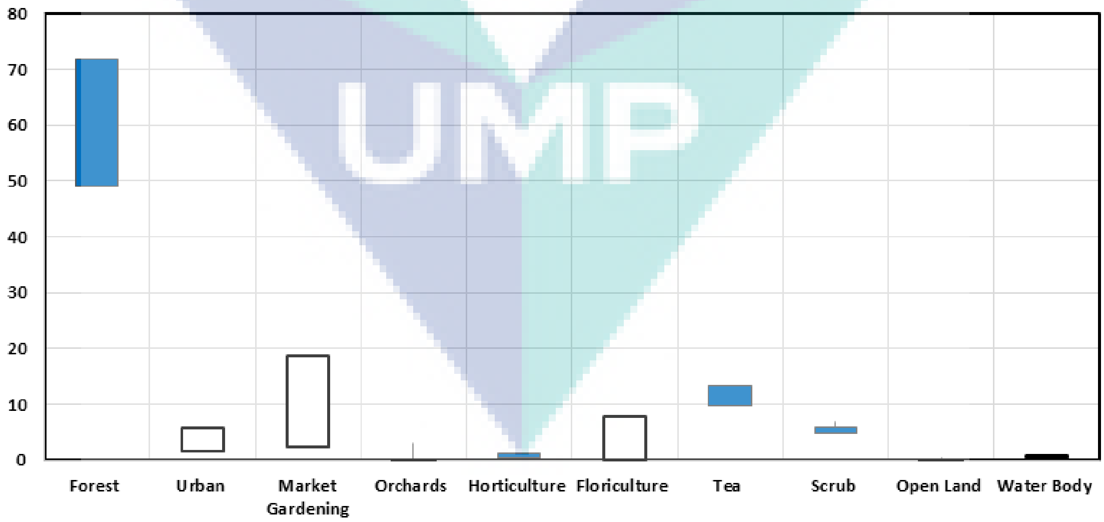

Figure 5.4 Change differences between the different categories of land types within the catchment area.

5.4 Change Detection in Land Type Area

Change detection study of different landuse categories was derived over a period of twenty-six years (1984 to 2010). The data were summarized based on changed landuse areas for a given period of time span indicating the flow of transformation that changed to/from other categories (Table 5.2). The changes are varying in extent among the categories. The changing trends of different landuse types for a different period of time span also presented in Figure 5.5).

5.4.1 Changing Trend During 1984-1997

During the changing period, the area covered by forest (16.71 km^2) was mostly converted to market gardening (10.23 km^2), scrub (2.91 km^2), orchard (2.48 km^2) and urban land (1.85 km^2) areas. However, a percentage of forest area was compensated by the conversion contribution of tea garden (0.77 km^2) and horticulture land type (0.37 km^2). Other than the forest area, the additional expansion of market gardening (2.54 km^2) was mainly converted from 0.86 km^2 of tea land type and 1.33 km^2 of scrubland type.

Similarly, the growing extension of urban areas (1.30 km^2) was mainly transformed from 0.23 km^2 of tea land type and 0.96 km^2 of scrubland type. A little portion of horticulture (0.44 km^2) was observed to convert to market gardening in this period. Tea area of 2.69 km^2 was decreased by converting its maximum portion to the forest (0.77), urban (0.23 km^2), market gardening (0.86 km^2) and scrubland (0.65 km^2) type. Conversely, an orchard of 2.96 km^2 was increased mostly from the forest (2.48 km^2) and a slightly from scrub (0.25 km^2).

5.4.2 Changing Trend During 1997-2004

The mainland transformation during 1997 to 2004 was the reduction of forest, scrub and orchard land types and expansion of market gardening and floriculture in the study area. During the period, the forest land altered to other categories in varying extent, mainly to market gardening, urban, tea, floriculture, open land and scrub. Orchard land gradually decreased during the period, by transforming its area to floriculture and market gardening. Along with the forest and orchard conversion areas, market gardening further expanded its land area by utilizing 1.71 km^2 of scrubland during the time span. Floriculture became a mainland type area of around 2.86 km^2 during the time by switching over 1.27 km^2 land from market gardening and 1.30 km^2 from orchard land other than forest.

Table 5.2 Change detection of different landuse categories

Categories	F	Ur	MG*	Or*	HC*	FC*	Tea	Scrub	OL*	WB*	Change Area
1984-1997											
Forest	0.00	-1.85	-10.23	-2.48	0.37	0.00	0.77	-2.91	-0.30	-0.09	-16.71
Urban	1.85	0.00	0.08	0.00	0.00	0.00	0.23	0.96	0.00	0.03	3.15
MG	10.23	-0.08	0.00	-0.07	0.44	0.00	0.86	1.33	0.00	0.06	12.77
Orchards	2.48	0.00	0.07	0.00	0.07	0.00	0.01	0.25	0.00	0.05	2.93
Horticulture	-0.37	0.00	-0.44	-0.07	0.00	0.00	0.08	-0.15	0.00	0.01	-0.95
Floriculture						0.00					0.00
Tea	-0.77	-0.23	-0.86	-0.01	-0.08	0.00	0.00	-0.65	-0.07	-0.02	-2.69
Scrub	2.91	-0.96	-1.33	-0.25	0.15	0.00	0.65	0.00	-0.22	0.00	0.96
Open Land	0.30	0.00	0.00	0.00	0.00	0.00	0.07	0.22	0.00	0.02	0.60
Water Body	0.09	-0.03	-0.06	-0.05	-0.01	0.00	0.02	0.00	-0.02	0.00	-0.07
1997-2004											
Forest	0.00	-0.64	-2.59	0.00	-0.03	-0.27	-0.55	-0.11	-0.19	0.00	-4.39
Urban	0.64	0.00	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.71
MG	2.59	-0.08	0.00	0.22	0.00	-1.27	0.01	1.71	0.26	-0.02	3.43
Orchards	0.00	0.00	-0.22	0.00	0.00	-1.30	0.00	-0.02	0.00	0.00	-1.54
Horticulture	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03
Floriculture	0.27	0.00	1.27	1.30	0.00	0.00	0.00	0.02	0.00	0.00	2.86
Tea	0.55	0.00	-0.01	0.00	0.00	0.00	0.00	0.06	0.00	0.00	0.60
Scrub	0.11	0.00	-1.71	0.02	0.00	-0.01	-0.06	0.00	-0.04	0.00	-1.69
Open Land	0.19	0.00	-0.26	0.00	0.00	0.00	0.00	0.04	0.00	0.00	-0.04
Water Body	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02
2004-2010											
Forest	0.00	0.06	-1.46	0.09	-0.01	-0.36	0.07	-0.03	-0.01	-0.10	-1.76
Urban	-0.06	0.00	0.18	0.01	0.00	-0.01	0.00	0.06	0.10	-0.01	0.25
MG	1.46	-0.18	0.00	0.58	0.05	-3.53	2.37	1.84	0.41	0.00	3.00
Orchards	-0.09	-0.01	-0.58	0.00	-0.02	-0.56	0.00	-0.12	0.00	0.00	-1.37
Horticulture	0.01	0.00	-0.02	0.02	0.00	-0.01	0.04	-0.01	0.04	0.00	0.07
Floriculture	0.36	0.01	3.54	0.56	0.01	0.00	0.12	0.37	0.01	0.00	4.98
Tea	-0.07	0.00	-1.13	0.00	-0.04	-0.12	0.00	-0.20	0.02	0.00	-1.53
Scrub	0.03	-0.06	-0.51	0.12	0.01	-0.37	0.20	0.00	0.15	0.02	-0.42
Open Land	0.01	-0.10	-0.19	0.00	-0.02	-0.01	-0.02	-0.15	0.00	-0.01	-0.49
Water Body	0.10	0.01	0.00	0.00	0.00	0.00	0.00	-0.02	0.01	0.00	0.09

* **F=** Forest; **Ur=** Urban **MG**=Market Gardening; **Or**=Orchards, **FC**=Floriculture; **HC**=Horticulture; **OL**=Open Land; **WB**=Water Body

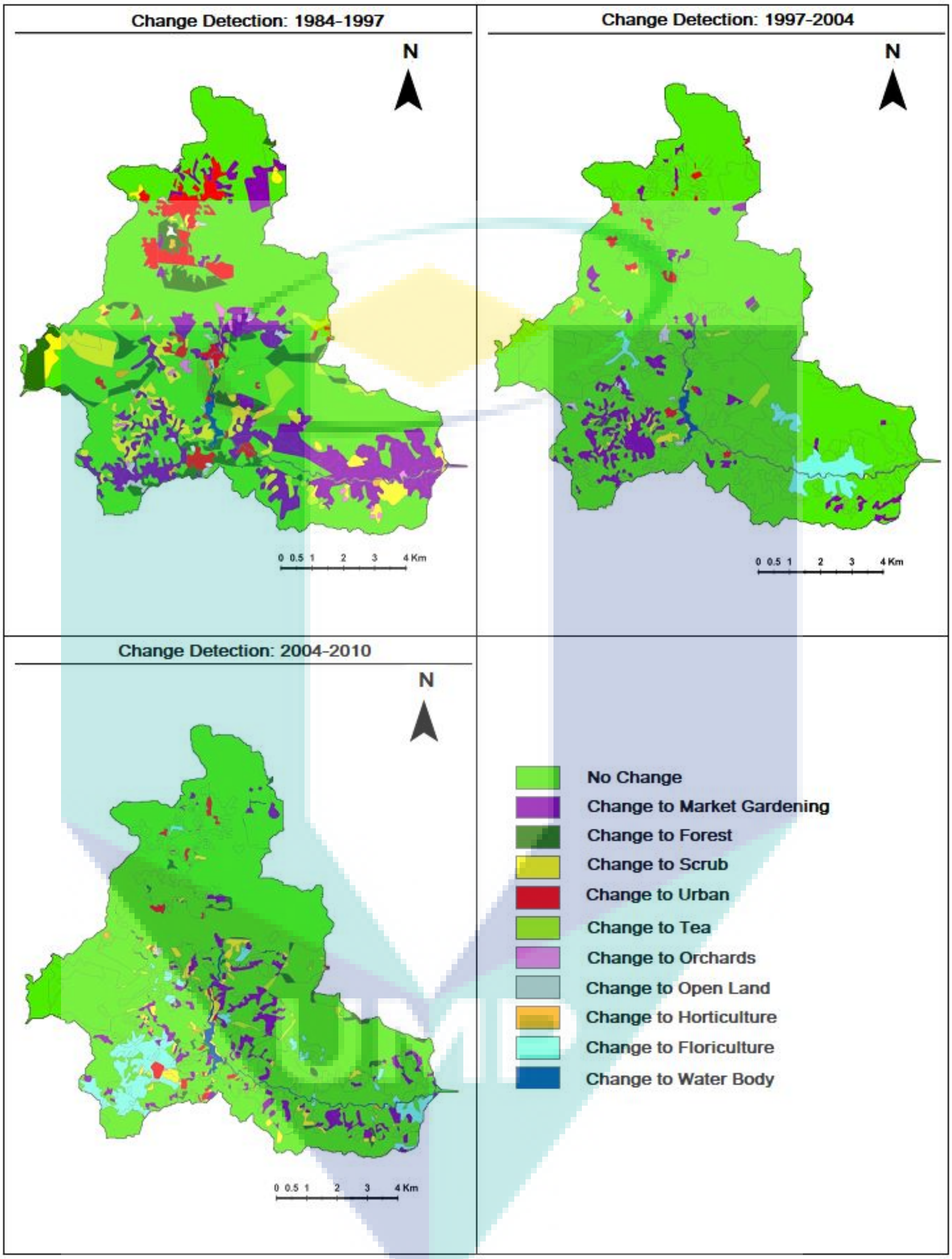

Figure 5.5 Land use change detection maps of the study area during 1984-1997, 1997-2004, 2004-2010

5.4.3 Changing Trend During 2004-2010

Floriculture expanded and orchard reduced its land portion continually during 2004-2010. A total 4.98 km^2 of floriculture land area was grown up by switching over from market gardening, orchard, scrub, and forest. Conversely, orchard land significantly reduced its land by converting to market gardening, floriculture, and scrub. It was evident that during the period cropping pattern changed to floriculture from market gardening. The floriculture has become promoted and grown increasingly in the study area, due to a good market, lucrative returns, government support and campaigns (Hamir et al., 2008).

5.5 Landuse Types Distribution by Slope Classes over Time

The changes in elevation over distance as well as the surficial features of the catchment area were shown in Figure 5.6. The data presented in Table 5.3 represents the slope classes, percentage, landuse types distribution according to slope classes. For this calculation, all agriculture land types except tea were considered as market gardening land type. The ranges of slope classes and areal percentages were considered same for the whole study period.

Within the catchment, it was estimated that 23.70% of the area has slopes in between 10°-20° and 17.76% has slopes in between 20°-30° (Table 5.3). Slopes that are in between 20°-30° are classified as dangerous by Department of Environment. These steeper slopes emphasize the high potential of the study area to soil erosion and landslides (Chan, 2006).

During the study period, forest land type was distributed in higher amount in all slope classes followed by market gardening and tea except 1984 wherein tea showed higher area than market gardening (Table 5.3 and Figure 5.6). Over time, the forest area decreased in all slope classes with increasing market gardening. Though the distribution of market gardening area increased in all the slope classes, the noticeable rate of increment was observed in steeper slope classes of 20°-30° and 10°-20° (Figure 5.6).

Table 5.3 Change types distribution according to slope classes within Bertam River Catchment area

Land Type	**Slope Classification**				
1984					
	0°-5°	5°-10°	10°-20°	20°-30°	>30°
Forest	27.76	10.52	17.75	13.94	1.83
Urban	0.97	0.35	0.30	0.04	0.04
Market Gardening	2.05	0.56	0.68	0.30	0.06
Tea	5.10	2.36	3.36	2.41	0.24
Scrub	3.45	0.89	0.96	0.60	0.05
Others	0.69	0.06	0.02	0.00	0.00
Area (km^2)	40.02	14.76	23.07	17.29	2.22
Percentage	41.11	15.16	23.70	17.76	2.28
1997					
	0°-5°	5°-10°	10°-20°	20°-30°	>30°
Forest	20.51	8.19	13.76	10.86	1.70
Urban	3.24	0.86	0.60	0.19	0.02
Market Gardening	8.50	2.53	4.01	3.12	0.17
Tea	5.08	1.63	2.34	1.56	0.21
Scrub	1.86	1.37	2.14	1.46	0.08
Others	0.83	0.17	0.21	0.10	0.04
Area (km^2)	40.02	14.76	23.07	17.29	2.22
Percentage	41.11	15.16	23.70	17.76	2.28
2004					
	0°-5°	5°-10°	10°-20°	20°-30°	>30°
Forest	18.63	7.53	12.79	10.15	1.61
Urban	3.57	1.07	0.67	0.19	0.01
Market Gardening	10.75	3.05	5.10	3.95	0.31
Tea	3.80	2.19	3.15	2.12	0.16
Scrub	2.43	0.73	1.14	0.82	0.11
Others	0.84	0.20	0.19	0.06	0.01
Area (km^2)	40.02	14.76	23.07	17.29	2.22
Percentage	41.11	15.16	23.70	17.76	2.28
2010					
	0°-5°	5°-10°	10°-20°	20°-30°	>30°
Forest	17.82	7.37	12.35	9.77	1.57
Urban	3.66	1.16	0.78	0.17	0.03
Market Gardening	12.30	3.59	6.12	4.66	0.38
Tea	3.35	1.81	2.73	1.88	0.14
Scrub	2.09	0.77	1.04	0.81	0.11
Others	0.78	0.06	0.03	0.02	0.00
Area (km^2)	40.02	14.76	23.07	17.29	2.22
Percentage	41.11	15.16	23.70	17.76	2.28

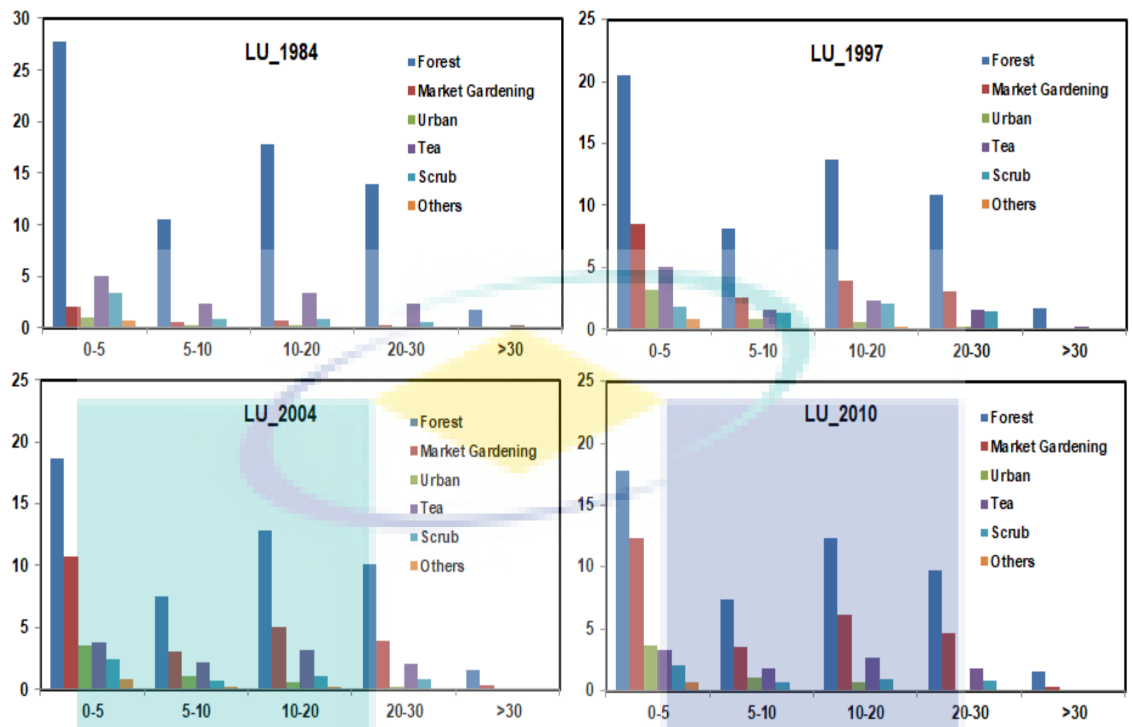

Figure 5.6 Land use types distribution by slope classes in Bertam Catchment over time.

5.6 Composition (%) of Landuse Types

The studied catchment was sub-divided into 12 sub-catchment areas. For the calculation of different land types with each catchment, early categorized 10 land types were re-classified into 6 distinct land classes as forest, urban, market gardening, tea, scrub and water based on usage (Figure 5.7). The areas of orchard, floriculture, and horticulture were calculated with market gardening. Similarly, the open land was added with urban land type as it had a very minimal percentage.

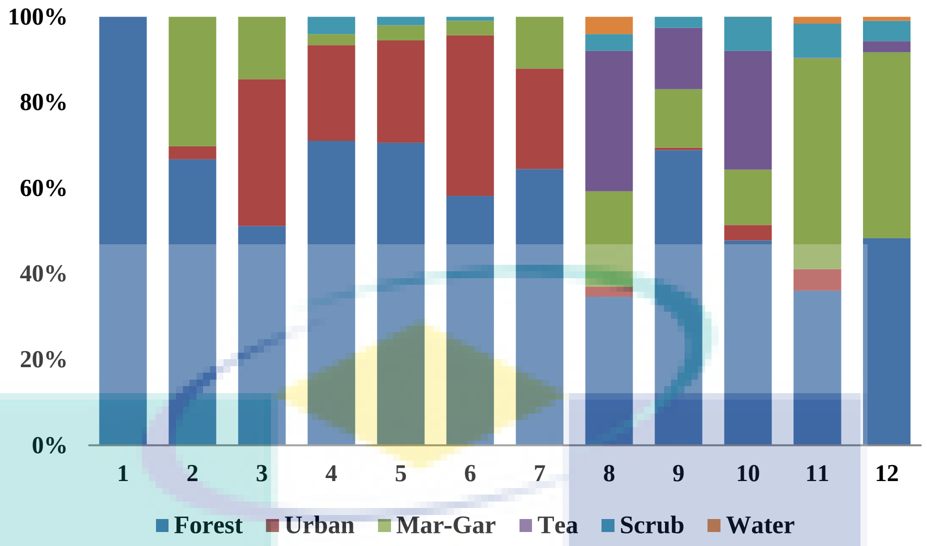

Figure 5.7 Landuse composition (%) in the Bertam Sub-catchment area

5.6.1 Land Type Wise Distribution

In the study area, forest land type covers a significant quantity of area in almost all sub-catchment. More than 50% forest area is observed in the sub-catchment zone 1,2,3,4,5,6,7, and 9. The highest percentage of the forest is seen in the zone 1 is around 100% while the lowest percentage is observed near about 35% in the zone 8. In the remaining zones, the forest area spreads from 36% to 48%.

Urban land type is distributed dominantly in sub-catchment 3, 4, 5, 6, and 7 with a range of 22% to 38%. All these sub-catchments are located mainly in the upper catchment of the study area. The highest percentage of urban land type is observed in the zone 6. While in zone 1, there is no any urban land type. In the sub-catchment 10 and 11, 3% to 5% urban land type is observed, located mainly in the lower catchment.

Market gardening land type varies from 0% to 49% within the whole catchment. The higher percentage market gardening land types are found in the zone 11 and 12, areas ranging from 49% to 43%. In the middle of the catchment, market gardening land types are mainly centralized in sub-catchment 8-10 wherein 12% to 22% of their areal extensions are observed. No market gardening is observed in sub-catchment 1. About 32% market gardening area is seen in the sub-catchment 2 that makes its areal extension as the highest in the upper catchment. A noticeable 15% of this land type is also observed in sub-catchment 3 with the upper catchment.

Dominated tea land type is observed mainly in the middle catchment within sub-catchment zones 8 to 10. The highest percentage of this land type is observed in sub-catchment 8 amounting 33%. The land area ranges in between 12% to 13% in sub-catchment 9 to 10. No tea plantation is seen in the upper catchment while a very little is observed in lower catchment. There is only 2% tea land type found in sub-catchment 12. Scrubland type is mostly found in the sub-catchment 4, 8, 10, 11, and 12. Among them, the highest percentage is observed in zone 10 (7.94%) while the lowest is in zone 8 (3.99%). No scrubland type is observed in sub-catchment 1, 2, 3, and 7. The wider water land is seen sub-catchment 8 and 11

5.6.2 Sub-catchment Wise Distribution

Sub-catchment 1-7 are located in the upper catchment of the studied area. Sub-catchment 1 is completely covered by forest land type. In sub-catchment 2, 3 and 7, along with forest, urban and market gardening land types are observed. In sub-catchment 2, market gardening shows the much higher percentage (30.21%) than that of catchment 3 (14.55%) and 7 (12.07%). Conversely, urban land type shows the higher percentage (34.26%) in sub-catchment 3 than that of sub-catchment 7 (23.44%) and sub-catchment 2 (3.02%). In sub-catchment 4, 5, and 6, along with these 3 land types, scrubland area is also observed. In sub-catchment 4, forest land type shows the highest percentage (71.04%) and successively followed by urban (22.36%) and scrub (4.00%) while in sub-catchment 5 and 6, these forest land types (70.57% and 58.22%) followed by urban (23.91% and 37.47%) and market gardening (3.52% and 3.38%) respectively.

Sub-catchments 8, 9 and 10 are located in the middle part of the studied catchment. In this part, all types of landform are observed. Forest is higher in sub-catchment 9 (68.87%) than other two (34.65% in 8 and 47.79% in 10). Urban land type shows the higher percentage (3.63%) in sub-catchment 10 than of sub-catchment 8 (2.37%). It is very small in percentage in and sub-catchment 9 (0.56%). Market gardening ranges an area of 12.93% to 22.28% from sub-catchment 10 to 8. Tea is the highest percentage in sub-catchment 8 (32.77%).

In the lower part of the catchment, sub-catchment 11 and 12 are located. This two sub-catchment mainly dominated by market gardening land type Market gardening shows its highest percent along the catchment in zone 11 (49.22%) followed by zone 12

(43.40%). No urban land type is found in sub-catchment 12 while 5.05% is observed in sub-catchment 11. Tea land type ranges from 0.11% to 2.60% while scrub is found 4.73 to 7.99% within two sub-catchments.

5.7 Impact of Landuse Types on Water Quality

All the measured land types' percentage and water quality parameters were analyzed statistically to determine the relation among landuse types and water quality (Chen and Lu, 2014). The relationship was calculated both for dry and rainy seasons (Bu et al., 2014). Table 5.4, shows the relationship in dry season while Table 5.5 shows the relationship in the rainy season.

5.7.1 Dry Season

Results of the correlation analysis Table 5.4, showed a strong positive correlation between the proportion of urban land uses and NH_3-N (r=0.702) as well as moderate correlation with BOD (r=0.641). The land type also showed a mutual correlation with COD (r=0.390). Conversely, a negative correlation was also calculated between the urban land type and DO (r= -0.482) in the catchment.

The proportion of market gardening land types showed a strong positive correlation with NO_3-N (r=0.843) along with a moderate correlation with EC (r=0.652), TDS (r=0.616), turbidity (r=0.495), TSS (r=0.585), TN (r=0.519), PO_4-P (r=0.650) and TP (r=0.603) in dry season. There were no significant relationships with organic matters. Tea land types showed a moderate positive correlation with NO_3-N (r=0.528) in the catchment during the dry season. It also showed mutual positive correlation with DO (r=0.414), PO_4-P (r=0.313) and TP (r=0.396). A weak positive correlation was also observed with turbidity (r=0.221) and TSS (r=0.277). On the other hand, this land type showed mutual negative correlation with BOD (r=-0.372) and NH_3-N (r=-0.328).

The area of forest land type showed significant negative relationships with physico-chemical water quality parameters as EC (r=0.585), TDS (r=0.558), Turbidity (r=0.374), TSS (r=0.401) and nutrient variables as NO_3-N (r=0.725), TN (r=0.572), PO_4-P (r=0.507) and TP (r=0.628) in dry season (Bu et al., 2014; Tong and Chen, 2002).These results are consistent with findings of previous studies reporting a positive contribution of forests to water quality (Tong and Chen, 2002). Moreover, scrubland uses showed weak correlated with NO_3-N (r=0.435), TN (r=0.325), PO_4-P (r=0.279) and TP (r=0.369) as well as turbidity (r=0.230) and TSS (r=0.263) in the area.

5.7.2 Rainy Season

Results of the correlation analysis showed the part of urban land uses in catchment was positively correlated with NH_3-N (r=0.685), COD (r=0.605) and BOD (r=0.473) as well as negatively correlated with DO (r=0.607) in a rainy season similar to the dry season.

Market gardening land uses showed a significant strong positive correlation with physico-chemical parameters as turbidity (r=0.735), TSS (r=0.715). It also exhibited similar strong correlation with nutrient variables like NO_3-N (r=0.905), PO4-P (r=0.747) and TP (r=0.712) in rainy season. A moderate correlation was further observed with EC (r=0.690), TDS (r=0.663) and TN (r=0.567). Similar to the dry season, no significant correlation observed with any organic matter. The proportion of tea land types, positively correlated with DO (r=0.611), NO3-N (r=0.497), PO4-P (r=0.588) and TP (r=0.586), turbidity (r=0.368) and TSS (r=0.327) and showed moderate to mutual correlation with these parameters. A negative mutual correlation also observed among the land types and COD (r=0.372) as well as NH3-N (r=0.399). Similar to tea land type, scrubland type showed a positive correlation with the nutrient variables as NO_3-N (r=0.404), TN (r=0.474), PO_4-P (r=0.430) and TP (r=0.435) in the rainy season.

Similar to the dry season the proportion of forest land areas showed significant negative relationships with physico-chemical parameters as EC (r=0.513) and TDS (r=0.496), as well as nutrient variables as NO_3-N (r=0.745), TN (r=0.598), PO_4-P (r=0.453) and TP (r=0.462) in the rainy season (Tong and Chen, 2002).

Table 5.4 Spearman's Correlation among the Land use types and Water Quality Variables (Dry Season)

Land Type	EC	TDS	Turb.	TSS	DO	BOD	COD	NH_3-N	NO_3-N	TN	PO_4-P	TP
Forest	**-0.585****	**-0.558****	**-0.374****	**-0.401****	0.008	-0.146	-0.164*	-0.231**	**-0.725****	**-0.572****	**-0.507****	**-0.628****
Urban	0.218**	0.242**	0.135	0.094	**-0.482****	**0.641****	0.390**	**0.702****	-0.221**	0.209*	-0.003	0.039
Market Gardening	**0.652****	**0.616****	**0.230****	**0.585****	0.001	0.058	0.060	0.083	**0.843****	**0.519****	**0.650****	**0.603****
Tea	0.102	0.080	0.221**	0.277**	**0.414****	**-0.372****	-0.143	-0.328**	**0.528****	0.168*	0.313**	0.396**
Scrub	0.208*	0.232**	**0.495****	0.263**	0.010	-0.153	-0.009	0.000	**0.435****	0.325**	0.279**	0.369**
Water	0.376**	0.361**	**0.460****	**0.519****	0.147	-0.134	-0.010	-0.004	0.679**	0.421**	0.394**	0.513**

N=144; the bold-faced numerical values indicate a significant relationship at a level of $p < 0.01$.

Table 5.5 Spearman's Correlation among the Land use types and Water Quality Variables (Rainy Season)

Land Type	EC	TDS	Turb.	TSS	DO	BOD	COD	NH_3-N	NO_3-N	TN	PO_4-P	TP
Forest	-0.513**	-0.496**	-0.250*	-0.221	-0.053	-0.172	-0.068	-0.114	-0.745**	-0.598**	-0.453**	-0.462**
Urban	0.171	0.203	-0.022	0.030	**-0.607****	**0.473****	**0.605****	**0.685****	-0.227	0.049	-0.310**	-0.310*
Market Gardening	**0.690****	**0.663****	0.188	**0.715****	0.056	0.085	0.077	0.021	**0.905****	**0.567****	**0.747****	**0.712****
Tea	0.082	0.048	0.368**	**0.327****	**0.611****	-0.156	-0.342**	-0.399**	**0.497****	0.294*	**0.588****	**0.586****
Scrub	0.193	0.196	**0.735****	0.135	0.169	0.075	-0.084	0.031	0.404**	0.474**	0.430**	0.435**
Water	0.326**	0.307**	0.429**	0.401**	0.243*	-0.024	-0.193	-0.075	0.689**	0.543**	0.456**	0.482**

N=72; the bold-faced numerical values indicate a significant relationship at a level of $p < 0.01$.

5.7.3 Seasonal Impact

In the catchment, BOD, COD, and NH_3-N showed positive relationships with the proportion of urban land uses in both the seasons. The relationships of BOD, COD, and NH3-N with urban uses were consistent over the seasons with small variances. However, BOD in the dry season seemed to be more sensitive to urban land while COD in the rainy season. The correlation revealed that the high BOD, NH_3-N, and COD could be attributed to the discharge of domestic sewage into the river system in both the seasons. Similar findings have consistently reported such close relationships between urban land uses and degraded water quality (Chen and Lu, 2014; Lee et al., 2009; Zhang et al., 2015; Zhou et al., 2012). The sensitivity of relationship may play important role in the variations of BOD and COD seasonally.

Nutrient variables like NO_3-N, TN, PO_4-P, and TP as well as physico-chemical parameters as turbidity and TSS showed significant positive relationships with market gardening land use in both the seasons. All the parameters tend to more sensitive during the rainy seasons than dry season. All the relationships revealed that TSS, turbidity and nutrient variables like NO_3-N, TN, PO_4-P, and TP could be attributed to agricultural runoff from market gardening. The sensitivity of relationship might increase their variations as high in a rainy season. Significant relationships between market gardening and organic matters were observed neither dry nor rainy season. Numerous studies have reported that agricultural land uses have a negative contribution to water quality in watersheds (Bu et al., 2014; Khoi and Suetsugi, 2014; Kibena et al., 2014b). The results of this study are consistent with such previous findings. In the catchment, nutrient variables like NO_3-N, PO_4-P, and TP also showed positive relationships with tea and scrubland types in both the seasons. These two land uses could also be responsible for nutrient variations in water quality along the catchment (Huang et al., 2016; Zaini et al., 2014).

The area of forest land type showed significant negative relationships with physico-chemical water quality parameters as EC, TDS, turbidity, TSS and nutrient variables as NO_3-N, TN, PO_4-P and TP in both the seasons. These results are consistent with findings of previous studies reporting a positive contribution of forests to water quality (Bu et al., 2014; Chen and Lu, 2014; Lee et al., 2009; Pratt and Chang, 2012; Tong and Chen, 2002; Tu, 2013; Zhou et al., 2012)

5.8 Summary

As part of the present research, the landuse change study was carried out to understand the relationship between landuse and water quality within the catchment. For landuse assessment, data acquisition, georeferencing, digitization, change detection and slope analysis techniques were applied to analyze the changing status and trends of land usage over time (1984-2010) using GIS approach.

The results of landuse changes and land type distribution showed that 10 (ten) categorical land types were distributed during the study periods (1984-2010) within the catchment. In 1984, the land type followed the rank order as forest > tea > scrub > market gardening > urban > horticulture > water body. Forest was the major landuse type covered more than 73 percent of total catchment in 1984. With the passage of time, the forest successively decreased to 50 percent in 2010. Tea plantation was the second land type followed by forest covering about 14 percent area in 1984. The land type also reduced and became 10 percent in 2010. Scrub, horticulture, orchards and open land types also followed the similar decreasing trend with the passage of time. Conversely, market gardening and urban land type showed a consistently increasing trend in the catchment over time. In 1984, the market gardening occupied a total area of 2.4 percent which was dramatically increased to more than 19 percent in 2010. Similarly, urban land type increased to 6 percent in its total area in 2010 that was only about 1.7 percent in 1984. Floriculture introduced as a new land type within the catchment in 2004. The land type significantly increased its amount of land area to 8 percent in 2010. With the passage of time, the major changes in market gardening, floriculture, urban and orchards area turned the land use categories as its most recent situation and ranked as forest > market gardening > tea > floriculture > urban > scrub > water body > horticulture > open land > orchard in 2010 within the catchment.

The pattern change results revealed that an increasing trend of positive change for market gardening followed by floriculture and urban. The substantial expansion of market gardening (16.37 km^2) and urban area (4.15 km^2) has taken place during the study period resulting in significant decrease in forest area (22.85 km^2). A major modification of floriculture land type (8.04 km^2) from market gardening was observed in the study area. The changing trend of land usage over the last 26 years clearly exhibited that forest land type mostly converted to market gardening (14.28 km^2), urban

($2.55\ km^2$) and scrub ($3.02\ km^2$) land types. It also showed that the additional extension of market gardening land altered from scrub ($3.55\ km^2$), tea ($2.00\ km^2$) and orchard ($1.87\ km^2$) land types. On the other hand, floriculture land type mainly converted from market gardening ($4.80\ km^2$), orchard ($1.86\ km^2$) and forest ($0.63\ km^2$) land types. Slope analysis showed that more than 40% area within catchment has slopes in between 10^0-30^0. A noticeable rate of agricultural activities developed along these slope ranges with replacing forest land type over time.

The studied catchment was sub-divided into 12 sub-catchment areas based on sampling sites. The sub-catchment wise land type distribution exhibited most of the sub-catchments were covered by more than 50 percent forest land. The urban land type was distributed dominantly in sub-catchments located mainly in the upper catchment of the study area with a range of 22% to 38%. A small urban land (3-5 percent) was also present in lower catchment. Market gardening land type varies from 0% to 49% within the whole catchment. The higher percentage market gardening land types were found in the zones of lower catchment ranging from 49% to 43%. At sub-catchment in middle catchment, market gardening varied from 12% to 22%. About 15%-32% market gardening was seen in the sub-catchments within the upper catchment. Dominated tea land type was observed mainly within sub-catchment zones in the middle catchment.

Statistical analysis showed significant seasonal relationships between the different landuse types and water quality parameters in the catchment. The urban land use had a significant positive correlation with BOD, COD, and NH_3-N in both the seasons suggested that the urban area might be one of the main sources of organic pollutants. BOD appeared more sensitive compared to COD in the dry season and vice versa. On the other hands, market gardening land type exhibited significant positive relationships with nutrient variables like NO_3-N, TN, PO_4-P, and TP as well as turbidity and TSS. All these parameters tend to more sensitive during the rainy seasons than the dry season. The relationships indicated that the nutrient variables, turbidity, and TSS might be attributed to non-point source pollutants from market gardening land type. Similarly, tea land type also showed positive relationships with nutrient variables like NO_3-N, PO_4-P, and TP in both the seasons. In addition, compared with other land types, market gardening and tea were the major source areas for nutrient variations in water quality along the catchment in both the seasons. Forest land type showed significant negative relationships with all physico-chemical water quality parameters in both the seasons indicative of better water quality within the catchment.

Overall, the land use changes in the Bertam Catchment were characterized by expansion of the land use types with higher development pressure (agricultural activities and urban) and reduction of land use types with higher environmental value (forest and scrubland). The study revealed that the economic benefit from rapid landuse changes had ultimately resulted in potential impacts on water quality degradation in the area. Sustainable landuse planning and management are urgent to handle the equilibrium between water resource conservation with land use development and utilization.

CHAPTER 6

SOIL EROSION ESTIMATION UNDER DIFFERENT LANDUSE

6.1 Introduction

Soil erosion is a complex and dynamic phenomenon affecting many areas all over the world. It represents one of the major sources of environmental worsening. In fact, soil erosion affects geomorphological features at both hillslope and watershed scales, soil fertility, sedimentation, agriculture productivity, water quality, reservoir capacity, and land degradation (Aiello et al., 2015; Priess et al., 2015; Ranzi et al., 2012). However, the rate of soil erosion depends on a number of factors such as vegetation cover, topographic feature, climatic variables and soil characteristics. Although soil erosion is characterized as a natural phenomenon, anthropogenic activities alter the vegetation cover can accelerate the soil erosion rate further (Karydas et al., 2009).

Spatial and quantitative information of soil erosion contributes significantly to the soil conservation management, erosion control, and general catchment areas management (Prasannakumar et al., 2012). Assessment of soil erosion is also useful in planning and conservation works in a watershed or catchment. Modeling can provide a quantitative and consistent approach to estimate soil erosion and sediment yield under a wide range of conditions. Thus, estimation of soil loss and identification of critical area for implementation of best management practice is crucial to the success of a soil conservation program.

The study area, Bertam Catchment, is a mountainous area subjected to torrential tropical showers. Favourable climatic condition allowed the catchment area most suitable for the cultivation of many subtropical crops, temperate vegetables, and flowers. However, the catchment is very susceptible to soil erosion because of extensive rainfall, rugged mountainous topography and characterized by agricultural activities on steep slopes. Moreover, soil erosion is the consequence effect of uncontrolled and unplanned landuse changes within the catchment. All these factors are responsible for increased soil erosion and led to tremendous pressure on the siltation of reservoirs, degradation of soils and deterioration of water quality in the catchment (Aminuddin et al., 2005; Fortuin, 2006; Midmore et al., 1996; Teh, 2011; Toriman et al., 2010).

Keeping the above views with the utmost attention, soil erosion assessment has been taken into consideration in the research as an important objective. In the present study, RUSLE integrated with GIS has been used to generate soil erosion map and to estimate average annual soil loss in the Bertam River Catchment. As a number of erosion and run-off relevant factors such as slope and landuse types and practices are varying in the studied area, sub-catchments of the Bertam Catchment have been analyzed to identify the spatial distribution of soil erosion and potentially vulnerable zones within the catchment. The landuse change within the sub-catchments also estimated to predict how landuse change impact on the soil erosion and thus on water quality.

6.2 Topographic Impact on Soil Erosion

According to the final result, topographic factor values for Bertam Catchment, range from 0 (lower slope) to 1468 (steep slope) is shown in Figure 6.1. The LS factor map shows a clear spatial correlation with the spatial pattern of annual average soil erosion map. The relation indicates that topography of the catchment played a major role in controlling soil movement in a Bertam Catchment (Toriman et al., 2010; Yu et al., 2016).

6.3 Management Factor Impact on Soil Erosion

Information on land use in the study area permits a better understanding of the land utilization aspects of agricultural practices, forest, urban, scrub and surface water bodies, which are vital for erosion studies. GIS technique generated a thematic layer of landuse-land changes of the catchment. Management factor was assigned to different land use patterns using the values shown in Table 3.9 in methodology chapter.

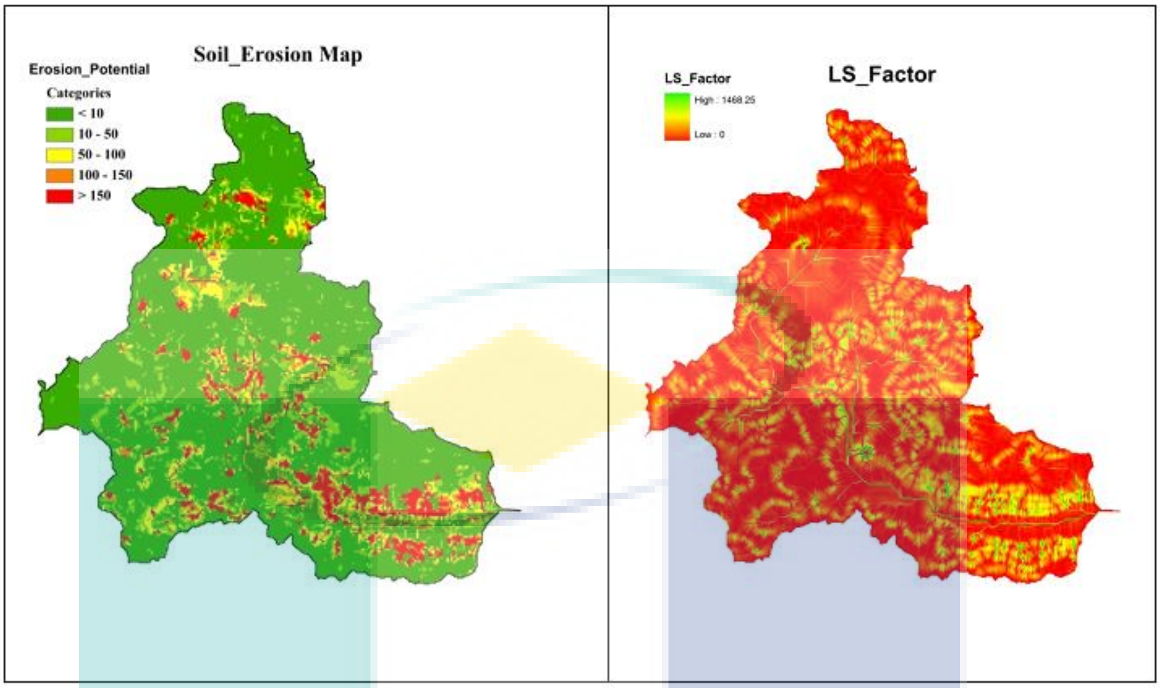

Figure 6.1 Spatial correlation between soil erosion map and LS factor map in the Bertam Catchment

Using land use-land cover map and C and P factor values, the C and P factor maps were prepared and shown in Figure 6.2. The results showed that the values of C and P vary between 0 and 1. C and P factor values are higher for open land, agricultural activities like mixed agriculture, market gardening, orchard and built up areas like urban and agricultural station while for vegetation land types like forest and scrub are close to 0. The lower the C and P values give rise to decrease in soil loss and more effective in soil conservation and vice versa. Thus, agricultural activities and built up landuses played a major role in soil erosion in Bertam Catchment (Aiello et al., 2015; Prasannakumar et al., 2012).

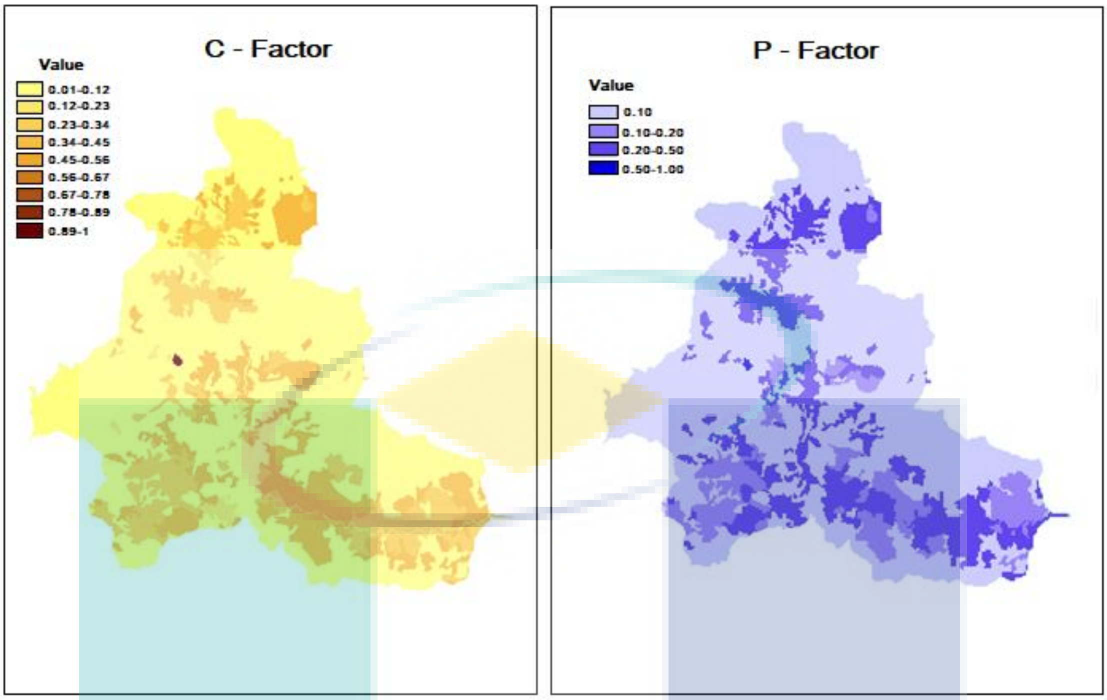

Figure 6.2 C and P factor maps of the studied catchment

6.4 Soil Erosion Map in Bertam Catchment

The soil erosion map for the present studied area was generated based on landuse map of the year 2010 (latest published landuse map from Department of agriculture, for the area) as shown in Figure 6.3. The final soil erosion map was reclassified into five erosion potential categories, such as low, moderate, moderately high, high and very high for visual interpretation. The spatial pattern of classified soil erosion potential classes indicates that the areas with high to very high categories are located in the lower catchment of the study area, while the areas with low to moderate categories are located in the middle part of the catchment area.

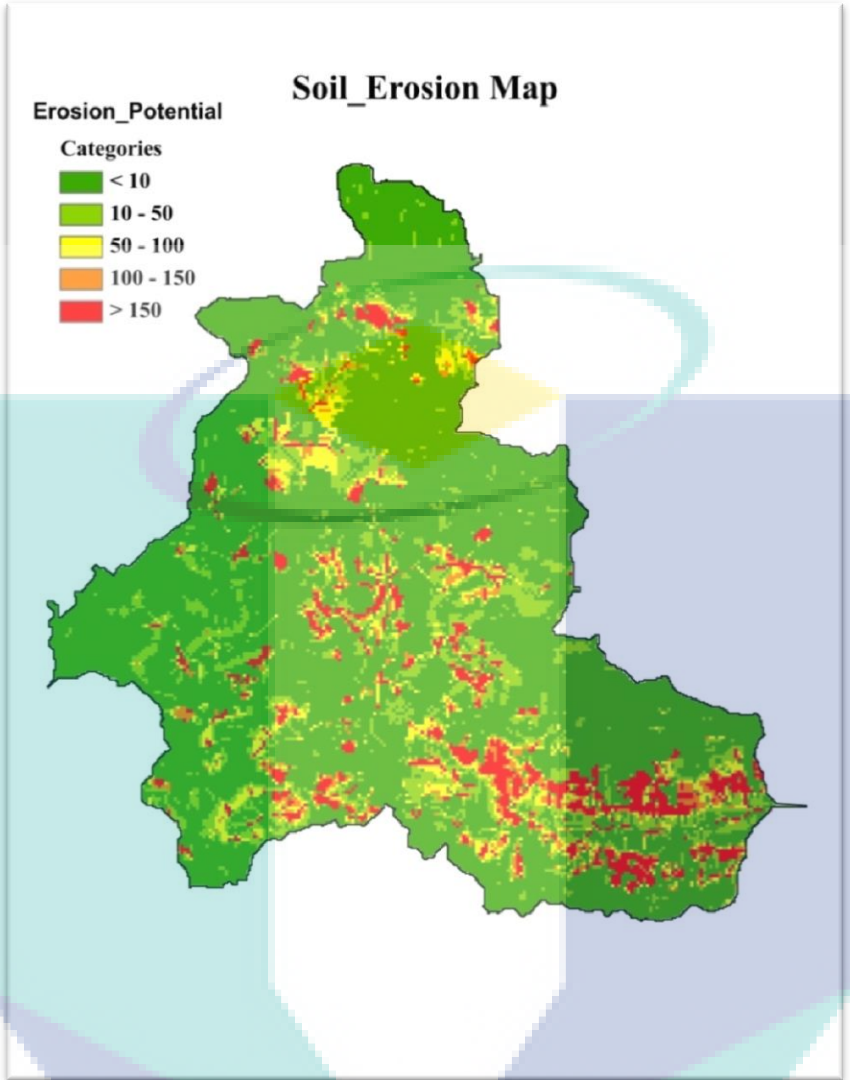

Figure 6.3 Soil erosion map of the Bertam Catchment area

The measured area (km^2) and areal percentage (%) according to erosion potential categories were also calculated and shown in Table 6.1. The results showed that about 72.33% of the catchment area is under low potential erosion level (<10 t/ha/yr), while rest of the area (27.67%) is under moderate to very high erosion categories. In the present study, high erosion risk area is calculated about 3% (100-150 t/ha/yr) while very high erosion risk area is about 6.57% (>150 t/ha/yr). The remaining 18.10 % area is under moderate to moderately high categories.

Table 6.1 Area and areal percentage of soil erosion losses for Bertam catchment area

Catchment	Potential Category	Soil Loss (ton/ha/yr)	Area (Km^2)	Area (%)
Bertam Catchment	Low	< 10	70.42	72.33
	Moderate	10 to 50	12.37	12.71
	Moderate High	50-100	5.25	5.40
	High	100-150	2.92	3.00
	Very High	> 150	6.39	6.57
		Total	97.36	100.00

6.4.1 Soil Erosion Map of Sub-catchment

The annual soil erosion maps for three sub-catchments were generated and shown in Figure 6.4.

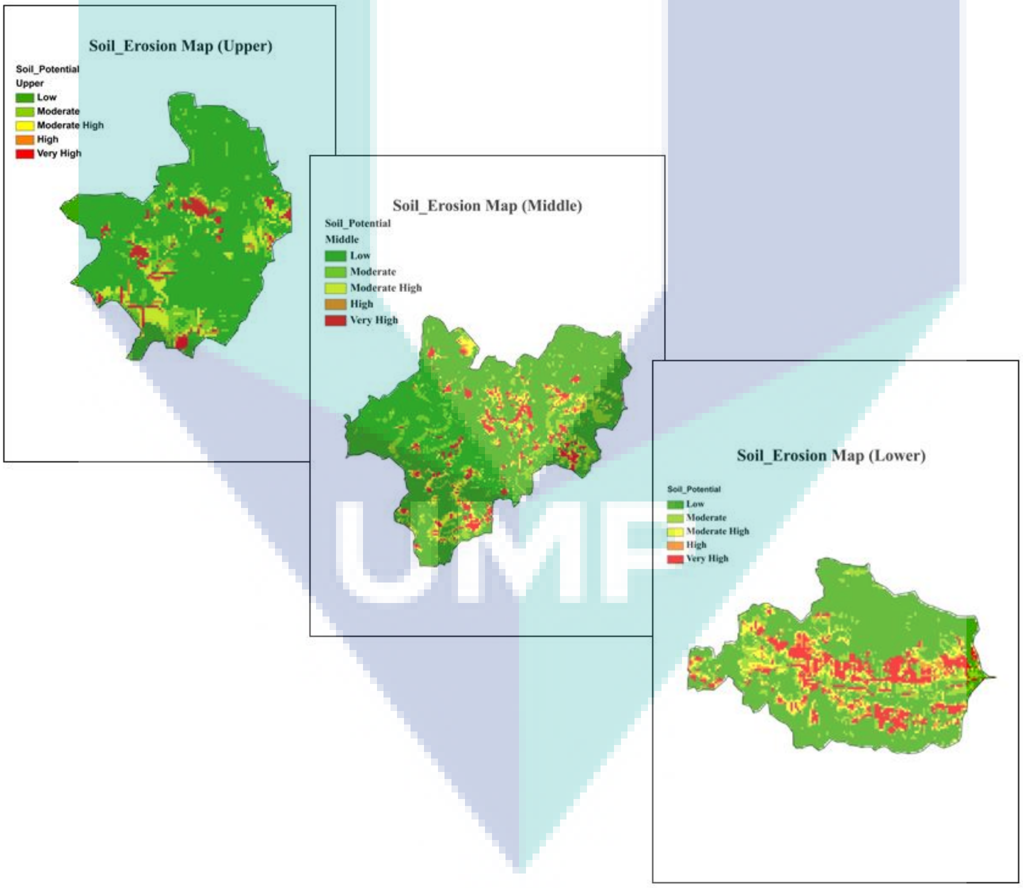

Figure 6.4 Soil erosion maps of sub-catchments based on soil potential categories.

Similar to Bertam Catchment, the soil erosion map of three sub-catchments, namely- i) Upper, ii) Middle, and iii) Lower Bertam Catchment were also classified into five categories. The calculated area (km^2) and areal percentage (%) according to erosion potential categories were described as follows:

6.4.2 Soil Erosion at Upper Bertam Sub-catchment

For the Upper sub-catchment, the soil erosion map and calculated area (km^2) and areal percentage (%) of erosion potential categories were presented in Figure 6.5 and Table 6.2.

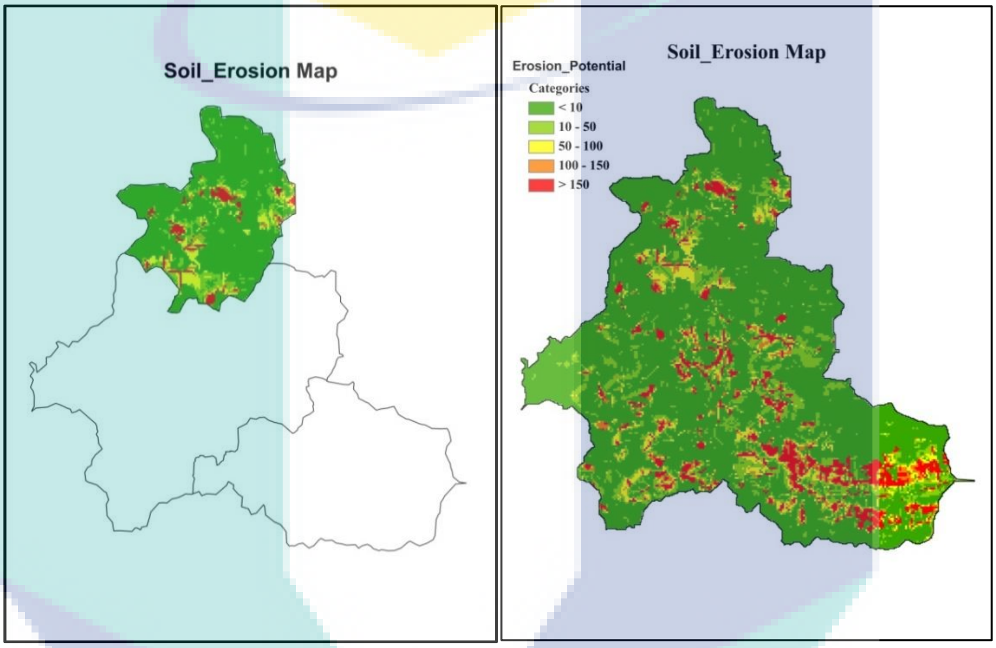

Figure 6.5 Soil erosion map of the Upper Bertam sub-catchment area

The areal extension of Upper sub-catchment is about 20.88 km^2 of the entire Bertam Catchment. The results presented in Table 6.2 shows that 6.22% area of the sub-catchment ranges between high to very high categories of erosion, while 77.63% results in the low potential category. The remaining 16.14% covers under moderate to moderately high potential categories.

Table 6.2 Area and areal percentage of soil erosion losses for Upper Bertam Sub-catchment area

Sub-Catchment	Potential Category	Soil Loss (ton/ha/yr)	Area (Km^2)	Area (%)
Upper Bertam Sub- catchment	Low	< 10	16.21	77.63
	Moderate	10 to 50	2.01	9.63
	Moderate High	50-100	1.36	6.51
	High	100-150	0.46	2.20
	Very High	> 150	0.84	4.02
		Sub-total	20.88	100.00

6.4.3 Soil Erosion at Middle Bertam Sub-catchment

For the interpretation of soil erosion in Middle Bertam sub-catchment, the soil erosion map and calculated area (km^2) and areal percentage (%) of erosion potential categories were presented in Figure 6.6 and in Table 6.3.

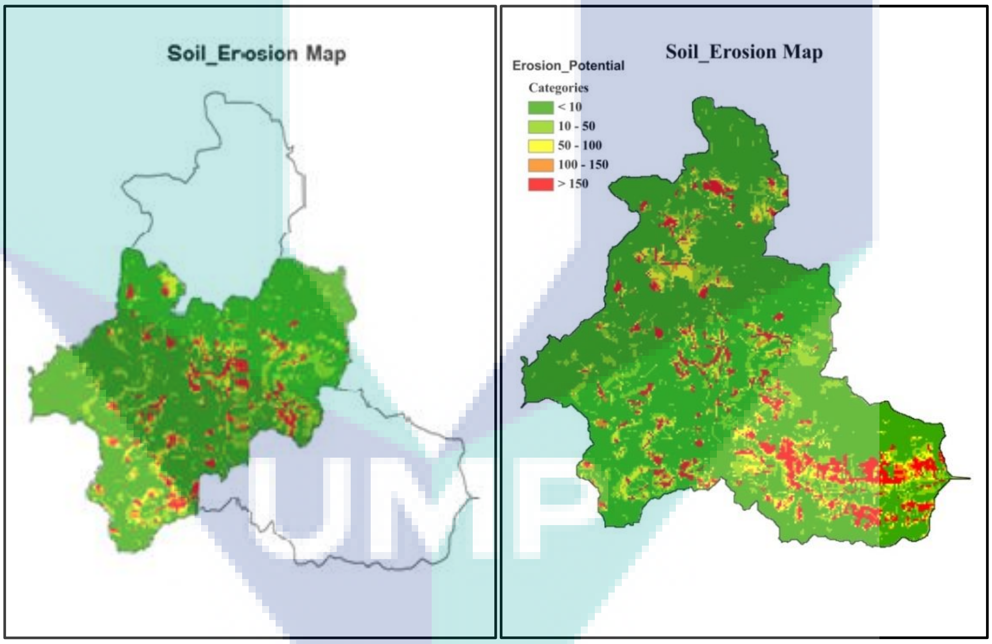

Figure 6.6 Soil erosion map of the Middle Bertam sub-catchment area

Middle Bertam sub-catchment spreads about 47.89 km^2 area of the entire Catchment. In this sub-catchment, about 75.95% area is under low potential erosion category while 6.81 % area is under high to very high erosion categories. About 17.24% of the middle sub-catchment area shows moderate to moderately high soil potential categories.

Table 6.3 Area and areal percentage of soil erosion losses for Middle Bertam sub-catchment area

Sub-Catchment	Potential Category	Soil Loss (ton/ha/yr)	Area (Km^2)	Area (%)
	Low	< 10	36.37	75.95
	Moderate	10 to 50	6.27	13.10
Middle Bertam Sub- catchment	Moderate High	50-100	1.98	4.14
	High	100-150	1.11	2.32
	Very High	> 150	2.15	4.49
		Sub-total	47.90	100.00

6.4.4 Soil Erosion at Lower Bertam Sub-catchment

The prepared soil erosion map and areal distributions of soil erosion loss at Lower Bertam sub-catchment were presented in Figure 6.7 and in Table 6.4. From the Figure 00, it can be seen that very high erosion potential category (>150 t/ha/yr) is more visible compared to other categories in this sub-catchment.

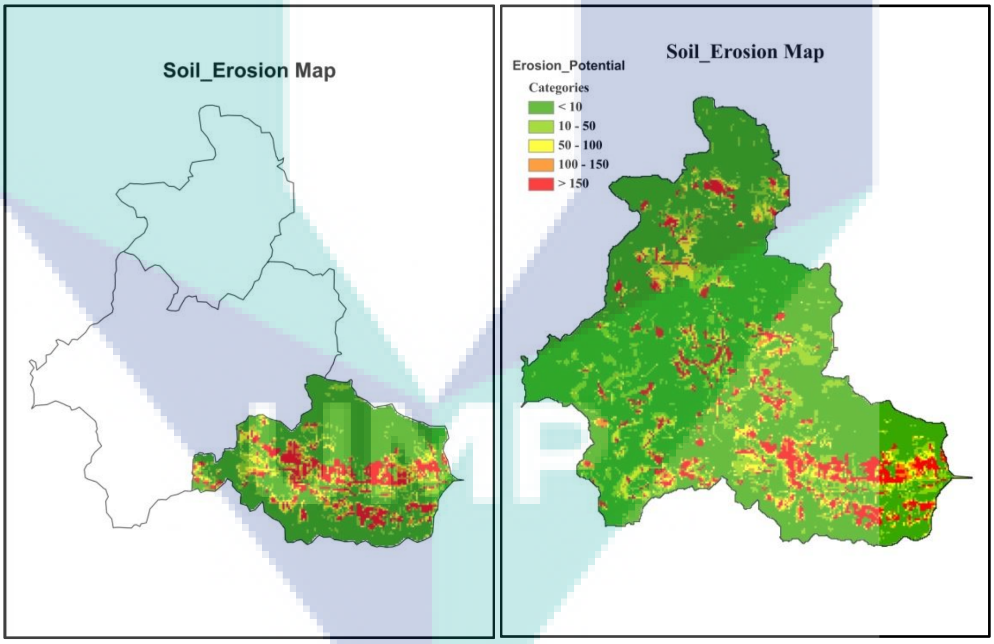

Figure 6.7 Soil erosion map of the Middle Bertam sub-catchment area

The areal extension of the Lower Bertam sub-catchment is about 28.58 km^2. Within the sub-catchment, high soil erosion potential area is calculated about 5.15% while the very high soil erosion potential is counted about 11.85%. About 19.79% area is under moderate to moderately high erosion categories.

Table 6.4 Area and areal percentage of soil erosion losses for Middle Bertam Sub-catchment area

Sub-Catchment	Potential Category	Soil Loss (ton/ha/yr)	Area (Km^2)	Area (%)
Lower Bertam Sub- catchment	Low	< 10	18.06	63.20
	Moderate	10 to 5	3.51	12.29
	Moderate High	50-100	2.14	7.50
	High	100-150	1.47	5.15
	Very High	> 150	3.39	11.85
		Sub-total	28.58	100.00

6.4.5 Spatial Pattern of Soil Erosion Risk Zones

Figure 6.8 shows the spatial pattern variation of soil erosion among the three sub-catchments of Bertam Catchment. The spatial distribution of soil erosion potential categories elucidates that high to very high erosional areas occur in all three sub-catchments within the catchment. The areal expansions of high as well as very high categories are gradually increased towards the Lower sub-catchment. The Lower sub-catchment shows more areas of high to very high erosion compare to Middle and Upper sub-catchment. Conversely, the Middle sub-catchment shows higher areas of high to very high erosion compare to Upper sub-catchment.

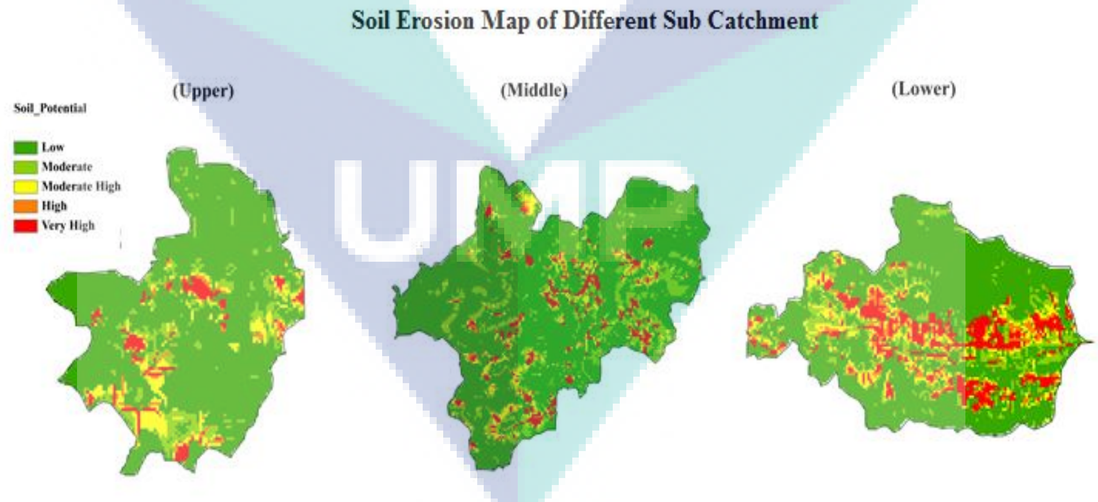

Figure 6.8 Spatial variation of soil erosion among the sub-catchment of Bertam Catchment

6.5 Average Annual Soil Loss in Bertam Catchment for 2010

Annual average soil loss rate of the sub-catchments of the Bertam Catchment using the RUSLE method was summarized in Table 6.5. The mean value of annual average soil loss rate for each sub-catchment was determined in ton/ha/year.

Table 6.5 Average Annual Soil Loss of Bertam Catchment for 2010

Catchment	Sub-Catchment	Description	Area (Km^2)	Annual Soil Loss (ton/ha/yr)		
				Min	Max	W. Mean
Bertam	Upper		20.88	0	4474.25	27.60
	Middle		47.90	0	8737.70	31.80
	Lower		28.58	0	7328.69	63.83
			97.36			123.23

Spatial distribution of soil loss information in GIS is given in continuous scale or on a cell-by-cell basis. Using RUSLE equation, the annual mean soil erosion rate was calculated by cell by cell analysis (Baja et al., 2014; Ganasri and Ramesh, 2016). The result estimates soil erosion ranges from minimum to maximum cell value with a mean value of soil erosion. The mean value can be considered as the representative of the current soil loss rate of the area. The minimum values of annual soil loss shows 0 as the topographic factor values for Bertam Catchment ranges from 0 (lower slope) to 1468 (steep slope) .

Using the RUSLE model, the annual average soil loss rate of the Bertam Catchment was predicted to be 123.23 ton/ ha/ year for the year 2010. Individually, the average annual soil loss rate for Upper, Middle and Lower sub-catchment was 27.60, 31.80 and 63.83 ton/ ha/ year respectively. Thus, the rate of average annual soil loss shows a gradually increasing trend from Upper sub-catchment to Lower sub-catchment (Figure 6.9). The increment of agricultural activities at the steep slopes in Lower Bertam might be the reason behind the higher soil erosion (Ganasri and Ramesh, 2016).

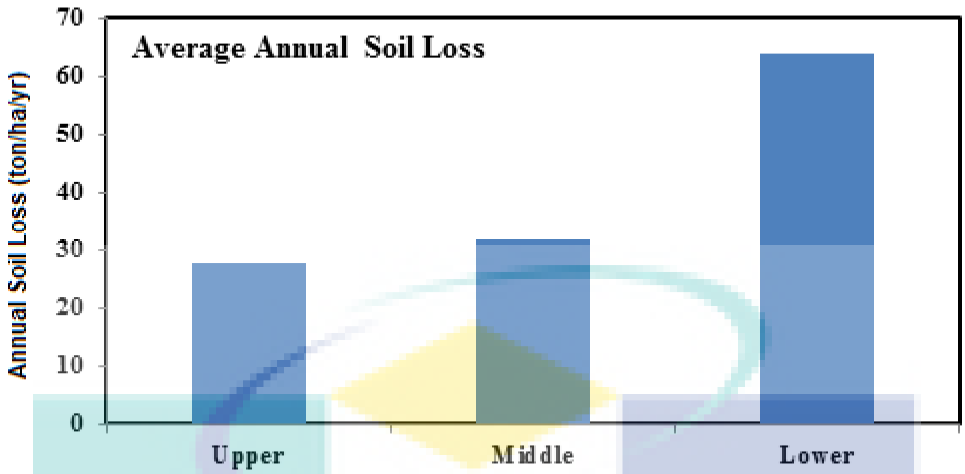

Figure 6.9 Annual average soil loss rates for the sub-catchments of Bertam Catchment

6.6 Landuse types at Each Sub-catchment of Bertam Catchment

The area and areal percentage of each land use type in each sub-catchment were calculated from landuse map of 2010. The results of these landuse types are shown in Table 6.6, Table 6.7 and Figure 6.10.

Form the Table 6.6 and Table 6.7, as can be seen in the Upper sub-catchment, the forest area covered 66.57% (13.90 km^2) of its total sub-catchment area. This land type was followed by urban and market gardening covered areas of 3.82 km^2 (18.30%) and 2.94 km^2 (14.08%), respectively. Tea showed a little existence with an area of 0.18 km^2. No scrub was observed in the sub-catchment. On the other hand, forest, market gardening, and tea were dominant landuse types as ranked in the middle sub-catchment. Forest covered 47.14% of its total sub-catchment area, while market gardening was that of 23.38%. Tea plantation and scrub areas of 8.01 km^2 (16.72%) and 4.34 km^2 (9.06%), respectively in the sub-catchment showed higher percentage compare to other two sub-catchments. However, in the Lower sub-catchment, landuse type showed a different scenario, where the area of market gardening (12.82 km^2) exceeded than that of forest (12.46 km^2). The land type covered an area of 44.86 % (12.82 km^2) of its total sub-catchment area followed by forest (43.60%), tea (6.30%) and urban (2.52%). Scrub was very less in the sub-catchment, which only about 1.75 % (0.50 km^2) of its total area.

Table 6.6 Area of each landuse type at each sub-catchment of Bertam Catchment

Sub-catchment	**Forest (Km^2)**	**Urban (Km^2)**	**Market Gardening (Km^2)**	**Scrub (Km^2)**	**Tea (Km^2)**	**Water Body (Km^2)**	**Total (Km^2)**
Upper Bertam	13.90	3.82	2.94	0.00	0.18	0.04	20.88
Middle Bertam	22.58	1.26	11.20	4.34	8.01	0.51	47.90
Lower Bertam	12.46	0.72	12.82	0.50	1.80	0.28	28.58
Sub Total	48.94	5.80	26.96	4.84	9.99	0.83	97.36

Table 6.7 Percentage of landuse type at each sub-catchment of Bertam Catchment

Sub-catchment	Forest (%)	Urban (%)	Market Gardening (%)	Scrub (%)	Tea (%)	Water Body (%)	Total (%)
Upper Bertam	66.57	18.30	14.08	0.00	0.86	0.19	100.00
Middle Bertam	47.14	2.63	23.38	9.06	16.72	1.06	100.00
Lower Bertam	43.60	2.52	44.86	1.75	6.30	0.98	100.00

From the Figure 6.10, it can be illustrated that the percentage of forest area is higher in the Upper sub-catchment compare to Middle and Lower sub-catchment. Conversely, market gardening showed an opposite trend among the sub-catchments. This land type was much higher in Lower sub-catchment than other two sub-catchments.

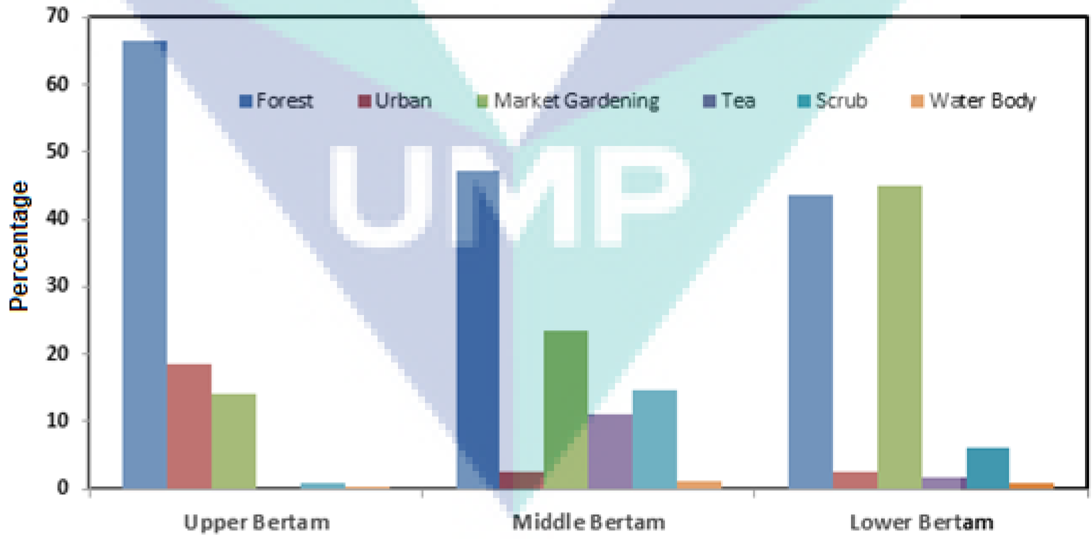

Figure 6.10 Percentage of land type areas within different sub-catchments under Bertam Catchment.

6.7 Impact of Landuse Type on Soil Erosion Rate

Soil erosion has a close relationship with landuse types of a region (Ganasri et al., 2017, (Moghadam et al., 2015). An attempt was made to analyze the impact of land use changes on erosion rate in the Bertam Catchment comparing the land use studies in the previous sub-section and landuse changes studies in Chapter 5.

Concerning the Bertam Catchment, major landuse types correspond to the forest, market gardening, urban and tea. Vegetation cover is changing during the last decades, due to deforestation for agricultural development and urbanization. In the previous chapter 5, the results showed that the substantial expansion of market gardening (16.37 km^2) and urban area (4.15 km^2) had occurred during the study period (1984-2010) along with a significant decreased in forest (22.85 km^2), tea (3.63 km^2) and scrub (1.11 km^2) area. Within the catchment, it was estimated that 23.70% of the area has slopes in between 10°-20° and 17.76% has slopes in between 20°-30° (Table 5.3). In addition, it was observed that a noticeable rate of agricultural activities developed along the slope ranges of 10°-30° with replacing the forest land type over time within the Bertam Catchment. All these changes contributed to severe soil erosion in the study catchment (Ali and Hagos, 2016; Priess et al., 2015; Ranzi et al., 2012; Teh, 2011).

From the results in Table 6.7 and Figure 6.10, it was clearly seen that the urban development dominated in the Upper sub-catchment area while agricultural activities expanded moderately in Middle sub-catchment and tremendously in Lower sub-catchment. In the Upper sub-catchment, high to very high erosion areas covered 1.30 km^2 of the total catchment. Most of these areas fell under urban land type in the sub-catchment. Thus, the major contribution of soil erosion in this sub-catchment was urban development as a result of land clearing in the name of hill land development (Masum et al., 2017; Teh, 2011). In the Middle sub-catchment, high to very high erosion covered an area of 3.26 km^2 which were mainly corresponded to market gardening and tea plantation land type. About 23.38% market gardening and 16.72% tea land areas played a vital role in increasing soil erosion rate in the sub-catchment (Priess et al., 2015; Ranzi et al., 2012; Zaini et al., 2014). In this study, the highest area of high to very high erosion categories was observed in the Lower sub-catchment covering an area of 4.86 km^2 of the total catchment. Observed soil erosional areas were mainly linked to market gardening land type. It is clearly elucidated from the Figure 6.10 that the lower sub-catchment dominated with market gardening land type covering an area of about 44.86% of the total market gardening land type. The market gardening areas were mainly concentrated at Ringlet and Bertam Valley in the Lower sub-catchment along the hill slopes (Rasul, 2016). According to Midmore et al. (1996), average soil erosion of 24 t/ ha/ year produced from the preparations of broad platform terraces, cut out of the natural slopes in the study area. As examined by Aminuddin et al. (2005), soil loss was in the range of 24–42 ton/ha/yr under vegetables and 1.3 ton/ha/yr under rain-shelter in the study area. Thus, agricultural activities were the main contributor to the highest soil erosion in Lower sub-catchment (Priess et al., 2015; Ranzi et al., 2012; Teh, 2011). According to model, the average annual soil erosion for the Lower catchment was predicted to be 63.83 ton/ ha/ year and 17.00% of the area ranges between high to very high soil erosion potential categories. These factors raised the sub-catchment as the most soil erosional risk zone within the Bertam Catchment. All these factors significantly intensify the soil erosion and subsequently leading to sedimentation in the existing river systems. Huge sedimentation in the catchment area ultimately resulted in water quality deterioration (Issaka and Ashraf, 2017; Mukundan et al., 2013). A huge concentration of TSS in all stations of the river in both the seasons is mainly due to the strong rate of soil erosion (Zaiha et al., 2015).

6.8 Summary

The RUSLE model in conjunction with GIS was applied to estimate the annual average soil erosion rate in the Bertam Catchment of Cameron Highlands. For model calculation, R, K, LS, C and P factor maps were generated using rainfall, soil erodibility, slope, and steepness, as well as landuse management data. The annual soil erosion map for each sub-catchment was also prepared. In addition, soil erosion risk map was generated for visual interpretation of spatial erosion distribution according to erosion potential categories.

Rainfall intensities, higher CP values for agricultural activities and built up landuse as well as LS factors (topographic factor) played major roles in soil erosion in the catchment. 27.7 percent of the catchment was under moderate to very high erosion categories. Among the percentages, the high erosion risk area (100-150 t/ha/yr) was 3 percent while that of very high (> 150 t/ha/yr) was measured about 6.75 percent in the entire catchment. The areal extension of the three sub-catchments was as 20.88 km^2, 47.89 km^2 and 28.58 km^2 for upper, middle and lower sub-catchment, respectively. 6.22 percent area of the upper sub-catchment was under the high to very high categories of erosion while 6.81 percent and 17 percent areas of middle and lower sub-catchments were under the similar categories. The link between spatial soil distribution and land type variations within the catchment predicted that dominated urban development in the upper sub-catchment area was the major contribution of soil erosion as a result of land clearing in the name of hill land development. In the middle sub-catchment, market gardening and tea land were mainly responsible for increasing soil erosion rate. Within the entire catchment, the highest area of high to very high erosion categories was found in the lower sub-catchment covering an area of 17 % (4.86 km^2) of the sub-catchment. The soil erosional areas in this sub-catchment were observed mainly linked to the market gardening land area.

From the results, it was clearly seen that the urban development dominated in the Upper sub-catchment while agricultural activities expanded moderately in Middle sub-catchment and tremendously in Lower sub-catchment. The results of landuse types in each sub-catchment show that urban development dominates in the Upper sub-catchment. Middle sub-catchment is characterized by market gardening and tea land type. Market gardening shows its highest percentage in the Lower sub-catchment. It is also clearly predicted from land types distribution that higher the market gardening, greater the soil erosion rate. Urban development is contributed to soil erosion in Upper sub-catchment as a result land clearing for hill land development. Agricultural activities and hill slope maintenance practices mainly increase the sediment erosion in the Lower sub-catchment and earmark the area as the most vulnerable zone within the catchment.

Finally, it can be concluded that the overall development of soil erosion is very closely related to the change in land use, the agricultural management situation along with the terrain features within the Bertam River Catchment. All these factors significantly intensify the soil erosion and subsequently leading to sedimentation in the existing river systems. Huge sedimentation in the catchment area ultimately resulted in water quality deterioration. Therefore, it is clear that the higher soil erosion and sediment transport from overland eroded area significantly increased the TSS concentrations at most of the stations of Bertam River and its tributaries within the catchment all around the year.

CHAPTER 7

SOCIAL SURVEY AND INTEGRATED ASSESSMENT FOR SUSTAINABLE MANAGEMENT

7.1 Introduction

From the previous three chapters (Chapter 4-6), it is obvious that the scientific findings confirm the deterioration of water quality in the Bertam River Catchment. Landuse changes and soil erosion play main roles in the process of water quality deterioration. Landuse changes within the study area are mainly characterized by rapid change in agricultural activities and urban development. Soil erosion is the major consequence of such land pattern changes along with human activities. Soil erosion process is dominating as a result of heavy rainfall, topographic features and agricultural practices along the slopes within the study area. However, it is now a matter of question whether the local communities' are concern about such changes as the causes of freshwater pollution as well as whether they are aware of such changes occurring to the environment and the consequence thereof. Actually, communities' awareness and engagement are very important in the process of finding solutions to the river catchment management affecting local communities in Cameron Highlands (Rolston et al., 2017; Weng and Mokhtar, 2013).

It is well known that the indigenous culture and local perceptions play a vital role in sustainable natural resource crisis intervention (Ayeni et al., 2014). The communities' around the area are the real observers of any environmental changes and subsequent problems. Any change in environment (water quality, landuse pattern and soil erosion) is a complex interaction between the human and the ecosystem. People modify the environment for their purposes and obtain benefits like water, timber, food, energy, information, land conversion for farming and much more from it. Therefore, it is important to be aware of specific characteristics of the human social systems in order to analyze the human-environmental interactions. The type of society strongly influences communities' values, knowledge, attitude, behavior and therefore their impact on ecosystems. Thus, the complexity of human-environmental influences can be addressed not through only scientific protocols but also through the active participation of community-based indigenous knowledge, perception and attitude (Ayeni et al., 2016; Chicas et al., 2016; Deng et al., 2012).

Keeping the view in consideration, a social survey (very similar to KAP survey) was conducted to evaluate the knowledge, perception, and awareness of the communities' on such changes with the Bertam Catchment. The main aim of this study is to generate quantitative information about catchment environment using a mixed method, integrating the scientific findings and communities' knowledge and perceptions. Statistical association and correlation analyses were applied to determine the relationship between people perceptions and knowledge about environmental changes with scientific findings. A logistic regression model was used to determine the factors that affect communities' involvement in participating catchment management program within the Bertam River Catchment. Finally, a model was developed using social and scientific assessment for sustainable management of the catchment.

Based on four key categories (Table 3.11 and Appendix E) of the questionnaire, statistical analysis was conducted to find out the descriptive summary, correlation matrix and regression analysis for the identification of relations among variables.

7.2 Demographic Characteristics

The description of some basic demographic factors and characteristics of respondents are shown in Table 7.1.From Table 7.1 and Figure 7.1, it is clearly shown that almost equal proportions of respondents have been selected from each age group. In terms of gender, almost two-thirds respondents were male. It was might be due to community survey where contacts with males were frequent rather than females. Almost 43% respondents were Malay and more than one-fourth (29%) of the Chinese race. Indian has also significant proportion in this survey (19%). Orang Asli had only 9.3% share.

Occupation wise, the majority (37%) of respondents were resident's professions. However, businessmen and service sector people shared same proportion with 22%. Least percentage belonged to student category about 7.7%. In this survey education is most important variable. Less than 5% people were illiterate in this study. Otherwise, all other educational groups had more or less similar amount of percentages ranged from 22.7 to 26%. This study was conducted in three different regions, namely Brinchang, Ringlet and Tanah Rata within the Bertam Catchment. Brinchang and Tanah Rata had a higher percent to 41.7% and 35.0% respectively, while Ringlet had only 23.3% of the total figure of 300.

Table 7.1 Demographic information of Respondents within Bertam Catchment

Characteristic	**Value**
Age	20-35 (18.7%), 36-45 (19.7%), 46-55 (21.7%), 55-65 (20.3%) and > 65 (19.7%)
Gender	Male (61.0%), Female (39.0%)
Race	Malay (42.7%), Chinese (29.0%), Indian (19.0%) and Ornag Asli (9.3%)
Occupation	Farmer (11.3%), Business (22.0%), Service (22.0), Resident (37.0) and Student (7.7%)
Educational Level	Illiterate (4.3%), Primary (23.7%), Secondary (22.7%), Diploma (23.3%) and Academic (26.0%)
Area of study	Brinchang (41.7%), Tanah Rata (35.0%) and Ringlet (23.3%)

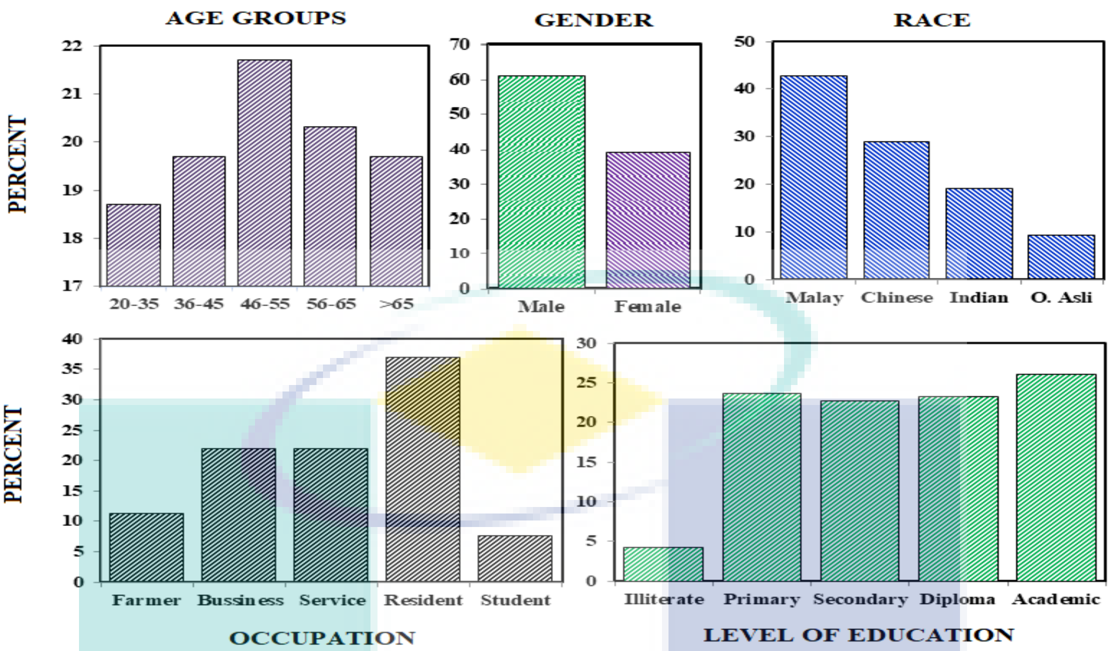

Figure 7.1 Demographic characteristics of respondents within Bertam Catchment.

7.3 Communities' Knowledge of Environment

Survey results of communities' observation on water quality, land type change, and soil erosion are shown in Figure 7.2, Figure 7.3 and Figure 7.4. Most respondents of the communities' believe that the water quality and landuse are changing as well as soil erosion is often observed with the passages of time. The bar chart of Figure 7.2 shows that 75% (three-fourth) of all the respondents observed the change in the water quality of Bertam River.Similar to water quality, more than two-thirds (68.70%) of respondents had reported that they observed the land pattern changes in their locality with the passages of time (Figure 7.3). Almost similar proportion showed an inclination towards observing the change in soil erosion trends within the catchment (Figure 7.4). Overall it means the majority of people of the community observed the change in the environmental elements within the Bertam Catchment.

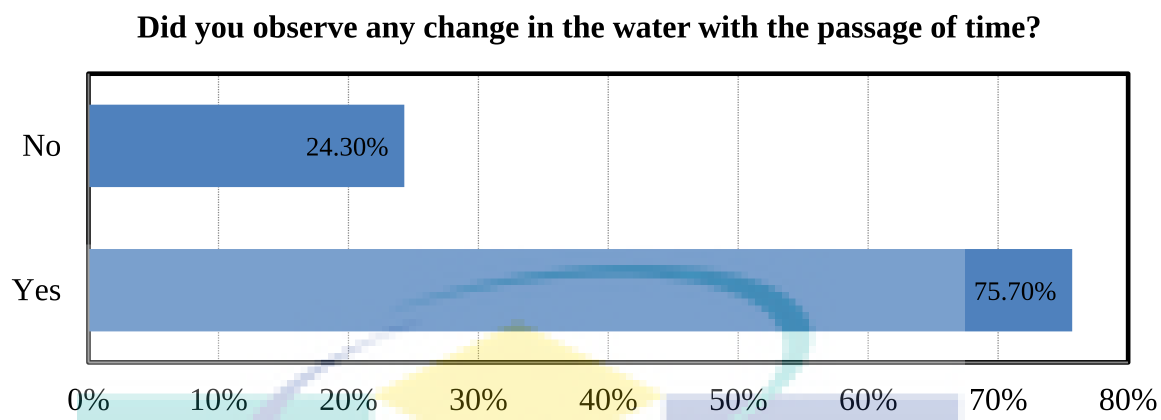

Figure 7.2 Communities' observation on water quality change within the catchment

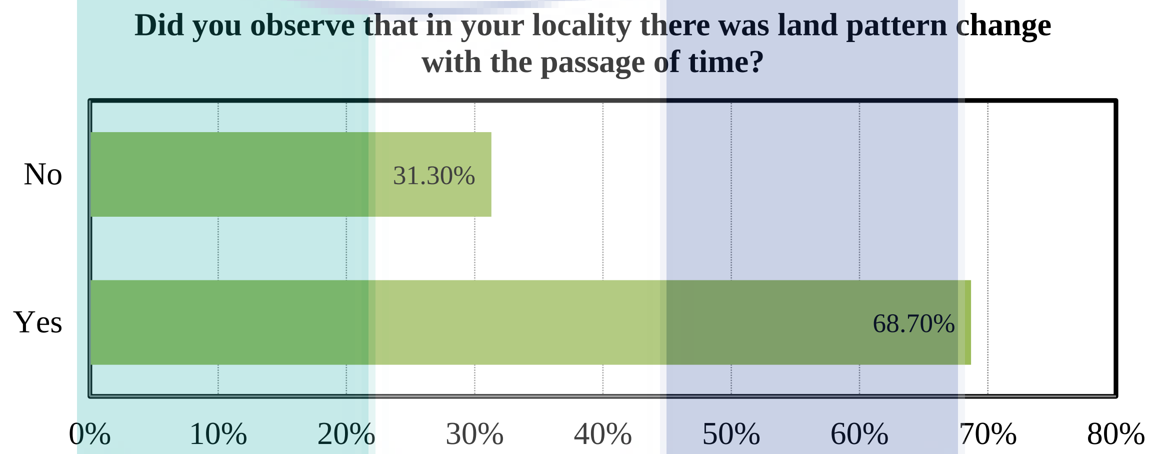

Figure 7.3 Communities' observation on land type change within the catchment

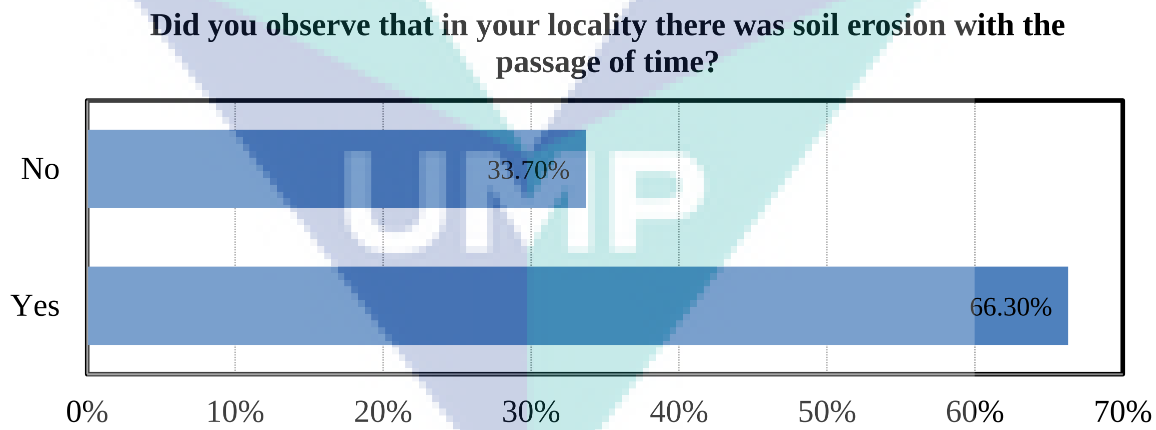

Figure 7.4 Communities' observation on soil erosion within the Bertam Catchment

7.4 Impact of Age and Level of Education on Observation of Change

Literature has highlighted that some demographic factors have a strong impact on the people perception and observational findings (Chicas et al., 2016; Deng et al., 2012; Gachango et al., 2015). A statistical test of association has been analyzed to observe the impacts of the demographic characteristic on the observation of respondents on different environmental changes as water quality, landuse, and soil erosion. In the present study, age and level of education have been identified as the important demographic factors that have an impact on the communities' knowledge.

7.4.1 Age Groups Vs Observation of Water Quality Change

The cross Table 7.2 has shown that as the age increases, there is an increase in the reporting of a change in the water quality and vice versa. People from younger age group (20-35 years) have both types of opinion about the water quality change with the passage of time. But in higher age group people have almost one statement that they have observed significant quality change in the water. Chi-square test of association has shown that age groups significantly (at 0.05 level of significance) change the observation of communities' about changing water quality with the passage of time.

Table 7.2 Age Groups vs observation of water quality change

Age Groups	Did you observe any change in the water with the passage of time?		Total	Chi-Square Value	P-Value
	Yes	No			
20-35	35	21	56		
36-45	43	16	59		
46-55	42	23	65	22.747	0.000
56-65	52	9	61		
>65	55	4	59		
Total	227	73	300		

7.4.2 Age Groups Vs Observation of Land Type Change

Similar to the previous cross table, this Table 7.3 also showed similar findings of the land type change in the locality with the passage of time. It is again very obvious that higher age group can observe the change with the passage of time. Therefore higher age group in majority supports that there is a significant land type change in the locality at the time. Test of association has also confirmed the association at 0.05 level of significance. Moreover, the difference of opinion in younger and higher age groups is shown in reverse pattern.

Table 7.3 Age Groups vs observation of land type change

Age Groups	Did you observe that in your locality there was land type change with the passage of time?		Total	Chi-Square Value	P-Value
	Yes	No			
20-35	28	28	56		
36-45	42	17	59		
46-55	40	25	65	19.157	0.001
56-65	46	15	61		
>65	50	9	59		
Total	206	94	300		

7.4.3 Age Groups Vs Observation of Soil Erosion

Soil erosion is the major consequence of landuse changes and topographic characteristics within the catchment. Similar to water quality and land type change, older age groups also confirms that this phenomenon is also happening in their locality. Majority of younger age groups had a different opinion from older age groups. This difference has shown in Table 7.4 that there is an association between these two variables and chi-square test also confirmed it (at 0.05 level of significance).

Table 7.4 Age groups vs observation of soil erosion

Age Groups	Did you observe that in your locality there was soil erosion with the passage of time?		Total	Chi-Square Value	P-Value
	Yes	No			
20-35	23	33	56		
36-45	42	17	59		
46-55	39	26	65	28.260	0.000
56-65	45	16	61		
>65	50	9	59		
Total	199	101	300		

7.4.4 Level of Education Vs Observation of Water Quality Change

Similar to a different level of ages, the impact of educational levels was also assessed in this study on the communities' observation about their surroundings. This given in Table 7.5 has shown that people with higher education level were more aware of the water quality change. Higher the level of education more people from them reported the change in water with the passage of time. Test of association (at 0.05 level of significance) has also confirmed this relationship. Simply it means education level has an impact on the people observation about the surrounding changes. It is very important that education usually raises awareness about the surrounding through media and other sources of information. In this study, it was also tested.

Table 7.5 Level of education vs observation of water quality change

Level of Education	**Did you observe any change in the water with the passage of time?**		**Total**	**Chi-Square Value**	**P-Value**
	Yes	No			
Illiterate	4	9	13	21.397	0.000
Primary	50	21	71		
Secondary	50	18	68		
Diploma	55	15	70		
Academic	68	10	78		
Total	227	73	300		

7.4.5 Level of Education Level vs Observation of Land Type Change

In this following Table 7.6, land type change was associated with the level of education similar to the previous table. Almost similar findings have been observed in this table. People of higher education level reported that there was a change in the locality, in terms of the land type with the passage of time. The relationship between these two attributes has been confirmed through chi-square test of association (at 0.05 level of significance).

Table 7.6 Level of education vs observation of land type change

Level of Education	Did you observe that in your locality there was land type change with the passage of time?		Total	Chi-Square Value	P-Value
	Yes	No			
Illiterate	3	10	13	18.178	0.001
Primary	47	24	71		
Secondary	46	22	68		
Diploma	47	23	70		
Academic	63	15	78		
Total	206	94	300		

7.4.6 Level of Education Vs Observation of Soil Erosion

This cross Table 7.7 is a relationship between two attributes; the level of education and change observed by people in soil erosion. Illiterate people majority said that there was no soil erosion in the region. But higher educational levels showed that majority are in the favor of the change. It means perception and observational findings have been changed with the level of education. This association was seen in the chi-square test value 23.32 with a p-value (0.000) which is significantly less than 0.05 level of significance.

Table 7.7 Level of education vs observation of soil erosion

Level of Education	Did you observe that in your locality there was soil erosion with the passage of time?		Total	Chi-Square Value	P-Value
	Yes	No			
Illiterate	2	11	13	23.322	0.001
Primary	45	26	71		
Secondary	42	26	68		
Diploma	47	23	70		
Academic	63	15	78		
Total	119	101	300		

7.5 Communities' Perception of Causes and Consequences of Water Quality Change, Land Type Change, and Soil Erosion

The questionnaire investigated communities' perception about causes and consequences of water quality change, landuse change, and soil erosion. For these questionnaires, a number of potential causes and consequences were asked to get their perceptions. It is very obvious that there might be more than one reason to choose the answer. Therefore, respondent can tick more than one option. That is why each possible causes and consequences was considered as a separate question. If the respondent used tick in one reason ('yes'), it means he/she considered that this is one of the reasons/consequences. Similarly, if someone didn't tick ('no'), it means he/she did not consider it as a cause/consequence. So, the result of each cause or consequences is made on considering 100% for each.

7.5.1 Communities' Perception of Causes and Limitations of Water Quality Change

The bar chart presented in Figure 7.5 and Figure 7.6 is based on different potential causes of water pollution and the limitations/obstacles to protect water pollution in the Bertam Catchment. Due to the choice of more than one option for expressing their perceptions, every bar in this chart, therefore, is measured by considering 100% for each bar. From the Figure 7.5, it is clearly observed that land clearing and poor agricultural practices are two main reasons behind water pollution in the locality. 66.70% of the respondents considered land clearing while 63% considered poor agricultural practices. However, 54% respondents selected excess sedimentation as a cause for water pollution while 40% preferred domestic discharge as such reason. Poor solid waste management was a problem only for 1/4th respondents of study.

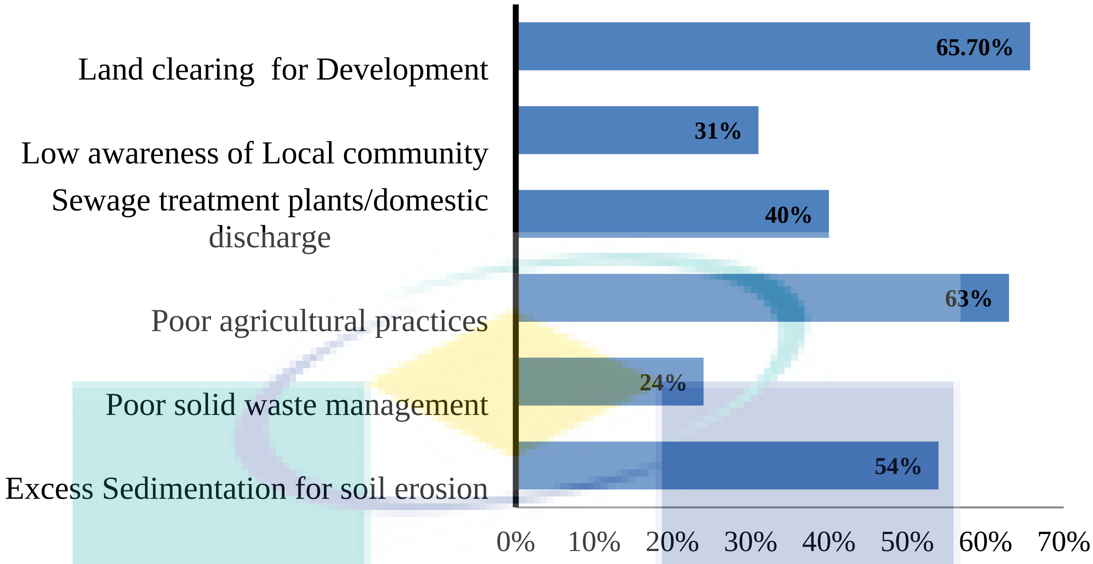

Figure 7.5 Perception of communities about Causes of Water Pollution

In Figure 7.6, the bar chart is about the potential limitations or obstacles which people usually face to protect water. The survey results of perceptions in this domain elucidate that almost two-thirds of respondents (64.70%) said lack of strict enforcement of policies was the main hurdle behind this. Rapid urbanization (50.70%) and poor agricultural practices (50.30%) and uncontrolled land clearing (51%) were almost second main obstacles; as these obstacles got almost equal weight. According to Eduful and Shively (2015) the lack of appropriate land use regulations, low compliance with existing regulations, and the lack of enforcement are enhancing degradation of water bodies in Kumasi, Ghana.

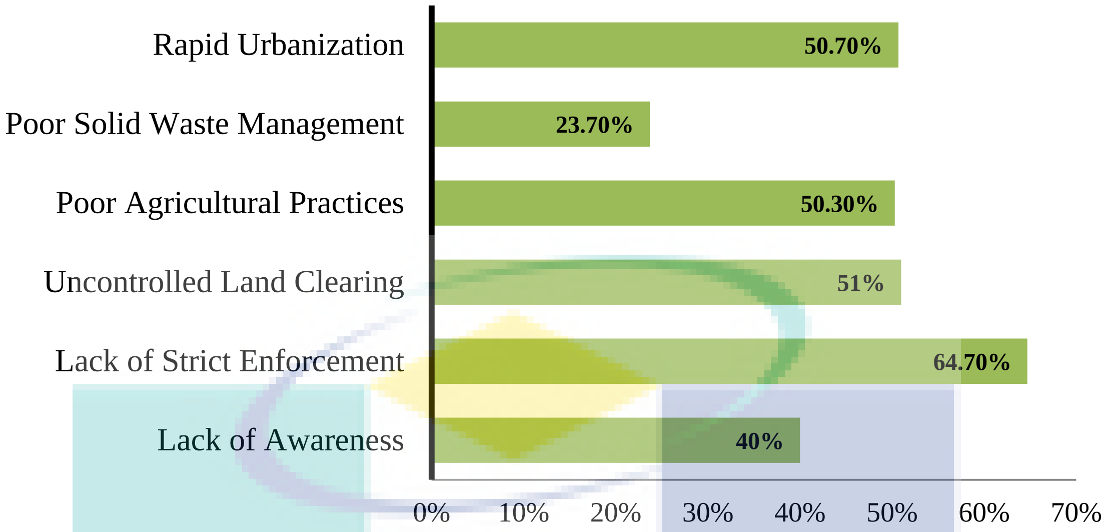

Figure 7.6 Perception of communities about limitations to protect water pollution

7.5.2 Communities' Perception of Causes and Consequences of Land Type Change

Next domain of questions was asked about the potential causes and consequences of land type change in the locality. This bar chart in Figure 7.7 was based on total 100%. This bar chart shows that about 60% of total respondents said both types of activities; intensive farming activities and rapid urbanization were the reasons behind land type change. However, 25% respondents believed that intensive farming activity was the only reason. On the other hand, about 15% said that rapid urbanization was the reason behind land type change.

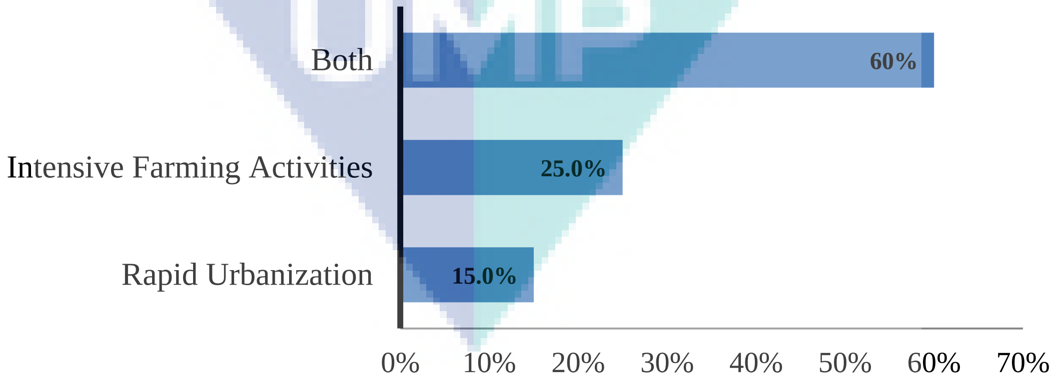

Figure 7.7 Perception of People about causes of land type change

From the Figure 7.8, as can be seen, that environmental change and deforestation were the main consequences of land type change, as majority (63% and 55.7%) people said respectively. But one-third of respondents supporting that climate change (34%) and loss of biodiversity (32.70%) could be the other consequences of land type change.

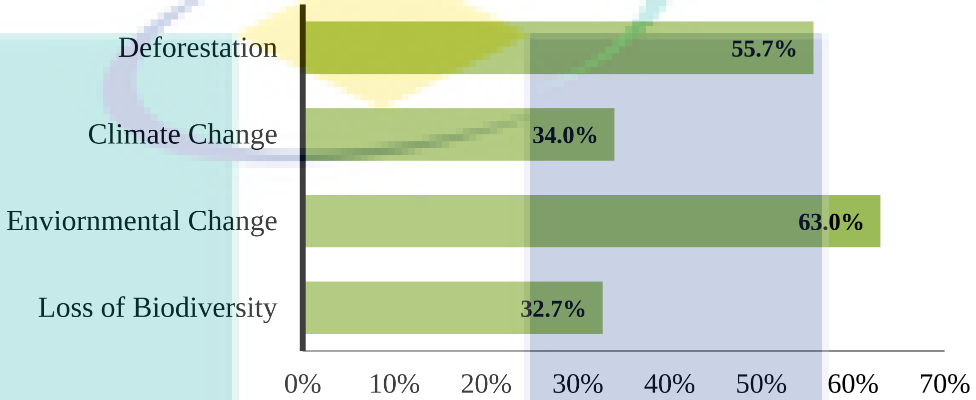

Figure 7.8 Perception of communities' about consequences of land type change

7.5.3 Communities' Perception of Sources and Consequences of Soil Erosion

The communities' perception of sources and consequences of soil erosion were presented in bar chart according to their responses in Figure 7.9 and Figure 7.10. Regarding the causes, 61% respondents selected clearing of slopes and 52% said deforestation as the leading causes of erosion in the study area. In Figure 7.9, bar chart also highlighted that farming got sufficient attention of the communities' as 41.7% said so. 29% of respondents selected Heavy rain as one of the causes of soil erosion within the catchment.

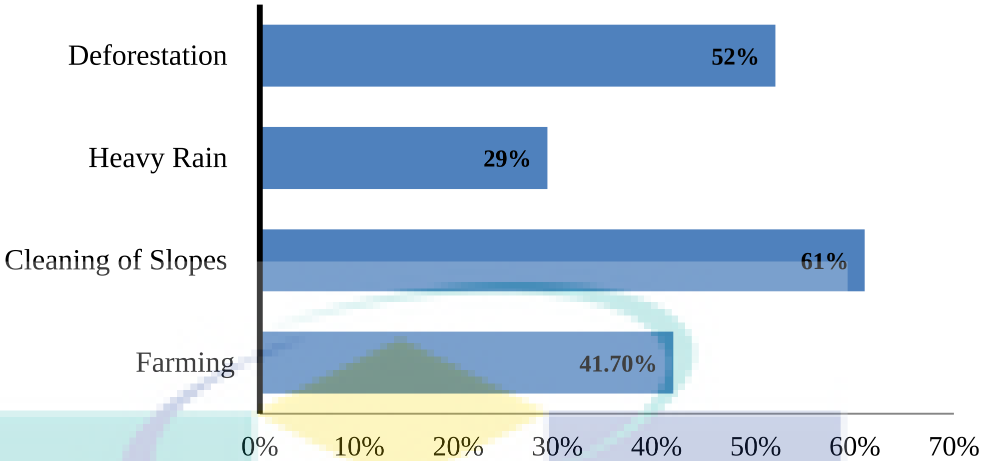

Figure 7.9 Perception of People about Sources of Soil Erosion

For perceptions about the consequences of soil erosion, almost 58% respondents think that pollution of river water was the main consequence of soil erosion. Half of the people said the flooding was another consequence of soil erosion. Soil degradation was the least significant consequence as people thought (Figure 7.10).

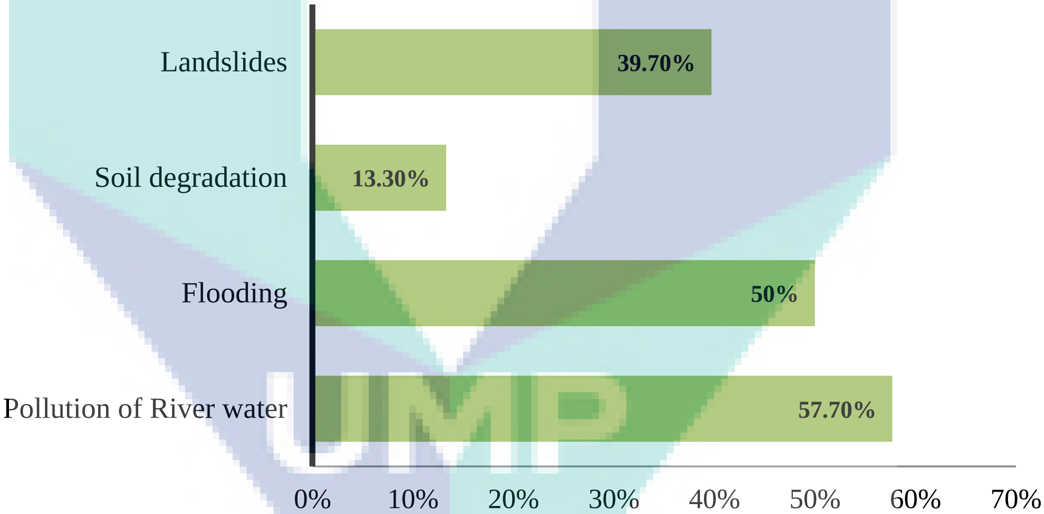

Figure 7.10 Perception of respondents about consequences of soil erosion

7.6 Association between People Observations and Scientific Findings of Water Quality, Land Type Change, and Soil Erosion

This part is the most important section of the current chapter. In this section, the correlation or association has been analyzed between the scientific findings and people perceptions. This part will use responses of only those respondents who observe the change in water quality, landuse and soil erosion with the passage of time. Therefore total sample would be different here.

7.6.1 Association Between People Observations and Scientific Findings of Water Quality

In this following Table 7.8, there is a description of water quality through two approaches; scientific method and people perception. Scientifically, there are three status of surface water quality in the different localities within the Bertam Catchment; clean, slightly polluted and polluted. However, people usually used two terms; good and poor. So this table showed that majority of people categorize the slightly polluted and polluted water into relevant categorize. In some locations, clean water was declared as poor by people. It is mainly for communities' general observation of river status. Overall people perception about the water is poor. Further chi-square test of association has shown a strong relationship between scientific and people perception based findings of water quality. Kappa test was performed to measure the level of agreement among the categories. The Kappa test of agreement usually performs better when there is an equal number of rows and columns. However, in the water quality case, it created only 0.501 values, which showed that 50% agreement in the two types of findings.

Table 7.8 Association between communities' perception and scientific findings of water quality

Characteristics		Water Quality Rating by People		Total	Chi-Square	p-value	Kappa-test
		Good	Poor				
Water Quality Rating through Scientific Experiments	Clean	18	7	25	158.0	0.000	0.501
	Slightly Polluted	0	179	179			
	Polluted	0	23	23			

7.6.2 Association Between People Observations and Scientific Findings of Land type Change

This chi-square table of association has shown that majority of places had a high level of change in the land type and people also confirming the scientific findings (Table 7.9). Similarly, 59 people out of 300 validate that there was moderate land type change in the locality. Overall chi-square test and p-value showed that there was a strong association between the scientific findings and people observations. Kappa test also confirmed this relationship as its value was 0.707. It means more than 70% people observations matches with scientific findings.

Table 7.9 Association between communities' perception and scientific findings of land type change

Characteristics		Land Type Change by People			Total	Chi-Square	p- value	Kappa - test
		Low	Moderate	High				
Land Type Change through Scientific Experiments	Low	29	5	1	35	211.0	0.000	0.707
	Moderate	18	41	0	59			
	High	0	13	99	112			
	Total	47	59	100	206			

7.6.3 Association Between People Observations and Scientific Findings of Soil Erosion

The association between people observation and scientific findings was shown in Table 7.10. When people perception about soil erosion was linked with scientific findings, high level of agreement was observed (0.760). Further, this table has shown that similar to water quality table, the majority of observations were matched with scientific findings, therefore relationship was very strong. It can be said that people perceptions and observations are strongly linked with scientific findings.

Table 7.10 Association between communities' perception and scientific findings of land type change

Characteristics		Soil Erosion Observed by People			Total	Chi-Square	p- value	Kappa - test
		Moderate	High	Very High				
Soil Erosion Observed in Scientific Experiments	Moderate	115	10	4	129	230.6	0.000	0.75
	High	7	37	3	47			
	Very High	0	2	21	23			
	Total	122	49	28	199			

7.7 The Frequency of Awareness Programs in the Locality

In general communities' awareness and understanding of Bertam Catchment environment is expected to lead them in making an informed judgment regarding water quality. This awareness, therefore, plays a key role in forming their attitudes to water quality (Gachango et al., 2015). Keeping the view in mind, through the questionnaire the frequency of awareness programs regarding water quality protection, precaution to protect environment consequences and their sources of information on such difficulties were interpreted.

The bar chart in Figure 7.11, is about the frequency and sufficiency of any awareness program in the community by authorities and any other volunteers. This chart clearly indicates that 46% respondents said that there was no awareness program about the water quality of river Bertam. But 33.7% of respondents responded that very few programs had been conducted within communities. Remaining 21.3% was felt that sufficient programs had been conducted.

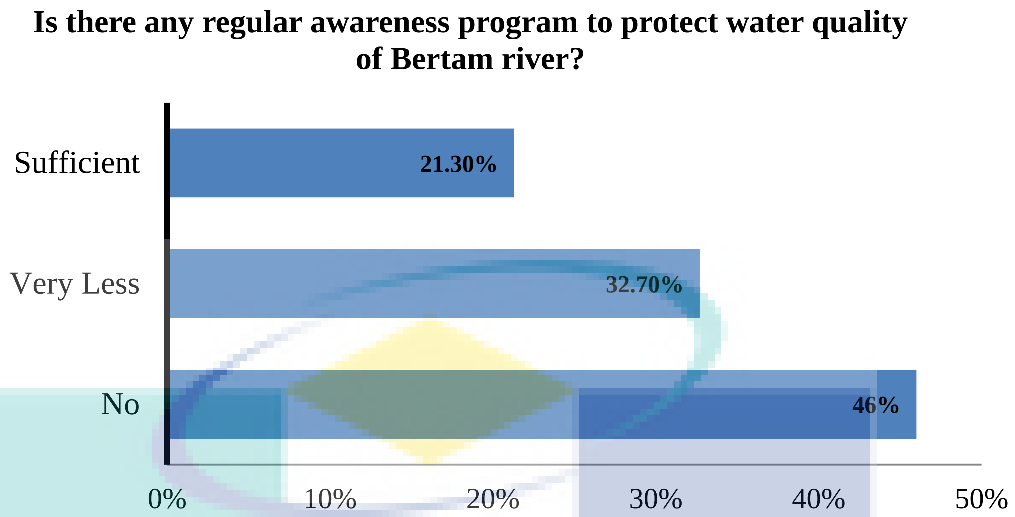

Figure 7.11 Frequency of awareness program to protect water quality within Bertam Catchment

Similarly, awareness plans about environmental consequences had drawn an almost same conclusion like water quality programs and are shown in Figure 7.12. Here some proportion shifted from “No” category to other two categories.

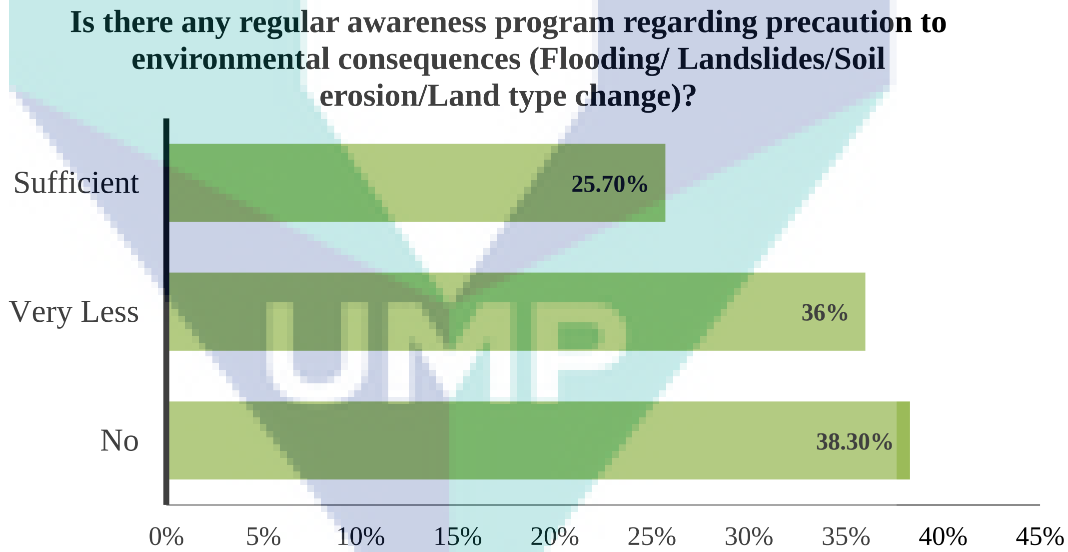

Figure 7.12 Frequency of awareness program regarding precaution to environmental consequences within Bertam Catchment

7.7.1 Sources of Information in the Community About Catchment Environment

A follow-up question was asked to state their source of information about catchment environment in the community within the catchment. The respondents' responses are shown in Figure 7.13. The bar chart of Figure 7.13 shows that internet as the key information source with 58.7% of the respondents. About 50.7% respondents indicate having received information through local authorities. Peers/friends and REACH (Regional Environmental Awareness Cameron Highlands) are rated as sources of information by 40.3% and 37% of the respondents respectively. The educational syllabus has also got significant importance by the people. Seminar and conferences from authorities had a least significant role in the awareness of people.

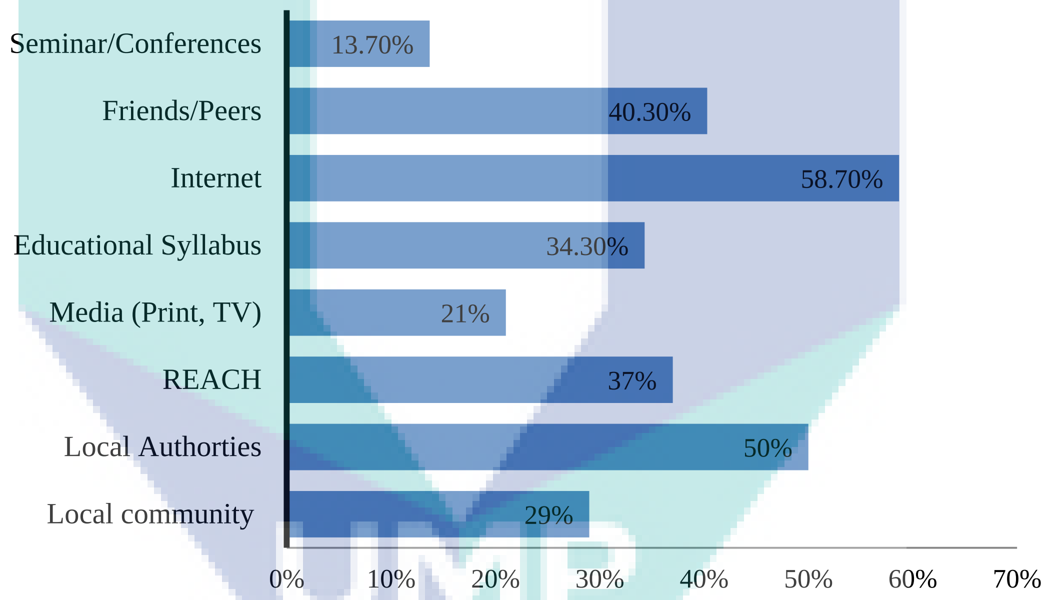

Figure 7.13 Sources of information for awareness about protection of catchment environment (water quality/land change/ soil erosion)

7.7.2 Easy Access to Media

In this era, media (electronic or print) has got sufficient importance to create awareness in the people. In this study, it was also asked about the easy access to media.

Figure 7.14 shows that majority (82%) of community people said that they had easy access to any type of media to gather information about different issues of society.

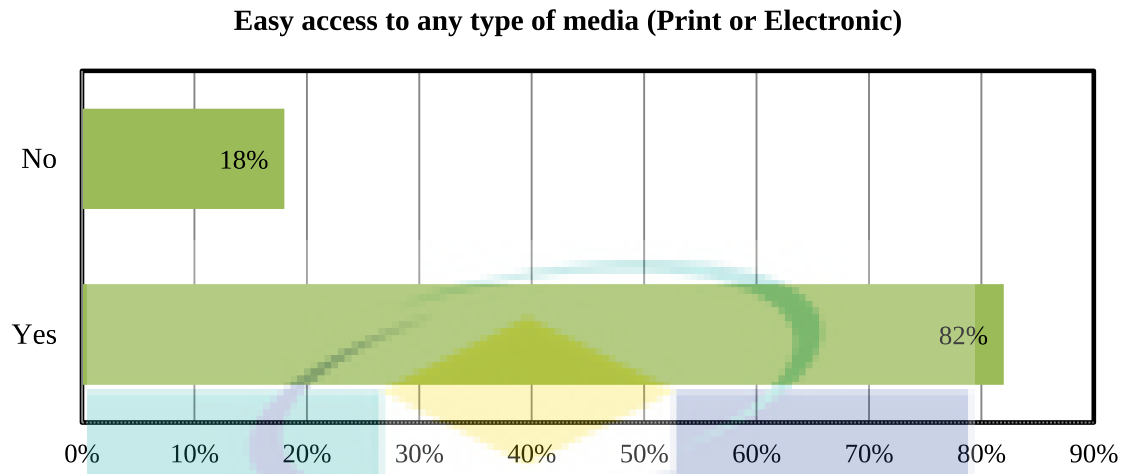

Figure 7.14 Communities response to easy access to media

7.7.3 Correlation Between Awareness Score and Years of Living in the Community

An attempt has been taken to observe the relationship between communities' awareness and their demographic characteristics. For the calculation of correlation, each variable should be in the quantitative form. In survey questionnaire, we have nine questions on the awareness. Therefore for quantitative conversion, we made an index of these questions by adding the individual's scores on these nine questions. For more elaboration here is the calculation of the index.

Index = C1+C2+C3+C4+C5+C6+C7+C8+C9= Total score of awareness.

This score ranges from 9-45. If a person responds strongly disagree to all nine questions he will get 9 scores. And if he responds strongly agree on all questions then he/she will get 45 scores.

The result of person's correlation coefficients is shown in Table 7.11. The findings disclosed that there are significant positive correlations between levels of awareness and years of living ($r=0.42$, $p<0.01$) as well as the level of education ($r=0.43$, $p<0.01$) about the environmental protection. The correlation coefficient values are 0.430 and 0.420 which is usually considered a moderate level of correlation. But p-value has shown that these relationships were highly significant at 0.01 level of significance. It means both variables move in the same direction. If years of living and age increase there will be a high level of awareness and vice versa. It is quite natural that if someone is living in particular area for a long time then there is a chance that he/she will be more concerned about the area. Similarly, the people who have higher age have a higher level of awareness regarding environmental protection.

Table 7.11 Pearson's Correlation Coefficient for Communities' Awareness in the Bertam Catchment Area

Pearson's Correlations Coefficient

Variables	Age	Level of Education	Years of Living	Total Score of Awareness
Age	1			
Level of Education	.309**	1		
Years of Living	.480**	.219**	1	
Total Score of Awareness	.337**	.430**	.420**	1

**. Correlation is significant at the 0.01 level (2-tailed); N=300

7.7.4 Levels of Awareness in the Community

The level of awareness of the communities' was also determined and shown in Figure 7.15. Awareness was initially calculated by adding the scores of individual questions but for better understanding, it was converted into different levels. Awareness score was converted into three equal categories by dividing the difference of 9-45 into three consecutive categories; 9-21, 22-33 and 34-45 nominated as low, moderate and high. This chart has shown that majority of people have a high level of awareness about the environmental change, its consequences, and protection. Because only 2% respondents have a low level of awareness so it was merged in the moderate category of awareness for a better depiction of data. The communities are well aware of the factors and consequences of water degradation as most of the Malaysians (Mei et al., 2016).

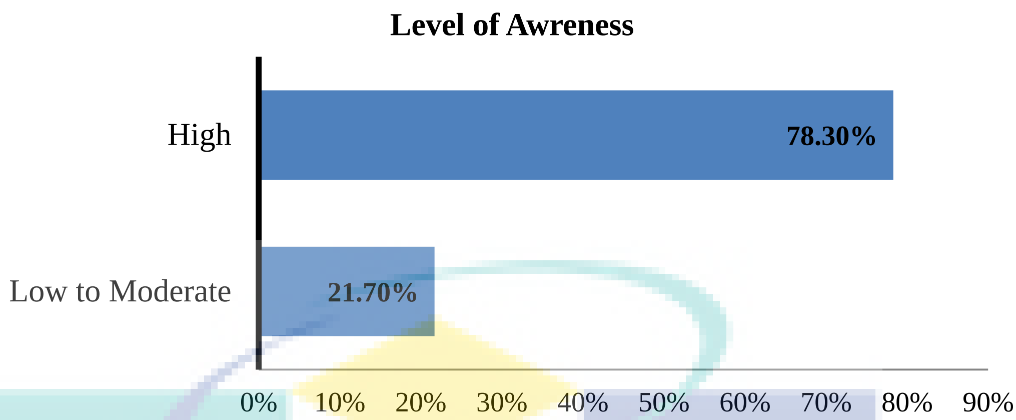

Figure 7.15 Level of awareness regarding Bertam Catchment environmental protection

7.7.5 The relationship Between Level of Education, Age Groups, Access to Any Type of Media and Level of Awareness

Table 7.12, Table 7.13 and Table 7.14 are the association tables; age, level of education, access to media with a level of awareness. Results have clearly shown that relationships are significant in all these tables. First association table has indicated that level of awareness is high in higher age groups and vice versa. Similarly higher level of education has a high level of awareness about the environment and its components. In the end, the last table has indicated that people having easy access to any type of media, they have better chances of having a high level of awareness. It means awareness can be increased by educating the people and providing easy access to media.

Table 7.12 Relationship between Age groups and level of awareness

Age Groups	**Levels of Awareness**		**Total**	**Chi-Square Value**	**P-Value**
	Low to Moderate	High			
20-35	30	26	56	49.322	0.000
36-45	16	43	59		
46-55	5	60	65		
56-65	8	53	61		
>65	6	53	59		
Total	65	235	300		

Table 7.13 Relationship between Level of education and level of awareness

Level of Education	Levels of Awareness		Total	Chi-Square Value	P-Value
	Low to Moderate	High			
Illiterate	13	0	13	75.360	0.000
Primary	28	43	71		
Secondary	8	60	68		
Diploma	10	60	70		
Academic	6	72	78		
Total	65	235	300		

Table 7.14 Relationship between access to any type of media and level of awareness

Access to Media	Levels of Awareness		Total	Chi-Square Value	P-Value
	Low to Moderate	High			
No	40	14	54	106.5	0.000
Yes	25	221	246		
Total	65	235	300		

On the basis of above findings, it can be concluded that these four background variables; age, education level, years of living and easy access to media are strongly linked with awareness score or level of awareness. So the following diagram in Figure 7.16 made on the basis of these relationships. The diagram is considered as Model 1 in this study.

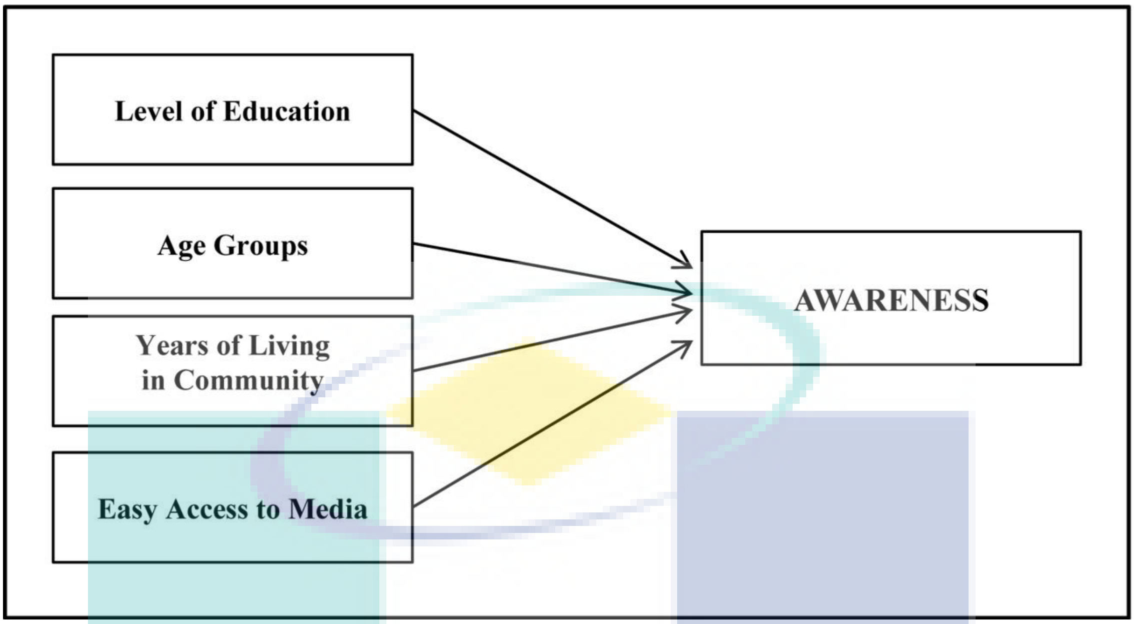

Figure 7.16 Diagram showing relationship between awareness and background variables

7.8 People Willingness for Management Projects for Catchment Protection

A very important question was asked about the willingness of communities to participate in some collaborative projects with authorities. Majority of people (79%) had shown their willingness if any plan or program conducted and arranged by authorities (Figure 7.17). It shows that majority of people are concerned about their local catchment environment protection. Communities' behavior towards the preservation of water quality conservation is environmentally friendly like most of the Malaysian (Mei et al., 2016).

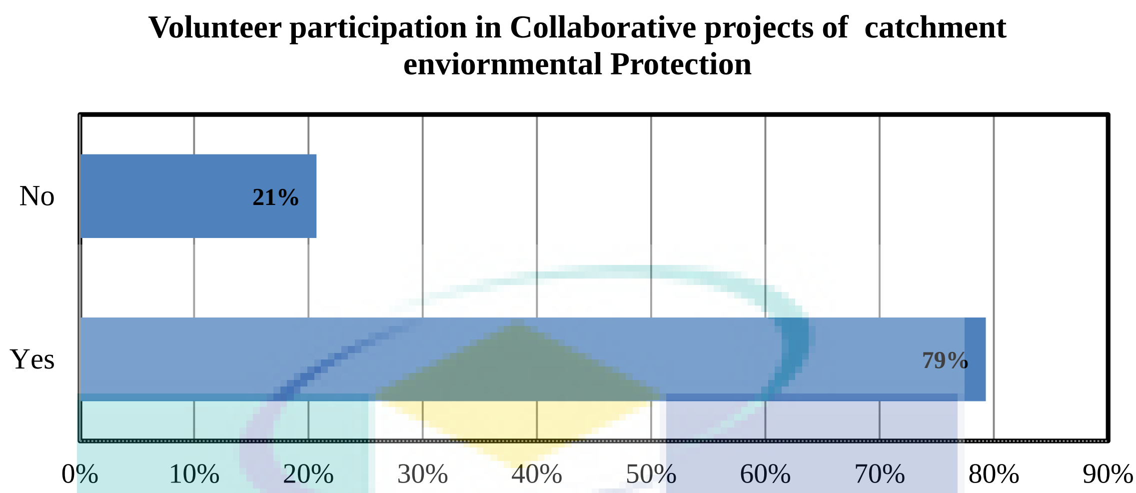

Figure 7.17 Communities willingness to engage collaborative project for catchment management

7.9 A Predictive Model for Communities' Willingness for Collaboration Projects for Catchment Management

In this study, a logistic regression model has been used to determine the factors affecting communities' awareness regarding willingness to participate in catchment environmental protection program. The respondents were asked about their volunteer involvement for environmental protection with the help of authorities. The respondents answered this question in "yes" and "no" form (No=1 and Yes=1). Therefore this is an ideal condition for applying the logistic regression. If the respondent answer is yes, it will be measured as aware/agree or if the answer is no, it will be measured as not aware/not agree. The model was utilized to model the communities' awareness regarding their willingness to involve in volunteer collaborative projects and to improve understanding of the demographic characteristics that impact communities' awareness on the implementation of collaborative projects.

In this regression model, five important factors were used as independent variables in the model. The variables were measured by age (20-35=1, 36-45=2, 46-55=3, 55-65=4 and >65=5); educational level (Illiterate=1, Primary=2, Secondary=3, Diploma=4 and Academic=5); year of living in the community (1 to 65 years); access to any type of media (No=1 and Yes=1) and awareness (score 15 to 45). For better prediction and avoid subjectivity in the modeling, stepwise Wald model was applied (Chicas et al., 2016). At step four this model was finalized with four more important variables; the level of education, access to any type of media, years of living and awareness about environment protection.

In the present study, the logistic regression model was validated through a number of tests. The first table of logistic regression has shown that overall model coefficients are good and significant for prediction (Table 7.15). Cox and Snell R-square (51.8%) and Nagelkerke R-square (81.1%) found to be good and satisfactory and indicating most of the predictions are correct (Table 7.16). However, these two types of R-Square used in the binary logistic regression are pseudo-R^2 values which are not true measures of variation in logistic regression. So they consider as pseudo-methods. Instead of using these two methods, Classification table is a better approach to assess the prediction ability of the model. This Table shows that it has 95% correct classification (Table 7.17). It means that if these four above mentioned variables are used as predictors, the model can predict with 95% accuracy. Further Hosmer and Lameshow test for goodness of fit based on Chi-square test heightened that overall model is good for prediction as its significance value is above than 0.05 level of significance

Table 7.15 Omnibus Tests of Model Coefficients

Steps	**Model**	**Chi-square**	**df**	**Sig.**
Step 4	Step	4.242	1	.039
	Block	219.113	4	.000
	Model	219.113	4	.000

Table 7.16 Model summary and Hosmer and Lameshow test

Steps	**Model Summary**			**Hosmer and Lameshow test**		
	-2Log likelihood	Cox & Snell R Square	Nagelkerke R Square	Chi-square	df	Sig.
Step 4	86.591	.518	.811	12.578	8	.127

Table 7.17 Classification Table for the ability to predict the model

Steps	**Willingness to involve in volunteer collaborative projects**			
	Observed	No	Yes	Correct (%)
Step 4	No	53	9	85.5
	Yes	5	233	97.9
	Overall correct %	58	242	95.3

Table 7.18 Data from final logistic regression equation

Predictors	**Model**			
	Estimated Coefficient (β)	**Standard Error (S.E)**	**Sig.**	**Exp (β) Odds ratio**
Constant	-11.30	1.71	.000	.000
Level of education	.529	.265	.046	1.697
Years of Living	.066	.032	.036	1.068
Awareness score	.200	.038	.000	1.222
Easy access to media	3.511	.728	.000	33.469
2LL	86.591			
Hosmer & Lemeshow test	p =0.127			
Classification accuracy	95.3			
Chi square statistic	219.113			

The estimated result of a logistic regression model of the communities' awareness regarding willingness to participate in catchment management program is given in Equation (7.1). The probability for a dependent variable can be calculated by putting all the values of independent variables. The final logistic regression equation is estimated by using the maximum likelihood estimation for the determination of factors that affects awareness in relation to respondents' willingness to participate is as follows:

$$\log p(x)/1\text{-}p(x) = -11.33 + 0.529X_1 + 0.066X_2 + 0.200X_3 + 3.511X_4 \qquad 7.1$$

where X_1 is level of education

X_2 is years of living in the community

X_3 is awareness score and

X_4 is access to media.

The finding of the model shows that the level of education (X_1), year of living in the community (X_2), awareness score (X_3) and access to media (X_4) are significantly related to the respondents in participation to catchment environmental protection program. A positive value shows that it will cause positively increase in the probability of the dependent variable value of higher code; in this case, it is "Yes" category. Among the variables, X_1 (level of education) and X_4 (access to media) are proved to be important determining factors for the communities' awareness. From the equation and Table 7.18, the values of access to media (X_4) and level of education (X_4) regression coefficient are 3.51 and 0.529. These mean an increase in one unit change (one respondent) in access to media or level of education will cause 3.51 or 0.529 log odds change in the dependent variable (awareness to participate). Simply it means if there is an increase in the level of education or access to media there will be a higher probability that a person will support the volunteer work and vice versa. Similarly, other two variables X_2 (year of living in the community) and X_3 (awareness score) have a positive impact on the dependent variable. It means higher the value of awareness higher will be the probability of volunteer support, higher the value of years of living higher will be the probability of support. The most significant factor is to have access to media.

On the other hands, the estimated odds ratio of access to media is 33.47 means that the communities' awareness to participate in catchment environmental program is higher for who has access to media than who don't have access to media. Moreover, in the model, the odds ratio of the level of education is 1.697. It indicates that the attitude of higher educated people is 1.697 times more positive than the less educated people concerning the awareness to participate.

From the results of the logistic regression model, the relationship between the significant variables can be explained by the below-given diagram (Figure 7.18). This is the 2nd model from the social survey information using logistic regression analysis. This model can be used for prediction by using logit function in the future.

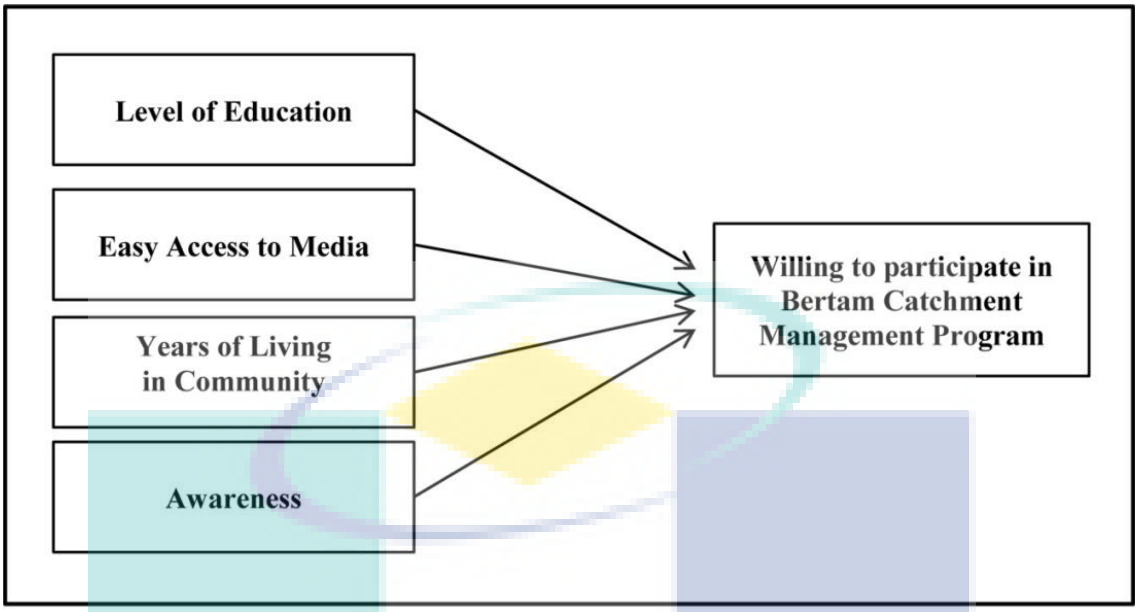

Figure 7.18 Diagram of factors for communities' awareness to participate in Bertam Catchment Management program.

However, logistic regression with only awareness as independent variable causes more than 90% correct classification of dependent variable categories. So both models 1 and 2 (Figure 7.16 and Figure 7.18) can be used in future. Model 1 from association test already shows that for awareness there are four variable; years of living, age groups, level of education and easy access to media. So it is better to use a comprehensive model (3rd model) by adding both awareness and other components as well (Figure 7.19).

The final outcome of the model shows that respondents with higher age groups, high level of education, having easy access to any type of media as well as years of living for a long time have a higher level of awareness about the Bertam environment and vice versa. Consequently, higher awareness people have the higher positive attitude to participate willingly as a volunteer in Integrated Bertam Catchment Management Program.

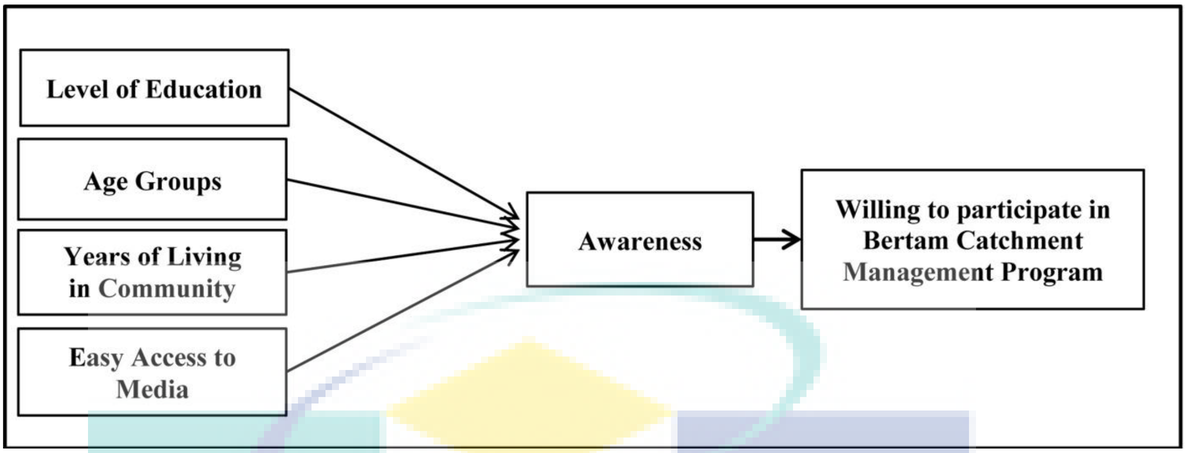

Figure 7.19 Model for willing to participile in Integrated Bertam Catchment Management program

7.10 Integration of Socio-scientific Assessment for Sustainable Management Model

The final proposed model was developed using the integrated socio-scientific assessment for the sustainable management of the Bertam River Catchment. The scientific assessment was conducted on three important studies namely the water quality, landuse and soil erosion. The summary of overall scientific findings is shown in Table 7.19.

The findings revealed that the water quality of the catchment was deteriorated by various degrees of contaminant concentrations in terms of space and time. Except for the mountainous forest, the water quality was worsened in other areas due to seasonal rainfall and varying level of human activities. Nutrients, organic matter, and TSS were the major sources of water quality pollution in the catchment. The average concentrations of turbidity, TSS, BOD, NH_3-N, and PO_4-P exceeded NWQS level. Among the twelve sampling sites, two showed clean, nine was slightly polluted and one was polluted in terms of water quality status in both the seasons. Overall, water quality status was identified as slightly polluted.

Landuse study revealed that the catchment was mainly characterized by the expansion of agricultural activities and urban development. Subcatchment-wise land type distribution exhibited most of the sub-catchments was covered by more than 50 percent forest land. The urban land was dominated in the upper catchment with a range of 22 to 38 percent. A small urban land (3-5 percent) was also present in lower catchment. Market gardening varied within the entire catchment. Higher percent was observed in lower catchment ranged from 43 to 49 percent. The land type covered 12 to 22 percent in middle catchment while that of 15 to 32 percent in the upper catchment. Dominated tea land was mainly observed in the middle catchment. Scrubland type was mostly found in the lower catchment. Statistical analysis revealed that BOD, COD, and NH_3-N were significantly correlated with urban land type while nutrients (NO_3-N, TN, PO_4-P, and TP), as well as turbidity and TSS, were correlated with market gardening land type in both the seasons. Tea land type also showed positive relationships with nutrient variables like NO_3-N, PO_4-P, and TP. All these parameters except COD tend to more sensitive during the rainy seasons than the dry season. The soil erosion assessment indicated that the annual average soil erosion rate for the entire catchment was predicted to be 123.23 ton/ ha. The individual rate was also calculated as 27.60, 31.80 and 63.83 ton/ ha/ year for upper, middle, and lower sub-catchment, respectively. The results also showed that 6.22 percent area of the upper sub-catchment was under the high to very high categories of erosion while 6.81 and 17 percent areas were estimated under the similar categories for the middle and lower sub-catchments. The results of land type distribution of the sub-catchments showed that the soil erosion in the upper catchment was interlinked with urban development activities. The soil erosion rate in the middle catchment and lower sub-catchments was mainly interrelated to market gardening land type. Among the three, the lower sub-catchment was identified as the most soil erosion vulnerable zone.

Results of the social survey showed high levels of associations between the scientific findings and communities' observations, indicating that majority of people knew about the catchment environment. Statistical association and correlation revealed that awareness of respondents depends on their age, level of education, duration of living and access to media. Logistic regression analysis showed that communities' willingness to participate in catchment management program also depends on their awareness.

The overall socio-scientific findings are shown in Figure 7.20 as a process flow of developing the model. Considering all the socio-scientific assessment, a future model for sustainable management of the Bertam River Catchment was developed and proposed (Figure 7.21). According to the proposed model, all the scientific findings provide crucial information to policymakers and authorities that can be served for proper landuse management and for conserving water resources in mountainous Bertam Catchment. The model also suggests that authorities should communicate and distribute the scientific information through the internet and physical appearance in seminars/conferences to motivate and create awareness. Similarly, they should more focus on the aged, higher educated and old residents whenever taking initiative for management program within the Bertam River Catchment considering their higher level of awareness and positive willingness for participation. All these activities will lead to sustainable management of the Bertam Catchment and its pollution.

The effective implementation of the model will be helpful for both authorities and the local communities'. It will aid stakeholders to garner community support, develop and implement sustainable management of river catchment.

Table 7.19 Overall findings from scientific assessment of the Bertam Catchment

	Upper Catchment							Middle Catchment			Lower Catchment	
Stations	UB-1	TB-1	UB-2	TB-2	UB-3	TB-3	UB-4	UB-5	TB-4	TB-5	LB-1	LB-2
Bertam and Tributaries	Upper Bertam	Sg. Burung	Upper Bertam	Sg. Ruil	Upper Bertam	Sg. Jasar	Upper Bertam	Middle Bertam	Sg. Batuh Pipih	Sg. Ulu	Lower Bertam	Lower Bertam
Water Quality Assessment												
BOD		9.09	9.09									
COD			26.33				4.83	11.54			4.83	11.54
Turbidity				588.86	170.70	82.85	113.26	304.63	242.11	127.23	303.42	377.60
TSS				1326.61	255.94	129.28	149.44	430.39	443.83	156.56	340.44	550.39
NH3-N			1.14		1.18	2.10	0.89	0.80				
PO4-P			0.83	0.34	0.72	0.54	0.52	0.89	1.06		1.02	1.34
WQI	C	SP	SP	SP	SP	P	SP	SP	SP	C	SP	SP
Landuse Assessment												
Forest	100%	67%	51%	71%	71%	58%	65%	35%	48%	68%	36%	48%
Urban		3%	34%	22%	24%	38%	23%	2%	4%	1%	5%	
MG		30%	15%	2%	4%	4%	12%	22%	13%	14%	50%	43%
Tea								33%	27%	14%		
Impact	No	MG	U	U	U	U	U+MG	MG+T	U+MG+T	NO	U+MG	MG
Soil Erosion Assessment (Areal percentage)												
High				2.20%					2.32%		5.15%	
Very High				4.02%					4.49%		11.85%	
Impact				High Erosion					High Erosion		Very High Erosion	

WQI: Water Quality Index; C=Clean; SP= Slightly Polluted; P= Pollute; U=Urban; MG=Market Gardening; DOE Guideline level (NWQS): BOD:>3.00 mg/L (IIB); COD: >25.00 mg/L (IIB); Turb: >50.00 NTU (IIB); TSS: >50.00 mg/L (IIB); NH_3-N: >0.30 mg/L (IIB); PO4-P:> 0.10 mg/L (IIB).

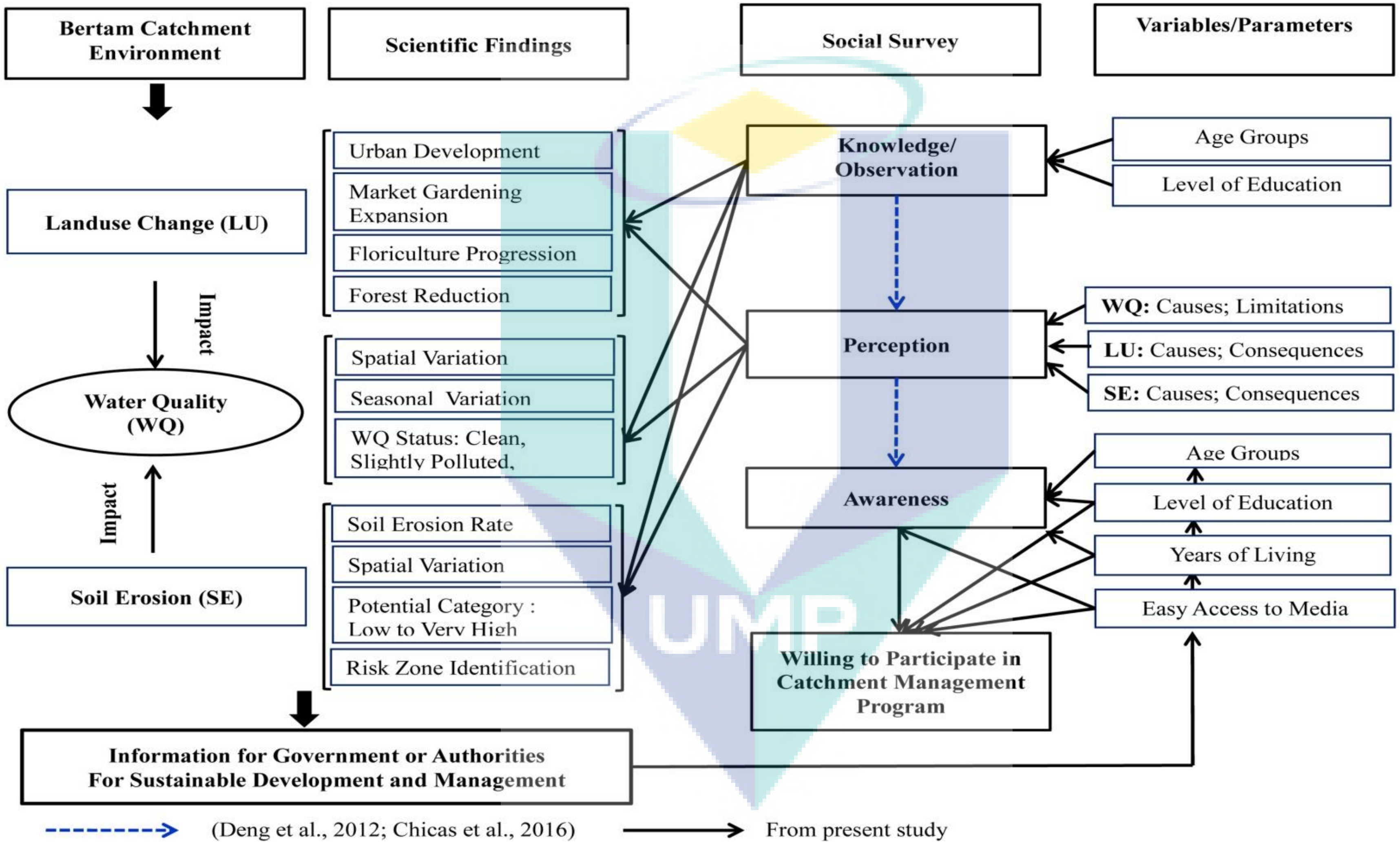

Figure 7.20 Overall Socio-scientific findings and Process flow for Sustainable Management.

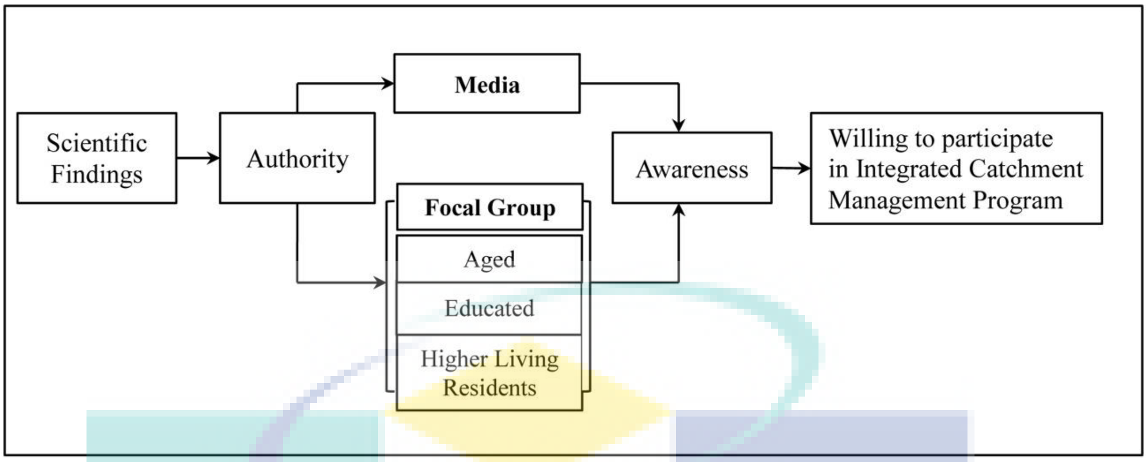

Figure 7.21 Proposed Model for sustainable development of catchment management program

7.11 Summary

The present chapter of the current study was based on the community or people perception and integrated the observations with scientific findings for the development of a sustainable management model. For this study, a well-structured questionnaire survey was conducted to better understand the communities' knowledge, perceptions, and awareness of environmental issues (water quality, landuse change and soil erosion) within the catchment area. Their willingness to participate in catchment management program was also elicited.

The survey results on demographic characteristic showed that the respondents were mostly equal proportion in each age group. Among them two-third respondents were male. The highest respondents were Malay followed by Chinese race. Indian had also significant proportion. Occupation wise, the majority of respondents were resident's professions. It was followed by businessmen and service sector people and shared same proportion. Least percentage belonged to student category. According to educational level, academic, diploma, secondary and primary groups were more or less similar amount of percentage ranged from 22.7 to 26 percent. Less than 5 percent respondents were counted as illiterate.

Survey results of communities' observation on water quality, land type change and soil erosion is shown that most respondents of the communities' were well known of these environmental issues. They know that water quality and landuse are changing as well as soil erosion is regularly observed with the passages of time. A statistical test of association revealed that age and level of education have a significant impact on the observation of respondents on different environmental changes. Concerning the communities' perceptions about causes and limitations to protect water pollution, the majority believed that land clearing and poor agricultural practices were two main reasons behind the pollution in the locality. Furthermore, more than 50 percent respondents' selected excess sedimentation while 40 percent considered domestic discharge as such reason. Lack of strict enforcement of policies was the main hurdle behind control the pollution. Rapid urbanization, poor agricultural practices, and uncontrolled land clearing were almost second main obstacles. Considering the landuses, the majority of people said intensive farming activities and rapid urbanization were the reasons behind land type change. They also ratified that deforestation and environmental change were the main consequences of land type change. Regarding the causes of soil erosion, respondents selected clearing of slopes and deforestation as the leading causes of erosion in the study area. The also thought that pollution of river water was the main consequence of soil erosion. More importantly, results of the social survey showed high levels of statistical associations between the scientific findings and communities' observations.

The survey results also showed that there was less frequency of awareness program about the water quality of river Bertam by authorities and any other volunteers. However, the majority of people had shown their willingness if any plan or program conducted and arranged by authorities. It indicated that majority of people are aware of their local catchment environment. From statistical association and correlation, it was revealed that awareness of respondents depends on their age, level of education, duration of living and access to media. Logistic regression analysis showed that communities' willingness to participate in catchment management program also depends on their awareness. From all these statistical findings, two model diagrams were developed; model 1from association and correlation test, and model 2 from the logistic regression analysis. In the model 1, people awareness related to four variables (age, level of education, living duration and access to media). However, in model 2, logistic regression analysis determined four factors (age, level of education, senior living residents and awareness score) that affect awareness in relation to respondents' willingness to participate. Adding these two models, a comprehensive model 3 was developed adding both awareness and other factors as well. Finally, a new proposed model was developed using integrated assessment of scientific findings and the model developed from social findings.

The final outcome of the model 3 (combined of model 1 and 2) shows that respondents with higher age groups, high level of education, having easy access to any type of media as well as years of living for a long time have a higher level of awareness about the Bertam environment and vice versa. Consequently, higher awareness people have the higher positive attitude to participate willingly as a volunteer in catchment management program. Final proposed model suggests that authorities should communicate and distribute the scientific information through the internet and physical appearance in seminars/ conferences to motivate and create awareness. Similarly, whenever they take any initiative for environment management program within the catchment considering the scientific findings they should more focus on the aged, higher educated and higher living residents for their high awareness and positive willingness to participate. All these activities will lead to sustainable management of the Bertam Catchment and its pollution.

CHAPTER 8

CONCLUSION

8.1 Conclusions

In the present research, an effective model for sustainable management of local catchment was developed using integrated assessment of scientific findings with quantitative social information. The study suggests that the implementation of socio-scientific integrated approach can be an effective and visionary strategy for the sustainable management of the Bertam River Catchment, Cameron Highlands in Malaysia. The scientific assessment focuses on three important studies namely the spatio-temporal variability of surface water quality, landuse changes and their impacts on water quality, and the variations of soil erosion under different landuses within the catchment. Social information emphasizes communities' knowledge, perception, and awareness towards environmental issues (water quality, landuse, and soil erosion) as well as their willingness to participate in catchment management program.

Important calculations based on the objectives are presented below:

Objectives 1: To determine the spatio-temporal variability of surface water quality and status; and to identify the potential sources of water pollution in the study area

The spatial and temporal variations as well as sources identification of water quality were evaluated based on measured fourteen numbers of water quality parameters and streamflow. The spatial characterization of water quality was mainly influenced by EC, TDS, turbidity, TSS, BOD, COD, and nutrient parameters. Results demonstrated that the higher concentrations of BOD, COD, and NH_3-N were largely observed around the urban areas. Conversely, higher concentrations of nutrient variables as NO_3-N, TN, PO_4-P, and TP were found around the agricultural practice areas. TSS and turbidity showed higher values than the limit of Malaysian standard at most of the catchment areas. The temporal variability was observed for temp, DO, COD, turbidity, TSS, NO_3-N, PO_4-P, and TP across the catchment. Except for DO and COD, all other parameters displayed higher values in the rainy season. From the assessment, the overall water quality status of the Bertam Catchment was classified as "Slightly Polluted" all around the year according to DOE-WQI.

Clustering procedure classified the uppermost part of the catchment as clean to less polluted class while that of at lower part correspond to highly polluted class. The spatio-temporal variability was also clearly demarcated clean to polluted areas using the integrated approach. The deterioration of water quality variations were predominantly influence by the nutrient enrichment, soil erosion and organic decomposition factors. The result suggested that the variations are mainly related to untreated domestic and municipal wastewater discharge from urban areas and influenced by agricultural runoff from eroded land due to agricultural activities. The spatial and seasonal variations in contaminant concentrations are largely affected by anthropogenic influences as a result of urbanization and agricultural intensification as well as by precipitation and stremflow. The spatial variation of water quality parameters gives the general ideas about the impacts of landuse on water quality. The seasonal and spatial patterns of water quality variables explicit the pollutant sources and contaminated areas, which is very important for the water quality conservation and monitoring strategy.

Results from above reviewed revealed that most of the water quality studies were highly linked with land use patterns and discharge from industry and/or sewage as well as agricultural runoff. All these studies demonstrated that spatial-temporal variations of water quality strongly depend on the spatial and temporal scales of analysis.

Objectives 2: To model the landuse pattern variations as well as land transformation and to assess their possible effects on seasonal surface water quality.

The changes in pattern of land usage within the Bertam River Catchment were investigated to understand the potential impact of such changes on water quality. A GIS approach with digitization, change detection and slope analysis techniques were applied to analyze the changing status and trends of land usage over time (1984-2010) using GIS approach. Ten categories of landuse were identified and mapped. The analytical results revealed that substantial expansion of market gardening (16.37 km^2) and urban area (4.15 km^2) has taken place during the study period resulting in significant decrease in forest area (22.85 km^2). A major modification of floriculture land type (8.04 km^2) from market gardening was also observed in the study area. Land use changes were characterized by expansion of the land use types with higher development pressure (agricultural activities and urban) and reduction of some land use types with higher environmental value (forest and scrubland) during the study period. Slope analysis showed that a noticeable rate of agricultural activities developed along the higher slope ranges (>20°) with replacing forest land type with the passage of time.

From the correlation studied of water quality-landuse relationships it was found that the urban land use had a significant positive correlation with BOD, COD, and NH_3-N in both the seasons suggested that the urban area might be one of the main sources of organic pollutants. On the other hands, market gardening land type exhibited significant positive relationships with nutrient variables like NO_3-N, TN, PO_4-P, and TP as well as turbidity and TSS. The relationships indicated that the nutrient variables, turbidity, and TSS might be attributed to non-point source pollutants from market gardening land type. On the contrary, forest land represented the negative correlation with all with all physico-chemical water quality parameters in both the seasons indicative of better water quality within the catchment and acting as a "sink".

Overall, the landuse study revealed that the rapid development of urban and agricultural activities have brought significant changes in land use pattern and led to negative impacts on water quality within the Bertam Catchment during last two decades.Sustainable landuse planning and management are urgent to handle the equilibrium between water resource conservation with land use development and utilization.

<u>Objectives 3:</u> To evaluate the spatial variations of soil erosion loss at the catchment scale in relation to the potential role of different land use changes in the study area

The soil erosion map was prepared and the average annual soil erosion rate was estimated in the Bertam River Catchment using the Revised Universal Soil Loss

Equation (RUSLE) integrated with GIS environment. The landuse changes within the sub-catchments have also been calculated to predict how landuse change impact on the soil erosion and thus on water quality.

With the help of this map and soil erosion results, spatial pattern variations of soil erosion and potentially vulnerable zones within the catchment have been identified. It was revealed that the annual average soil erosion estimated using RUSLE model is about 123.23 ton/ ha/ year during the study period in the catchment. The rate of annual soil erosion ranges from 27.60 to 63.83 ton/ ha/ year and gradually increases toward the Lower sub-catchment.

The erosion map revealed that about 9.57% of the area comes under the high to very high erosion category. The spatial distribution of soil erosion category elucidated that high to very high erosional areas occur in all three sub-catchments within the catchment. The Lower sub-catchment shows more areas of high to very high erosion compare to Middle and Upper sub-catchment.

The results of soil erosion assessment also identify that the agricultural activities are the main contributor to higher soil erosion in different sub-catchments. The rainfall intensities, landuse management, and topography play vital roles in regulating soil erosion, movement, and sedimentation within the catchment.

All these scientific assessments provide crucial information to policy makers and authorities for proper landuse management and for conserving water resources in mountainous Bertam River Catchment.

Objectives 4: To investigate the communities' knowledge and perceptions on water quality, landuse change and soil erosion to corroborate with scientific findings and to develop an integrated approach of scientific assessment with social information for sustainable catchment management.

Community-based survey findings concluded that the majority people of the community observed the change in water quality, land type and soil erosion with the passage of time within the Bertam Catchment. High level of associations between the scientific findings and communities' observations indicate that people have good knowledge and perception about the catchment environment. The results of the study reveals that respondents with higher age groups, high level of education, having easy access to any type of media as well as years of living for long time have higher level of awareness about the Bertam environment. And higher awareness people have higher positive attitude to participate willingly in the catchment management program.

Considering all the socio-scientific findings, this study suggest that awareness and motivation can be increased by providing the scientific information through internet and organizing workshops. It also suggests that if authorities take any initiative for a management program within the studied catchment considering the scientific findings, they should focus more on the aged, higher educated and higher living residents for their higher level of awareness and positive willingness for participation. Overall, this study provides a technical support for sustainable management of the catchment which has a great significance for the sustainable economic development of Cameron Highlands, Malaysia.

8.2 Recommendations

The scientific and social assessment was carried out for developing an effective model for sustainable management of the Bertam River Catchment. However, further works should be taken to the following directions.

1. Higher resolution remote sensing imagery and more in-situ water quality data will be employed to improve the linking of land uses and water quality.

2. Estimating the nutrient and sediment loads and their future change scenario could provide crucial scientific data to the authorities for better management of the catchment.

3. Communities' knowledge, attitude and practices (KAP) survey would be an essential tool for adaptation of environmentally friendly techniques (agricultural practices) for soil erosion prevention in the region.

REFERENCES

Ab d Manap, M., Ramli, M. F., Wan, N., & Surip, N. (2010). Application of remote sensing in the identification of the geological terrain features in Cameron Highlands, Malaysia. *Sains Malaysiana, 39*(1), 1-11.

Abdullah, P., Abdullah, S. M. S., Jaafar, O., Mahmud, M., & Khalik, W. M. A. W. M. (2015). Characterization of spatial and temporal variability in hydrochemistry of Johor Straits, Malaysia. *Marine Pollution Bulletin, 101*(1), 378-385.

Abdullah, W. W., Aminuddin, B., Salama, R., Cheah, U., Jamaluddin, J., & Osman, G. (2001). *Site descriptions and project field activities in the Cameron Highlands.* Paper presented at the ACIAR PROCEEDINGS.

Abdullah, W. W., Aminuddin, B., & Zulkifli, M. (2005). Modelling pesticide and nutrient transport in the Cameron Highlands, Malaysia agro-ecosystems. *Water, Air, & Soil Pollution: Focus, 5*(1-2), 115-123.

Abildtrup, J., Garcia, S., & Stenger, A. (2013). The effect of forest land use on the cost of drinking water supply: A spatial econometric analysis. *Ecological Economics, 92*, 126-136.

Afroz, R., & Rahman, A. (2017). Health impact of river water pollution in Malaysia. *International Journal of Advanced and Applied Sciences, 4*(5), 78-85.

Ai, L., Shi, Z., Yin, W., & Huang, X. (2015). Spatial and seasonal patterns in stream water contamination across mountainous watersheds: linkage with landscape characteristics. *Journal of Hydrology, 523*, 398-408.

Aiello, A., Adamo, M., & Canora, F. (2015). Remote sensing and GIS to assess soil erosion with RUSLE3D and USPED at river basin scale in southern Italy. *Catena, 131*, 174-185.

Ajorlo, M., Abdullah, R. B., Yusoff, M. K., Halim, R. A., Hanif, A. H. M., Willms, W. D., & Ebrahimian, M. (2013). Multivariate statistical techniques for the assessment of seasonal variations in surface water quality of pasture ecosystems. *Environmental Monitoring and Assessment, 185*(10), 8649-8658.

Akan, J. C., Abbagambo, M. T., Chellube, Z. M., & Abdulrahman, F. I. (2012). Assessment of pollutants in water and sediment samples in Lake Chad, Baga, North Eastern Nigeria. *Journal of Environmental Protection, 3*(11), 1428.

Akinbile, C. O., Yusoff, M. S., Talib, S. H. A., Hasan, Z. A., Ismail, W. R., & Sansudin, U. (2013). Qualitative analysis and classification of surface water in Bukit Merah Reservoir in Malaysia. *Water Science and Technology: Water Supply, 13*(4), 1138-1145.

Akter, K. S., Kurisu, K., & Hanaki, K. (2017). Water Use and Pollution Recognition from the Viewpoint of Local Residents in Dhaka, Bangladesh. *Water, 9*(5), 331.

Al-Badaii, F., Shuhaimi-Othman, M., & Gasim, M. B. (2013). Water quality assessment of the Semenyih river, Selangor, Malaysia. *Journal of Chemistry, 2013*.

Al-doski, J., Mansor, S. B., & Shafri, H. Z. M. (2013). Change detection process and techniques. *Civil and Environmental Research, 3*(10).

Al-Mamun, A., & Zainuddin, Z. (2013). Sustainable river water quality management in Malaysia. *IIUM Engineering Journal, 14*(1).

Al-Mutairi, N., Abahussain, A., & El-Battay, A. (2014). Spatial and temporal characterizations of water quality in Kuwait Bay. *Marine Pollution Bulletin, 83*(1), 127-131.

Alberto, W. D., del Pilar, D. a. M. a., Valeria, A. M. a., Fabiana, P. S., Cecilia, H. A., & de los Ángeles, B. M. a. (2001). Pattern Recognition Techniques for the Evaluation of Spatial and Temporal Variations in Water Quality. A Case Study:: Suquía River Basin (Córdoba–Argentina). *Water Research, 35*(12), 2881-2894.

Alexakis, D. D., Hadjimitsis, D. G., & 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. *Atmospheric Research, 131*, 108-124.

Ali, S. A., & Hagos, H. (2016). Estimation of soil erosion using USLE and GIS in Awassa Catchment, Rift valley, Central Ethiopia. *Geoderma Regional, 7*(2), 159-166.

Alkharabsheh, M. M., Alexandridis, T., Bilas, G., Misopolinos, N., & Silleos, N. (2013). Impact of land cover change on soil erosion hazard in northern Jordan using remote sensing and GIS. *Procedia Environmental Sciences, 19*, 912-921.

Allen-Ankins, S., Stoffels, R., Pridmore, P., & Vogel, M. (2012). The effects of turbidity, prey density and environmental complexity on the feeding of juvenile Murray cod Maccullochella peelii. *Journal of Fish Biology, 80*(1), 195-206.

Amin, A., Fazal, S., Mujtaba, A., & Singh, S. K. (2014). Effects of land transformation on water quality of Dal Lake, Srinagar, India. *Journal of the Indian Society of Remote Sensing, 42*(1), 119-128.

Aminu, M., Matori, A. N., Yusof, K. W., Malakahmad, A., & Zainol, R. B. (2015). A GIS-based water quality model for sustainable tourism planning of Bertam River in Cameron Highlands, Malaysia. *Environmental Earth Sciences, 73*(10), 6525-6537. doi:10.1007/s12665-014-3873-6

Aminuddin, B., Ghulam, M., Abdullah, W. W., Zulkefli, M., & Salama, R. (2005). Sustainability of current agricultural practices in the Cameron Highlands, Malaysia. *Water, Air, & Soil Pollution: Focus, 5*(1-2), 89-101.

Angyal, Z., Sárközi, E., Gombás, Á., & Kardos, L. (2016). Effects of land use on chemical water quality of three small streams in Budapest. *Open Geosciences, 8*(1), 133-142.

Annalakshmi, G., & Amsath, A. (2012). An assessment of water quality of river cauvery and its tributaries arasalar with reference to physico-chemical paremeters at Tanjore Dt, Tamilnadu, India.

APHA. (2012). Standard Methods for the Examination of Water and Waste Water Analysis, 22nd ed. . *American Public Health Association: Washington, D.C, 22*.

Appelo, C. A. J., & Postma, D. (2004). *Geochemistry, groundwater and pollution*: CRC press.

Ariffin, A. R. M., Ali, Z. M., 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.* Paper presented at the SHS Web of Conferences.

Ariffin, M., & Sulaiman, S. N. M. (2015). Regulating sewage pollution of Malaysian rivers and its challenges. *Procedia Environmental Sciences, 30*, 168-173.

Aris, A. Z., Lim, W. Y., Praveena, S. M., Yusoff, M. K., Ramli, M. F., & Juahir, H. (2014). Water Quality Status of Selected Rivers in Kota Marudu, Sabah, Malaysia and its Suitability for Usage. *Sains Malaysiana, 43*(3), 377-388.

Ashraf, M. A., & Yusoff, I. (2015). Soil Erosion and its Impact on Hydro-Environment of Tasik Chini, Pahang. *E-proceedings of the 36th IAHR World Congress The Hague, the Netherlands*.

Aslin, H. J., & Lockie, S. (2013). Citizenship, engagement and the environment: Charles Darwin University Press.

Ayeni, A., Cho, M., Mathieu, R., & Adegoke, J. (2016). The local experts' perception of environmental change and its impacts on surface water in Southwestern Nigeria. *Environmental Development, 17*, 33-47.

Ayeni, A., Soneye, A., & Badru, F. (2014). Adaptation to Water Stress in Nigeria Derived Savanna Area: The Indigenous Knowledge and Socio-Cultural Nexus of Management and Humanitarian Services. *Journal of Management Policy and Practice, 15*(3), 78.

Ayivi, F. (2017). *Impact of Land-Use Land-Cover Change on Stream Water Quality in the Reedy Fork-Buffalo Creek Watershed, North Carolina: A Spatiotemporal Analysis.* The University of North Carolina at Greensboro.

Bailey, R. T., & Ahmadi, M. (2014). Spatial and temporal variability of in-stream water quality parameter influence on dissolved oxygen and nitrate within a regional stream network. *Ecological Modelling, 277*, 87-96.

Baja, S., Nurmiaty, U., & Arif, S. (2014). GIS-based soil erosion modeling for assessing land suitability in the urban watershed of tallo river, South Sulawesi, Indonesia. *Modern Applied Science, 8*(4), 50.

Baoligao, B., Xu, F., Chen, X., Wang, X., & Chen, W. (2016). Acute impacts of reservoir sediment flushing on fishes in the Yellow River. *Journal of hydro-environment research, 13*, 26-35.

Barakat, A., El Baghdadi, M., Rais, J., Aghezzaf, B., & Slassi, M. (2016). Assessment of spatial and seasonal water quality variation of Oum Er Rbia River (Morocco) using multivariate statistical techniques. *International Soil and Water Conservation Research, 4*(4), 284-292.

Barron, J. J., & Ashton, C. (2005). The effect of temperature on conductivity measurement. *TSP, 7*(73), 1-5.

Barrow, C., Ngai Weng, C., & Masron, T. (2009). Issues and challenges of sustainable agriculture in the Cameron Highlands. *Malaysian Journal of Environmental Management, 10*(2), 89-114.

Barthel, R., & Seidl, R. (2017). Interdisciplinary Collaboration between Natural and Social Sciences–Status and Trends Exemplified in Groundwater Research. *PloS one, 12*(1), e0170754.

Bartram, J., Ballance, R., & Organization, W. H. (1996). Water quality monitoring: a practical guide to the design and implementation of freshwater quality studies and monitoring programs.

Beck, M. B. (1987). Water quality modeling: a review of the analysis of uncertainty. *Water Resources Research, 23*(8), 1393-1442.

Bengraïne, K., & Marhaba, T. F. (2003). Using principal component analysis to monitor spatial and temporal changes in water quality. *Journal of hazardous materials, 100*(1), 179-195.

Bernhard, A. (2010). The nitrogen cycle: processes, players, and human impact [WWW Document]. *Nat. Educ. Knowl. URL* http://www. *nature. com/scitable/knowledge/library/the-nitrogen-cycle-processesplayers-and-human-15644632 (accessed 7.3. 14).*

Bhadja, P., & Vaghela, A. (2013). Effect of temperature on the toxicity of some metals to Labeo buta (Hamilton, 1822). *International Journal of Advanced Life Sciences, 6*(3), 252-254.

Blackstock, K. L., & Richards, C. (2007). Evaluating stakeholder involvement in river basin planning: a Scottish case study. *Water Policy, 9*(5), 493-512.

Brackin, R., Robinson, N., Lakshmanan, P., & Schmidt, S. (2013). Microbial function in adjacent subtropical forest and agricultural soil. *Soil Biology and Biochemistry, 57*, 68-77.

Bu, H., Meng, W., Zhang, Y., & Wan, J. (2014). Relationships between land use patterns and water quality in the Taizi River basin, China. *Ecological Indicators, 41*, 187-197.

Bu, H., Tan, X., Li, S., & Zhang, Q. (2010). Temporal and spatial variations of water quality in the Jinshui River of the South Qinling Mts., China. *Ecotoxicology and Environmental Safety, 73*(5), 907-913.

Butt, A., Shabbir, R., Ahmad, S. S., & Aziz, N. (2015). Land use change mapping and analysis using Remote Sensing and GIS: A case study of Simly watershed, Islamabad, Pakistan. *The Egyptian Journal of Remote Sensing and Space Science, 18*(2), 251-259.

Carpenter, S. R., Caraco, N. F., Correll, D. L., Howarth, R. W., Sharpley, A. N., & Smith, V. H. (1998). Nonpoint pollution of surface waters with phosphorus and nitrogen. *Ecological Applications, 8*(3), 559-568.

Carr, G. (2015). Stakeholder and public participation in river basin management—an introduction. *Wiley Interdisciplinary Reviews: Water, 2*(4), 393-405.

Carter, L. D., & Dzialowski, A. R. (2012). Predicting sediment phosphorus release rates using landuse and water-quality data. *Freshwater Science, 31*(4), 1214-1222. doi:10.1899/11-177.1

Chan, J. H. (2002). *A study on the sustainable development of Cameron Highlands. Retrived from studentsrepo.um.edu.my/1534/8/BAB_4.pdf.* University of Malaya.

Chan, N. W. (2006). Cameron Highlands Issues And Challenges In Sustainable Development [HC79. E5 C182 2006 f]: School of Humanities, Universiti Sains Malaysia.

Chan, N. W. (2012). Managing Urban Rivers and Water Quality in Malaysia for Sustainable Water Resources. *International Journal of Water Resources Development, 28*(2), 343-354. doi:10.1080/07900627.2012.668643

Chapman, D. V. (1996). Water quality assessments: a guide to the use of biota, sediments and water in environmental monitoring.World Health Organization.

Chará-Serna, A. M., Chará, J., Giraldo, L. P., Zúñiga, M. d. C., & Allan, J. D. (2015). Understanding the impacts of agriculture on Andean stream ecosystems of Colombia: a causal analysis using aquatic macroinvertebrates as indicators of biological integrity. *Freshwater Science, 34*(2), 727-740.

Check, J., & Schutt, R. K. (2011). *Research methods in education*: Sage Publications.

Chen, C. A., Soo, C. L., Long, S. M., & Nyanti, L. (2014). Assessing the Bottom Water Quality of a Ramsar Site Subjected to Anthropogenic Disturbances: A Case Study in Kuching Wetland National Park, Sarawak, Malaysia. *Sains Malaysiana, 43*(10), 1491-1501.

Chen, J., & Lu, J. (2014). Effects of land use, topography and socio-economic factors on river water quality in a mountainous watershed with intensive agricultural production in East China. *PloS one, 9*(8), e102714.

Chicas, S., & Omine, K. (2015). Forest Cover Change and Soil Erosion in Toledo's Rio Grande Watershed. *The International Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences, 40*(7), 353.

Chicas, S. D., Omine, K., & Ford, J. B. (2016). Identifying erosion hotspots and assessing communities' perspectives on the drivers, underlying causes and impacts of soil erosion in Toledo's Rio Grande Watershed: Belize. *Applied Geography, 68*, 57-67.

Connor, R. (2015). *The United Nations world water development report 2015: water for a sustainable world* (Vol. 1): UNESCO Publishing.

Connor, R., Renata, A., Ortigara, C., Koncagül, E., Uhlenbrook, S., Lamizana-Diallo, B. M., . . . Sjödin, J. (2017). The United Nations World Water Development Report 2017. Wastewater: The Untapped Resource. *The United Nations World Water Development Report*.

Danladi Bello, A.-A., Hashim, N. B., & Mohd Haniffah, M. R. (2017). Predicting Impact of Climate Change on Water Temperature and Dissolved Oxygen in Tropical Rivers. *Climate, 5*(3), 58.

Das, S. K., Ng, A. W. M., & Perera, B. J. C. (2011). Assessment of nutrient and sediment loads in the Yarra River Catchment. *19th International Congress on Modelling and Simulation (Modsim2011)*, 3490-3496.

Das, S. K., Ng, A. W. M., Perera, B. J. C., & Adhikary, S. K. (2013). Effects of climate and landuse activities on water quality in the Yarra River catchment. *20th International Congress on Modelling and Simulation (Modsim2013)*, 2618-2624.

Dasa, S., Nga, A., Pereraa, B., & Adhikarya, S. (2013). Effects of climate and landuse activities on water quality in the Yarra River catchment.

de Jesus-Crespo, R., & Ramirez, A. (2011). Effects of urbanization on stream physicochemistry and macroinvertebrate assemblages in a tropical urban watershed in Puerto Rico. *Journal of the North American Benthological Society, 30*(3), 739-750. doi:10.1899/10-081.1

Dean, A. J., Fielding, K. S., & Newton, F. J. (2016). Community knowledge about water: who has better knowledge and is this associated with water-related behaviors and support for water-related policies? *PloS one, 11*(7), e0159063.

Demirci, A., & Karaburun, A. (2012). Estimation of soil erosion using RUSLE in a GIS framework: a case study in the Buyukcekmece Lake watershed, northwest Turkey. *Environmental Earth Sciences, 66*(3), 903-913.

Deng, M., Qin, D., & Zhang, H. (2012). Public perceptions of climate and cryosphere change in typical arid inland river areas of China: Facts, impacts and selections of adaptation measures. *Quaternary international, 282*, 48-57.

Dewan, A. M., & Yamaguchi, Y. (2009). Land use and land cover change in Greater Dhaka, Bangladesh: Using remote sensing to promote sustainable urbanization. *Applied Geography, 29*(3), 390-401.

Di Santo, V., & Bennett, W. A. (2011). Effect of rapid temperature change on resting routine metabolic rates of two benthic elasmobranchs. *Fish physiology and biochemistry, 37*(4), 929-934.

DID. (2010). Guidline for Erosion and Sediment Control in Malaysia.Ministry of Natural Resources and Environment Malaysia. Department of Irrigation and Drainage Malayssia. .

Dodd, R., & Sharpley, A. (2015). Recognizing the role of soil organic phosphorus in soil fertility and water quality. *Resources, Conservation and Recycling, 105*, 282-293.

DOE. (2010). Malaysia Environmental Quality Report 2009. Kualalumpur: Department of Environment.

DOE. (2015). Malaysia Environmental Quality Report 2014. Kualalumpur: Department of Malaysia.

Doe, W., Jones, D., & Warren, S. (1999). The soil erosion model guide for military land mangers: Analysis of erosion models for natural and cultural resources applications. *US Army Engineer Waterways Experiment Station Tech. Rept. ITL*.

Duan, W., Takara, K., He, B., Luo, P., Nover, D., & Yamashiki, Y. (2013). Spatial and temporal trends in estimates of nutrient and suspended sediment loads in the Ishikari River, Japan, 1985 to 2010. *Science of the Total Environment, 461*, 499-508.

Eduful, M., & Shively, D. (2015). Perceptions of urban land use and degradation of water bodies in Kumasi, Ghana. *Habitat International, 50*, 206-213.

Efiong, J. (2011). Changing pattern of land use in the Calabar river catchment, Southeastern Nigeria. *Journal of Sustainable Development, 4*(1), 92.

Eisakhani, M., & Malakahmad, A. (2009). Water quality assessment of Bertam River and its tributaries in Cameron Highlands, Malaysia. *World Applied Sciences Journal, 7*(6), 769-776.

El-Kawy, O. A., Rød, J., Ismail, H., & Suliman, A. (2011). Land use and land cover change detection in the western Nile delta of Egypt using remote sensing data. *Applied Geography, 31*(2), 483-494.

Elsheikh, R. F. A., Ouerghi, S., & Elhag, A. R. (2015). Soil Erosion Risk Map Based on Geographic Information System and Universal Soil Loss Equation (Case Study: Terengganu, Malaysia). *Ind. J. Sci. Res. and Tech., 3*(2), 38-43.

EPA. (2012a). 5.5 Turbidity. In Water: Monitoring & Assessment. Retrieved from http://water.epa.gov/type/rsl/monitoring/vms55.cfm.

EPA. (2012b). 5.9 Conductivity. In Water: Monitoring and Assessment. Retrieved from http://water.epa.gov/type/rsl/monitoring/vms59.cfm.

Erickson, J. (2013). Perception Surveys: Their Importance and Role in Safety Performance. Predictive Solutions, Retrived from https://blog.predictivesolutions.com/blog/perception-surveys-their-importance-and-role-in-safety-performance.

FAO, U. (1999). Terminology for Integrated Resources Planning and Management. *Food and Agriculture Organization/United Nations Environmental Programme, Rome, Italy/Nairobi, Kenia*.

FEM. (2015). Fundamentals of Environmental Measurements. Retrived from http://www.fondriest.com/environmental-measurements/parameters/water-quality/ph/.

Fichera, C. R., Modica, G., & Pollino, M. (2012). Land Cover classification and change-detection analysis using multi-temporal remote sensed imagery and landscape metrics. *European Journal of Remote Sensing, 45*(1), 1-18.

Filippelli, G. (2009). *Phosphorus Cycle. From book Encyclopedia of Paleoclimatology and Ancient Environments (pp.780-783). Retrived from https://www.researchgate.net/publication/303176829_Phosphorus_Cycle*.

Fischer, J., & Lindenmayer, D. B. (2007). Landscape modification and habitat fragmentation: a synthesis. *Global ecology and biogeography, 16*(3), 265-280.

Fortuin, R. (2006). Soil erosion in Cameron Highlands: An erosion rate study in a highland area. *Saxion University, Deventer, the Netherlands, Regional Environmental Awareness Cameron Highlands*, 1-83.

Foster, G. (1982). Modeling the erosion process. *Hydrologic modeling of small watersheds*.

Francis-Floyd, R., Watson, C., Petty, D., & Pouder, D. B. (2009). Ammonia in aquatic systems. *University of Florida IFAS Extension Publication# FA-16*.

Franzén, F., Hammer, M., & Balfors, B. (2015). Institutional development for stakeholder participation in local water management—An analysis of two Swedish catchments. *Land Use Policy, 43*, 217-227.

Friesen, J., Sinobas, L. R., Foglia, L., & Ludwig, R. (2016). Environmental and socio-economic methodologies and solutions towards integrated water resources management: Elsevier.

Fulazzaky, M. A. (2014). Challenges of integrated water resources management in Indonesia. *Water, 6*(7), 2000-2020.

Gachango, F. G., Andersen, L. M., & Pedersen, S. M. (2015). Adoption of voluntary water-pollution reduction technologies and water quality perception among Danish farmers. *Agricultural Water Management*, *158*, 235-244.

Gadhia, M., Surana, R., & Ansari, E. (2013). Seasonal Variations in Physico-Chemical Characterstics of Tapi Estuary in Hazira Industrial Area. *Our Nature*, *10*(1), 249-257.

Ganasri, B., & 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.

Garizi, A. Z., Sheikh, V., & Sadoddin, A. (2011). Assessment of seasonal variations of chemical characteristics in surface water using multivariate statistical methods. *International Journal of Environmental Science & Technology*, *8*(3), 581-592.

Gasim, M. B., Ismail Sahid, E., Pereira, J., Mokhtar, M., & Abdullah, M. (2009a). Integrated water resource management and pollution sources in Cameron Highlands, Pahang, Malaysia. *American-Eurasian J Agric Environ Sci*, *5*, 725-732.

Gasim, M. B., Surif, S., Toriman, M. E., Rahim, S. A., Elfithri, R., & Lun, P. I. (2009b). Land-use change and climate-change patterns of the Cameron Highlands, Pahang, Malaysia. *The Arab World Geographer*, *12*(1-2), 51-61.

Gazzaz, N. M., Yusoff, M. K., Aris, A. Z., Juahir, H., & Ramli, M. F. (2012a). Artificial neural network modeling of the water quality index for Kinta River (Malaysia) using water quality variables as predictors. *Marine Pollution Bulletin*, *64*(11), 2409-2420. doi:10.1016/j.marpolbul.2012.08.005

Gazzaz, N. M., Yusoff, M. K., Aris, A. Z., Juahir, H., & Ramli, M. F. (2012b). Artificial neural network modeling of the water quality index for Kinta River (Malaysia) using water quality variables as predictors. *Marine Pollution Bulletin*, *64*(11), 2409-2420. doi:10.1016/j.marpolbul.2012.08.005

Gazzaz, N. M., Yusoff, M. K., Ramli, M. F., Aris, A. Z., & Juahir, H. (2012c). Characterization of spatial patterns in river water quality using chemometric pattern recognition techniques. *Marine Pollution Bulletin*, *64*(4), 688-698.

Glavan, M., Miličić, V., & Pintar, M. (2013). Finding options to improve catchment water quality—Lessons learned from historical land use situations in a Mediterranean catchment in Slovenia. *Ecological Modelling*, *261*, 58-73.

Glibert, P. M., Maranger, R., Sobota, D. J., & Bouwman, L. (2014). The Haber Bosch–harmful algal bloom (HB–HAB) link. *Environmental Research Letters*, *9*(10), 105001.

Gonzalez-Chica, D. A., Bastos, J. L., Duquia, R. P., Bonamigo, R. R., & Martínez-Mesa, J. (2015). Test of association: which one is the most appropriate for my study? *Anais brasileiros de dermatologia*, *90*(4), 523-528.

González-Ortegón, E., Subida, M., Cuesta, J., Arias, A., Fernández-Delgado, C., & Drake, P. (2010). The impact of extreme turbidity events on the nursery function of a temperate European estuary with regulated freshwater inflow. *Estuarine, Coastal and Shelf Science, 87*(2), 311-324.

Hach. (2005). *Water Analysis Guide, 1st ed*. Philadelphia, PA: Hach company.

Hamdan, M. E., Man, N., Yassin, S., DSilva, J. L., & Shaffril, H. A. M. (2014). Farmers sensitivity towards the changing climate in the Cameron Highlands. *Agricultural Journal, 9*(2), 120-126.

Hamir, N. A., Nor, L. M., Sulaiman, H., & Sandrang, A. K. (2008). The prospect of exporting Malaysian temperate cut flowers by sea shipment to Japan. *Economy and Technology Management*, 75-83.

Hartley, N., & Wood, C. (2005). Public participation in environmental impact assessment—implementing the Aarhus Convention. *Environmental impact assessment review, 25*(4), 319-340.

Hasan, H. H., Jamil, N. R., & Aini, N. (2015). Water quality index and sediment loading analysis in Pelus River, Perak, Malaysia. *Procedia Environmental Sciences, 30*, 133-138.

Hashim, G. M., Abdul Rahaman, A., & Chan, N. (2006). Soil erosion and water pollution in Cameron Highlands: Conservation and strategies. *Cameron Highlands Issues and Challenges in Sustainable Development. Universiti Sains Malaysia*, 76-85.

Hasmadi, M., Pakhriazad, H., & Shahrin, M. (2017). Evaluating supervised and unsupervised techniques for land cover mapping using remote sensing data. *Geografia-Malaysian Journal of Society and Space, 5*(1).

Hegazy, I. R., & Kaloop, M. R. (2015). Monitoring urban growth and land use change detection with GIS and remote sensing techniques in Daqahlia governorate Egypt. *International Journal of Sustainable Built Environment, 4*(1), 117-124.

Helsel, D., & Hirsch, R. (2002). Statistical Methods in Water Resources: Techniques of Water-Resources Investigations of the United States Geological Survey. *Book, 4*, 266-274.

Holm, P., Goodsite, M. E., Cloetingh, S., Agnoletti, M., Moldan, B., Lang, D. J., . . . Pohl, W. (2013). Collaboration between the natural, social and human sciences in global change research. *Environmental Science & Policy, 28*, 25-35.

Horn, S. (2010). Using a GIS to Determine how Different Types of Land Cover have Changed over Time in the State of Connecticut. *Papers in Resource Analysis, Volume 12*, 11 pp; Retrieved (15 september 2015) from http://www.gis.smumn.edu.

Horning, N. (2010). Land covers classification methods. American Museum of Natural History. *Center for Biodiversity and Conservation. http://biodiversityinformatics. amnh. org. Accessed on, 28*, 2014.

Hu, Y., & Cheng, H. (2013). Water pollution during China's industrial transition. *Environmental Development, 8*, 57-73.

Hua, A. K., Kusin, F. M., & Praveena, S. M. (2016a). Spatial Variation Assessment of River Water Quality Using Environmetric Techniques. *Polish Journal of Environmental Studies, 25*(6), 2411-2421. doi:10.15244/pjoes/64082

Hua, A. K., Kusin, F. M., & Praveena, S. M. (2016b). Spatial Variation Assessment of River Water Quality Using Environmetric Techniques. *Polish Journal of Environmental Studies, 25*(6).

Huang, F., Wang, X., Lou, L., Zhou, Z., & Wu, J. (2010). Spatial variation and source apportionment of water pollution in Qiantang River (China) using statistical techniques. *Water Research, 44*(5), 1562-1572.

Huang, Z., Han, L., Zeng, L., Xiao, W., & Tian, Y. (2016). Effects of land use patterns on stream water quality: a case study of a small-scale watershed in the Three Gorges Reservoir Area, China. *Environmental Science and Pollution Research, 23*(4), 3943-3955.

Hubbard, L., Kolpin, D., Kalkhoff, S., & Robertson, D. M. (2011). Nutrient and sediment concentrations and corresponding loads during the historic June 2008 flooding in eastern Iowa. *Journal of Environmental Quality, 40*(1), 166.

Huckett, S. P. (2010). *A comparative study to identify factors affecting adoption of soil and water conservation practices among smallhold farmers in the Njoro River watershed of Kenya*: Utah State University.

Ian, H. (2010). *An introduction to geographical information systems*: Pearson Education India.

Islam, M., Tusher, T., Mustafa, M., & Mahmud, S. (2013). Effects of solid waste and industrial effluents on water quality of Turag River at Konabari industrial area, Gazipur, Bangladesh. *Journal of Environmental Science and Natural Resources, 5*(2), 213-218.

Ismail, M. H., Othman, C. K. A. C. K., Malek, I. A. A., & Abdullah, S. A. (2014). Land Use Trends Analysis Using SPOT 5 Images and Its Effect on the Landscape of Cameron Highlands, Malaysia *Designing Low Carbon Societies in Landscapes* (pp. 223-238): Springer.

Issaka, S., & Ashraf, M. A. (2017). Impact of soil erosion and degradation on water quality: a review. *Geology, Ecology, and Landscapes, 1*(1), 1-11.

Jaafar, O., Toriman, M. E., Mastura, S. S., Gazim, M. B., Lun, P. I., Abdullah, P., . . . Aziz, N. A. A. (2010). Modeling the impacts of ringlet reservoir on downstream hydraulic capacity of bertain river using XPSWMM in cameron highlands, Malaysia. *Research Journal of Applied Sciences, 5*(2), 47-53.

Jakeman, A. J., Green, T. R., Beavis, S. G., Zhang, L., Dietrich, C. R., & Crapper, P. F. (1999). Modelling upland and instream erosion, sediment and phosphorus transport in a large catchment. *Hydrological Processes, 13*(5), 745-752.

Jamil, N. R., Ruslan, M. S., Toriman, M. E., Idris, M., & Razad, A. A. (2014). Impact of Landuse on Seasonal Water Quality at Highland Lake: A Case Study of Ringlet Lake, Cameron Highlands, Pahang *From Sources to Solution* (pp. 409-413): Springer.

Jha, D. K., Devi, M. P., Vidyalakshmi, R., Brindha, B., Vinithkumar, N. V., & Kirubagaran, R. (2015). Water quality assessment using water quality index and geographical information system methods in the coastal waters of Andaman Sea, India. *Marine Pollution Bulletin, 100*(1), 555-561.

Jha, M. K., & Paudel, R. C. (2010). Erosion predictions by empirical models in a mountainous watershed in Nepal. *Journal of Spatial Hydrology, 10*(1).

Jiménez Cisneros, B. E., Oki, T., Arnell, N. W., Benito, G., Cogley, J. G., Doll, P., . . . Mwakalila, S. S. (2014). Freshwater resources.

Jingling, L., Yun, L., Liya, S., Zhiguo, C., & Baoqiang, Z. (2010). Public participation in water resources management of Haihe river basin, China: the analysis and evaluation of status quo. *Procedia Environmental Sciences, 2*, 1750-1758.

Jouanneau, S., Recoules, L., Durand, M., Boukabache, A., Picot, V., Primault, Y., . . . Thouand, G. (2014). Methods for assessing biochemical oxygen demand (BOD): A review. *Water Research, 49*, 62-82.

Kagabo, D., Stroosnijder, L., Visser, S., & Moore, D. (2013). Soil erosion, soil fertility and crop yield on slow-forming terraces in the highlands of Buberuka, Rwanda. *Soil and tillage research, 128*, 23-29.

Kaiser, H. (1974). An index of factorial simplicity, Psychometrics 39: 31–36.

Kanazawa, M. (2017). *Research Methods for Environmental Studies: A Social Science Approach*: Routledge.

Kandel, D., Western, A., Grayson, R., & Turral, H. (2004). Process parameterization and temporal scaling in surface runoff and erosion modelling. *Hydrological Processes, 18*(8), 1423-1446.

Kang, J.-H., Lee, S. W., Cho, K. H., Ki, S. J., Cha, S. M., & Kim, J. H. (2010). Linking land-use type and stream water quality using spatial data of fecal indicator bacteria and heavy metals in the Yeongsan river basin. *Water Research, 44*(14), 4143-4157.

Kang, N., Sakamoto, T., Imanishi, J., Fukamachi, K., Shibata, S., & Morimoto, Y. (2013). Characterizing the historical changes in land use and landscape spatial pattern on the oguraike floodplain after the Meiji Period.

Kannel, P. R., Lee, S., Lee, Y.-S., Kanel, S., & Pelletier, G. (2007). Application of automated QUAL2Kw for water quality modeling and management in the Bagmati River, Nepal. *Ecological Modelling, 202*(3-4), 503-517.

Karydas, C. G., Sekuloska, T., & Silleos, G. N. (2009). Quantification and site-specification of the support practice factor when mapping soil erosion risk associated with olive plantations in the Mediterranean island of Crete. *Environmental Monitoring and Assessment*, *149*(1-4), 19-28.

Kashaigili, J., & Majaliwa, A. (2010). Integrated assessment of land use and cover changes in the Malagarasi river catchment in Tanzania. *Physics and Chemistry of the Earth, Parts A/B/C, 35*(13), 730-741.

Kaurish, F. W., & Younos, T. (2007). Developing a standardized water quality index for evaluating surface water quality. *JAWRA Journal of the American Water Resources Association, 43*(2), 533-545.

Khalik, W., Abdullah, M. P., Amerudin, N. A., & Padli, N. (2013). Physicochemical analysis on water quality status of Bertam River in Cameron Highlands, Malaysia. *J. Mater. Environ. Sci, 4*(4), 488-495.

Khoi, D. N., & Suetsugi, T. (2014). Impact of climate and land-use changes on hydrological processes and sediment yield—a case study of the Be River catchment, Vietnam. *Hydrological Sciences Journal, 59*(5), 1095-1108.

Kibena, J., Nhapi, I., & Gumindoga, W. (2014a). Assessing the relationship between water quality parameters and changes in landuse patterns in the Upper Manyame River, Zimbabwe. *Physics and Chemistry of the Earth, Parts A/B/C, 67*, 153-163.

Kibena, J., Nhapi, I., & Gumindoga, W. (2014b). Assessing the relationship between water quality parameters and changes in landuse patterns in the Upper Manyame River, Zimbabwe. *Physics and Chemistry of the Earth, 67-69*, 153-163. doi:10.1016/j.pce.2013.09.017

Kilonzo, F., Masese, F. O., Van Griensven, A., Bauwens, W., Obando, J., & Lens, P. N. (2014). Spatial–temporal variability in water quality and macro-invertebrate assemblages in the Upper Mara River basin, Kenya. *Physics and Chemistry of the Earth, Parts A/B/C, 67*, 93-104.

Kim, Y. (2014). Soil erosion assessment using GIS and revised universal soil loss equation (RUSLE). *Journal of Water Resources*.

Kimbell, H. S., & Morrell, L. J. (2015). Turbidity influences individual and group level responses to predation in guppies, Poecilia reticulata. *Animal behaviour, 103*, 179-185.

Kindu, M., Schneider, T., Teketay, D., & Knoke, T. (2015). Drivers of land use/land cover changes in Munessa-Shashemene landscape of the south-central highlands of Ethiopia. *Environmental Monitoring and Assessment, 187*(7), 452.

Kotoky, P., Dutta, M., & Borah, G. (2012). Changes in landuse and landcover along the Dhansiri River channel, Assam--A remote sensing and GIS approach. *Journal of the Geological Society of India, 79*(1), 61.

Kozaki, D., bin Ab Rahim, H., bin Wan Ishak, F., Yusoff, M. M., Mori, M., Nakatani, N., & Tanaka, K. (2016). Assessment of the River Water Pollution Levels in Kuantan, Malaysia, Using Ion-Exclusion Chromatographic Data, Water Quality Indices, and Land Usage Patterns. *Air, Soil and Water Research, 9*, 1.

Kozaki, D., Harun, N. I. B., Rahim, M. H. B. A., Mori, M., Nakatani, N., & Tanaka, K. (2017). Determination of Water Quality Degradation Due to Industrial and Household Wastewater in the Galing River in Kuantan, Malaysia Using Ion Chromatograph and Water Quality Data. *Environments, 4*(2), 35.

Kruskal, W. H., & Wallis, W. A. (1952). Use of ranks in one-criterion variance analysis. *Journal of the American statistical Association, 47*(260), 583-621.

Kumaran, S., & Ainuddin, A. (2006). *Forests, water and climate of Cameron Highlands*: School of Humanities, Universiti Sains Malaysia.

Kunasekaran, P., Ramachandran, S., Yacob, M. R., & Shuib, A. (2011). Development of farmers' perception scale on agro tourism in Cameron Highlands, Malaysia. *World Applied Sciences Journal, 12*(Special Issue of Tourism & Hospitality), 10-18.

Lam, Q., Schmalz, B., & Fohrer, N. (2012). Assessing the spatial and temporal variations of water quality in lowland areas, Northern Germany. *Journal of Hydrology, 438*, 137-147.

Lambin, E. F., Geist, H. J., & Lepers, E. (2003). Dynamics of land-use and land-cover change in tropical regions. *Annual review of environment and resources, 28*(1), 205-241.

Lambin, E. F., Turner, B. L., Geist, H. J., Agbola, S. B., Angelsen, A., Bruce, J. W., . . . Folke, C. (2001). The causes of land-use and land-cover change: moving beyond the myths. *Global environmental change, 11*(4), 261-269.

Lawson, E. (2011). Physico-chemical parameters and heavy metal contents of water from the Mangrove Swamps of Lagos Lagoon, Lagos, Nigeria. *Advances in Biological Research, 5*(1), 8-21.

Lee, I., Hwang, H., Lee, J., Yu, N., Yun, J., & Kim, H. (2017). Modeling approach to evaluation of environmental impacts on river water quality: A case study with Galing River, Kuantan, Pahang, Malaysia. *Ecological Modelling, 353*, 167-173. doi:10.1016/j.ecolmodel.2017.01.021

Lee, S.-W., Hwang, S.-J., Lee, S.-B., Hwang, H.-S., & Sung, H.-C. (2009). Landscape ecological approach to the relationships of land use patterns in watersheds to water quality characteristics. *Landscape and Urban Planning, 92*(2), 80-89.

Li, J., & Heap, A. D. (2008). A review of spatial interpolation methods for environmental scientists.

Li, S., Liu, W., Gu, S., Cheng, X., Xu, Z., & Zhang, Q. (2009). Spatio-temporal dynamics of nutrients in the upper Han River basin, China. *Journal of hazardous materials, 162*(2), 1340-1346.

Li, S., & Zhang, Q. (2010). Spatial characterization of dissolved trace elements and heavy metals in the upper Han River (China) using multivariate statistical techniques. *Journal of hazardous materials, 176*(1), 579-588.

Li, X., Li, P., Wang, D., & Wang, Y. (2014). Assessment of temporal and spatial variations in water quality using multivariate statistical methods: A case study of the Xin'anjiang River, China. *Frontiers of Environmental Science & Engineering, 8*(6), 895-904.

Li, Y., Li, Y., Qureshi, S., Kappas, M., & Hubacek, K. (2015). On the relationship between landscape ecological patterns and water quality across gradient zones of rapid urbanization in coastal China. *Ecological Modelling, 318*, 100-108.

Liebetrau, A. M. (1983). *Measures of association* (Vol. 32): Sage.

Ling, T. Y., Soo, C. L., Phan, T. P., Nyanti, L., Sim, S. F., & Grinang, J. (2017). Assessment of Water Quality of Batang Rajang at Pelagus Area, Sarawak, Malaysia. *Sains Malaysiana, 46*(3), 401-411. doi:10.17576/jsm-2017-4603-07

Ling, T. Y., Soo, C. L., Sivalingam, J. R., Nyanti, L., Sim, S. F., & Grinang, J. (2016). Assessment of the Water and Sediment Quality of Tropical Forest Streams in Upper Reaches of the Baleh River, Sarawak, Malaysia, Subjected to Logging Activities. *Journal of Chemistry*. doi:Artn 850393110.1155/2016/8503931

Liu, C.-W., Lin, K.-H., & Kuo, Y.-M. (2003). Application of factor analysis in the assessment of groundwater quality in a blackfoot disease area in Taiwan. *Science of the Total Environment, 313*(1), 77-89.

Long, K., & Pijanowski, B. C. (2017). Is there a relationship between water scarcity and water use efficiency in China? A national decadal assessment across spatial scales. *Land Use Policy, 69*, 502-511. doi:10.1016/j.landusepol.2017.09.055

Lu, X. X., Li, S., He, M., Zhou, Y., Bei, R., Li, L., & Ziegler, A. D. (2011). Seasonal changes of nutrient fluxes in the Upper Changjiang basin: An example of the Longchuanjiang River, China. *Journal of Hydrology, 405*(3-4), 344-351.

Lund, J. R. (2015). Integrating social and physical sciences in water management. *Water Resources Research, 51*(8), 5905-5918.

Magbanua, F. S., Mendoza, N. Y. B., Uy, C. J. C., Matthaei, C. D., & Ong, P. S. (2015). Water physicochemistry and benthic macroinvertebrate communities in a tropical reservoir: The role of water level fluctuations and water depth. *Limnologica-Ecology and Management of Inland Waters, 55*, 13-20.

Mallupattu, P. K., & Sreenivasula Reddy, J. R. (2013). Analysis of land use/land cover changes using remote sensing data and GIS at an Urban Area, Tirupati, India. *The Scientific World Journal, 2013*.

Manandhar, S., Pratoomchai, W., Ono, K., Kazama, S., & Komori, D. (2015). Local people's perceptions of climate change and related hazards in mountainous areas of northern Thailand. *International Journal of Disaster Risk Reduction, 11*, 47-59.

Markov, S. (2012). *Nitrogen cycle. In book: Earth Science. Water & Atmosphere., Chapter: Nitrogen cycle, Publisher: EBSCO, Editors: Joe Spradley, David Kenneth Elliott, Steven I. Dutch and Dr. Margaret Boorstein, pp.347-350.*

Martin, W. E., & Bridgmon, K. D. (2012). *Quantitative and statistical research methods: From hypothesis to results* (Vol. 42): John Wiley & Sons.

Masum, K. M., Mansor, A., Sah, S. A. M., & Lim, H. S. (2017). Effect of differential forest management on land-use change (LUC) in a tropical hill forest of Malaysia. *Journal of Environmental Management, 200*, 468-474. doi:10.1016/j.jenvman.2017.06.009

Mei, K., Liao, L., Zhu, Y., Lu, P., Wang, Z., Dahlgren, R. A., & Zhang, M. (2014). Evaluation of spatial-temporal variations and trends in surface water quality across a rural-suburban-urban interface. *Environmental Science and Pollution Research, 21*(13), 8036-8051.

Mei, N. S., Wai, C. W., & Ahamad, R. (2016). Environmental Awareness and Behaviour Index for Malaysia. *Procedia - Social and Behavioral Sciences, 222*(Supplement C), 668-675. doi:https://doi.org/10.1016/j.sbspro.2016.05.223

Mertens, D. M. (2014). *Research and evaluation in education and psychology: Integrating diversity with quantitative, qualitative, and mixed methods*: Sage publications.

Meyer, W. B., & Turner, B. L. (1992). Human population growth and global land-use/cover change. *Annual review of ecology and systematics, 23*(1), 39-61.

Midmore, D. J., Jansen, H. G., & Dumsday, R. G. (1996). Soil erosion and environmental impact of vegetable production in the Cameron Highlands, Malaysia. *Agriculture, ecosystems & environment, 60*(1), 29-46.

Mir, S. I., Sahid, I., Gasim, M. B., Rahim, S. A., & Toriman, M. E. (2015). Prediction of soil and nutrient losses from the lake Chini watershed, Pahang, Malaysia. *Journal of Physical Science, 26*(1), 53.

Mitas, L., & Mitasova, H. (1998). Distributed soil erosion simulation for effective erosion prevention. *Water Resources Research, 34*(3), 505-516.

Mitasova, H., & Mitas, L. (1999). Modeling soil detachment with RUSLE 3d using GIS. *University of Illinois at Urbana-Champaign*.

Moghadam, B. K., Jabarifar, M., Bagheri, M., & Shahbazi, E. (2015). Effects of land use change on soil splash erosion in the semi-arid region of Iran. *Geoderma, 241*, 210-220.

Mohtar, Z. A., Yahaya, A. S., & Ahmad, F. (2015). Rainfall erosivity estimation for Northern and Southern peninsular Malaysia using Fourneir indexes. *Procedia Engineering, 125*, 179-184.

Morgan, R. P. C. (2005). *Soil erosion and conservation, 3rd Edition*: Blackwell Publishing Ltd.

Morrison, E. H., Upton, C., Pacini, N., Odhiambo-K'oyooh, K., & Harper, D. M. (2013). Public perceptions of papyrus: community appraisal of wetland ecosystem services at Lake Naivasha, Kenya. *Ecohydrology & Hydrobiology, 13*(2), 135-147.

Mostapa, R., & Weston, K. (2016). Seasonal and spatial variability of selected surface water quality parameters in Setiu wetland, Terengganu, Malaysia. *Sains Malaysiana, 45*(4), 551-558.

Mouri, G., Golosov, V., Chalov, S., Takizawa, S., Oguma, K., Yoshimura, K., . . . Oki, T. (2013). Assessment of potential suspended sediment yield in Japan in the 21st century with reference to the general circulation model climate change scenarios. *Global and planetary change, 102*, 1-9

Mouri, G., Takizawa, S., & Oki, T. (2011). Spatial and temporal variation in nutrient parameters in stream water in a rural-urban catchment, Shikoku, Japan: Effects of land cover and human impact. *Journal of Environmental Management, 92*(7), 1837-1848.

Moyo, N., & Rapatsa, M. (2016). Impact of urbanization on the ecology of Mukuvisi River, Harare, Zimbabwe. *Physics and Chemistry of the Earth, Parts A/B/C, 92*, 14-19.

Mukundan, R., Pradhanang, S. M., Schneiderman, E. M., Pierson, D. C., Anandhi, A., Zion, M. S., . . . Steenhuis, T. S. (2013). Suspended sediment source areas and future climate impact on soil erosion and sediment yield in a New York City water supply watershed, USA. *Geomorphology, 183*, 110-119.

Mustapha, A., Aris, A. Z., Ramli, M. F., & Juahir, H. (2012). Spatial-temporal variation of surface water quality in the downstream region of the Jakara River, north-western Nigeria: A statistical approach. *Journal of Environmental Science and Health, Part A, 47*(11), 1551-1560.

Mustard, J. F., Defries, R. S., Fisher, T., & Moran, E. (2012). Land-use and land-cover change pathways and impacts *Land change science* (pp. 411-429): Springer.

Myhill, A. (2003). Community engagement in policing. *Lessons from the Literature. London: Home Office Report*.

Naddeo, V., Scannapieco, D., Zarra, T., & Belgiorno, V. (2013). River water quality assessment: Implementation of non-parametric tests for sampling frequency optimization. *Land Use Policy*, *30*(1), 197-205.

Naubi, I., Zardari, N. H., Shirazi, S. M., Ibrahim, N. F. B., & Baloo, L. (2016). Effectiveness of Water Quality Index for Monitoring Malaysian River Water Quality. *Polish Journal of Environmental Studies, 25*(1).

Noi, L. V. T., & Nitivattananon, V. (2015). Assessment of vulnerabilities to climate change for urban water and wastewater infrastructure management: Case study in Dong Nai river basin, Vietnam. *Environmental Development, 16*, 119-137.

Nordstokke, D. W., Zumbo, B. D., Cairns, S. L., & Saklofske, D. H. (2011). The operating characteristics of the nonparametric Levene test for equal variances with assessment and evaluation data. *Practical Assessment, Research & Evaluation, 16*.

Norhayati, M., Goh, S., Tong, S., Wang, C., & Abdul Halim, S. (1997). Water quality studies for the classification of Sungai Bernam and Sungai Selangor. *J. Ensearch, 10*, 27-36.

NWRS. (2011). Review of the national water resources study(2000-2050) and formulation of national water resources policy, Malaysia. *Vol12-Pahang*.

O'Driscoll, C., O'Connor, M., de Eyto, E., Brown, L. E., & Xiao, L. (2016). Forest clearfelling effects on dissolved oxygen and metabolism in peatland streams. *Journal of Environmental Management, 166*, 250-259.

Ogunbode, C. A., & Arnold, K. (2012). A study of environmental awareness and attitudes in Ibadan, Nigeria. *Human and Ecological Risk Assessment: An International Journal, 18*(3), 669-684.

Ogwueleka, T. C. (2015). Use of multivariate statistical techniques for the evaluation of temporal and spatial variations in water quality of the Kaduna River, Nigeria. *Environmental Monitoring and Assessment*, *187*(3), 1-17.

Othman, F., Elamin, M., Eldin, A., Azahar, H., Azireen, S., & Muhammad, S. A. (2014). *Utilizing GIS in the Development of Water Quality River Modeling for Penchala River, Malaysia.* Paper presented at the Applied Mechanics and Materials.

Othman, F., Eldin, M. E. A., & Mohamed, I. (2012). Trend analysis of a tropical urban river water quality in Malaysia. *Journal of Environmental Monitoring, 14*(12), 3164-3173. doi:10.1039/c2em30676j

Othman, J. (2011). Scenic beauty preferences of Cameron Highlands Malaysia: Local versus foreign tourists. *International Journal of Business and Social Science, 2*(6), 248-253.

Ouyang, Y., Nkedi-Kizza, P., Wu, Q., Shinde, D., & Huang, C. (2006). Assessment of seasonal variations in surface water quality. *Water Research*, *40*(20), 3800-3810.

Palerm, J. R. (1999). Public participation in environmental decision making: examining the Aarhus convention. *Journal of Environmental Assessment Policy and Management*, *1*(02), 229-244.

Panagos, P., Ballabio, C., Borrelli, P., Meusburger, K., Klik, A., Rousseva, S., . . . Olsen, P. (2015a). Rainfall erosivity in Europe. *Science of the Total Environment*, *511*, 801-814.

Panagos, P., Borrelli, P., Poesen, J., Ballabio, C., Lugato, E., Meusburger, K., . . . Alewell, C. (2015b). The new assessment of soil loss by water erosion in Europe. *Environmental Science & Policy*, *54*, 438-447.

Pandey, A., Himanshu, S. K., Mishra, S., & Singh, V. P. (2016). Physically based soil erosion and sediment yield models revisited. *Catena*, *147*, 595-620.

Paramananthan, S. (1977). *Soil genesis on igneous and metamorphic rocks in Malaysia*: State University of Ghent.

Park, J. H., Duan, L., Kim, B., Mitchell, M. J., & Shibata, H. (2010). Potential effects of climate change and variability on watershed biogeochemical processes and water quality in Northeast Asia. *Environ Int*, *36*(2), 212-225. doi:10.1016/j.envint.2009.10.008

Pathirana, A., Denekew, H. B., Veerbeek, W., Zevenbergen, C., & Banda, A. T. (2014). Impact of urban growth-driven landuse change on microclimate and extreme precipitation—A sensitivity study. *Atmospheric Research*, *138*, 59-72.

Perazzoli, M., Pinheiro, A., & Kaufmann, V. (2013). Effects of scenarios of landuse on water regime and sediment transport in the Concórdia River basin, SC. *Revista Arvore*, *37*(5), 859-869.

Perkins, P. E. E. (2011). Public participation in watershed management: International practices for inclusiveness. *Physics and Chemistry of the Earth, Parts A/B/C*, *36*(5-6), 204-212.

Perlman, H. (2013). Water Properties: Temperature. In The USGS Water Science School . Retrieved from http://ga.water.usgs.gov/edu/temperature.html.

Perrin, J.-L., Raïs, N., Chahinian, N., Moulin, P., & Ijjaali, M. (2014). Water quality assessment of highly polluted rivers in a semi-arid Mediterranean zone Oued Fez and Sebou River (Morocco). *Journal of Hydrology*, *510*, 26-34.

Piwpuan, N., Zhai, X., & Brix, H. (2013). Nitrogen nutrition of Cyperus laevigatus and Phormium tenax: effects of ammonium versus nitrate on growth, nitrate reductase activity and N uptake kinetics. *Aquatic botany, 106*, 42-51.

Ponto, J. (2015). Understanding and evaluating survey research. *Journal of the advanced practitioner in oncology, 6*(2), 168.

Pörtner, H.-O. (2010). Oxygen-and capacity-limitation of thermal tolerance: a matrix for integrating climate-related stressor effects in marine ecosystems. *Journal of Experimental Biology, 213*(6), 881-893.

Pradha, B., Mansor, S., & Pirasteh, S. (2011). Landslide Susceptibility Mapping: an Assessment of the Use of an Advanced Neural Network Model with Five Different Training Strategies *Artificial Neural Networks-Application*: InTech.

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.

Pratt, B., & Chang, H. (2012). Effects of land cover, topography, and built structure on seasonal water quality at multiple spatial scales. *Journal of hazardous materials, 209*, 48-58.

Priess, J., Schweitzer, C., Batkhishig, O., Koschitzki, T., & Wurbs, D. (2015). Impacts of agricultural land-use dynamics on erosion risks and options for land and water management in Northern Mongolia. *Environmental Earth Sciences, 73*(2), 697-708.

Prokop, P., & Płoskonka, D. (2014). Natural and human impact on the land use and soil properties of the Sikkim Himalayas piedmont in India. *Journal of Environmental Management, 138*, 15-23.

Qadir, A., Malik, R. N., Feroz, A., Jamil, N., & Mukhtar, K. (2013). Spatiotemporal distribution of contaminants in Nullah Palkhu-highly polluted stream of Pakistan. *Journal of Environmental Science and Water Resources, 2*(10), 342-353.

Ramli, M. N. A. B. (2014). Illegal Dumping in Cameron Highlands (Thesis)Retrived from https://www.researchgate.net/publication/271836678.

RAMP. (2016a). Regional Aquatics Monitoring Program. Water Quality Indicators: Nutrients. Retrived from http://www.ramp-alberta.org/river/water+sediment+quality/chemical/nutrient.aspx.

RAMP. (2016b). Regional Aquatics Monitoring Program. Water Quality Indicators: Temperature and Dissolve Oxygen. Retrieved from http://www.ramp-alberta.org/river/water+sediment+quality/chemical/temperature+and+dissolved+oxygen.aspx

Regional Aquatic Monitoring Proram., Retrieved September 2016, from http://www.ramp-alberta.org/river/water+sediment+quality/chemical/temperature+and+dissolved+oxygen.aspx

Ranzi, R., Le, T. H., & Rulli, M. C. (2012). A RUSLE approach to model suspended sediment load in the Lo river (Vietnam): effects of reservoirs and land use changes. *Journal of Hydrology, 422*, 17-29.

Rasul, G. (2016). Spatial and Temporal Variation of Water Quality in the Bertam Catchment, Cameron Highlands, Malaysia. *Water Environ Res*. doi:10.2175/106143017X14839994522740

Rault, P. A. K., Vreugdenhil, H., Jeffrey, P., & Slinger, J. H. (2013). Readiness and willingness of the public to participate in integrated water management: some insights from the Levant. *Water Policy, 15*(S2), 101-120.

Rawat, J., & Kumar, M. (2015). Monitoring land use/cover change using remote sensing and GIS techniques: A case study of Hawalbagh block, district Almora, Uttarakhand, India. *The Egyptian Journal of Remote Sensing and Space Science, 18*(1), 77-84.

Razali, N. M., & Wah, Y. B. (2010). *Power comparisons of some selected normality tests*. Paper presented at the Regional Conference on Statistical Sciences, Malaysia.

Reed, M. S. (2008). Stakeholder participation for environmental management: a literature review. *Biological Conservation, 141*(10), 2417-2431.

Renard, K., Foster, G., Yoder, D., & McCool, D. (1994). RUSLE revisited: status, questions, answers, and the future. *Journal of Soil and Water Conservation, 49*(3), 213-220.

Renard, K. G. (1997). Predicting soil erosion by water: a guide to conservation planning with the revised universal soil loss equation (RUSLE).

Renard, K. G., & Freimund, J. R. (1994). Using monthly precipitation data to estimate the R-factor in the revised USLE. *Journal of Hydrology, 157*(1-4), 287-306.

Rimal, B. (2011). Application of Remote Sensing and GIS, Landuse/Land Cover Change in Kathmaandu Metropolitan City, Nepal. *Journal of Theoretical & Applied Information Technology, 23*(2).

Roberts, A. D. (2016). The effects of current landscape configuration on streamflow within selected small watersheds of the Atlanta metropolitan region. *Journal of Hydrology: Regional Studies, 5*, 276-292.

Rolston, A., Jennings, E., & Linnane, S. (2017). Water matters: An assessment of opinion on water management and community engagement in the Republic of Ireland and the United Kingdom. *PloS one, 12*(4), e0174957.

Roose, E. (1977). *Application of the universal soil loss equation of Wischmeier and Smith in West Africa.* Paper presented at the Soil Conservation and Management in the Humid Tropics; Proceedings of the International Conference.

Rouillard, J., Reeves, A. D., Heal, K. V., & Ball, T. (2014). The role of public participation in encouraging changes in rural land use to reduce flood risk. *Land Use Policy, 38*, 637-645.

Rügner, H., Schwientek, M., Beckingham, B., Kuch, B., & Grathwohl, P. (2013). Turbidity as a proxy for total suspended solids (TSS) and particle facilitated pollutant transport in catchments. *Environmental Earth Sciences, 69*(2), 373-380.

Ruzdjak, A. M., & Ruzdjak, D. (2015). Evaluation of river water quality variations using multivariate statistical techniques. *Environmental Monitoring and Assessment, 187*(4), 1.

Santos, C. A., Watanabe, M., & Suzuki, K. (1998). A conceptual soil erosion model. *PROCEEDINGS OF HYDRAULIC ENGINEERING, 42*, 1033-1038.

Schulz, J. J., Cayuela, L., Echeverria, C., Salas, J., & Benayas, J. M. R. (2010). Monitoring land cover change of the dryland forest landscape of Central Chile (1975–2008). *Applied Geography, 30*(3), 436-447.

Secretariat, U. N. W. W. A. P. (2016). Water and jobs.

Selvanayagam, M. (2016). Use of benthic macro invertebrates as a biological indicator in assessing water quality of river Puyo, Puyo, Pastaza, Ecuador.

Selvanayagam, M., & Abril, R. (2015). Water quality assessment of Piatua River using macroinvertebrates in Puyo, Pastaza, Ecuador. *American Journal of Life Sciences, 3*(3), 167-174.

Shalaby, A., & Tateishi, R. (2007). Remote sensing and GIS for mapping and monitoring land cover and land-use changes in the Northwestern coastal zone of Egypt. *Applied Geography, 27*(1), 28-41.

Shapiro, S. S., & Wilk, M. B. (1965). An analysis of variance test for normality (complete samples). *Biometrika, 52*(3/4), 591-611.

Shen, Z., Hou, X., Li, W., & Aini, G. (2014). Relating landscape characteristics to non-point source pollution in a typical urbanized watershed in the municipality of Beijing. *Landscape and Urban Planning, 123*, 96-107.

Shinde, V., Tiwari, K., & Singh, M. (2010). Prioritization of micro watersheds on the basis of soil erosion hazard using remote sensing and geographic information system. *International Journal of Water Resources and Environmental Engineering, 5*(2), 130-136.

Shrestha, S., & Kazama, F. (2007). Assessment of surface water quality using multivariate statistical techniques: A case study of the Fuji river basin, Japan. *Environmental Modelling & Software, 22*(4), 464-475.

Shuhaimi-Othman, M., Lim, E. C., & Mushrifah, I. (2007). Water quality changes in Chini Lake, Pahang, West Malaysia. *Environmental Monitoring and Assessment, 131*(1-3), 279-292.

Silva, J. L., Man, N., Shaffril, H. A., & Samah, B. A. (2011). Acceptance of sustainable agricultural practices: the case of crop farmers. *American Journal of Agricultural and Biological Science*.

Singh, A. (1989). Review article digital change detection techniques using remotely-sensed data. *International Journal of Remote Sensing, 10*(6), 989-1003.

Singh, K. P., Malik, A., & Sinha, S. (2005). Water quality assessment and apportionment of pollution sources of Gomti river (India) using multivariate statistical techniques—a case study. *Analytica Chimica Acta, 538*(1), 355-374.

Singh, S., & Mishra, A. (2014). Spatiotemporal analysis of the effects of forest covers on stream water quality in Western Ghats of peninsular India. *Journal of Hydrology, 519*, 214-224.

Soo, C. L., Chen, C. A., & Mohd-Long, S. (2017). Assessment of Near-Bottom Water Quality of Southwestern Coast of Sarawak, Borneo, Malaysia: A Multivariate Statistical Approach. *Journal of Chemistry*. doi:Artn 1590329 .1155/2017/1590329

Sorooshian, S. (1991). Parameter estimation, model identification, and model validation: conceptual-type models *Recent advances in the modeling of hydrologic systems* (pp. 443-467): Springer.

SS. (2017). Snap Surveys. “Why Use Demographic Questions in Surveys?” Retrived from https://www.snapsurveys.com/blog/5-survey-demographic-question-examples/.

Sterling, E. J., Betley, E., Sigouin, A., Gomez, A., Toomey, A., Cullman, G., . . . Blair, M. (2017). Assessing the evidence for stakeholder engagement in biodiversity conservation. *Biological Conservation, 209*, 159-171.

Suratman, S., Sailan, M. I. M., Hee, Y. Y., Bedurus, E. A., & Latif, M. T. (2015). A Preliminary Study of Water Quality Index in Terengganu River Basin, Malaysia. *Sains Malaysiana, 44*(1), 67-73.

Tan, K., & Mokhtar, M. (2010). Evaluation of social perception on water issues in Cameron Highlands (Malaysia) by Principle Factor Analysis. *Journal of Environmental Science and Engineering, 4*(4), 45.

Tavares, A. O., Pato, R. L., & Magalhães, M. C. (2012). Spatial and temporal land use change and occupation over the last half century in a peri-urban area. *Applied Geography*, *34*, 432-444.

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

Tong, S. T., & Chen, W. (2002). Modeling the relationship between land use and surface water quality. *Journal of Environmental Management*, *66*(4), 377-393.

Toriman, M. E., Karim, O. A., Mokhtar, M., Gazim, M. B., & Abdullah, M. P. (2010). Use of InfoWork RS in modeling the impact of urbanisation on sediment yield in Cameron Highlands Malaysia. *Nat Sci*, *201*(8).

Toy, T., & Osterkamp, W. (1995). The applicability of RUSLE to geomorphic studies. *Journal of Soil and Water Conservation*, *50*(5), 498-503.

Tu, J. (2013). Spatial variations in the relationships between land use and water quality across an urbanization gradient in the watersheds of northern Georgia, USA. *Environmental Management*, *51*(1), 1-17.

Turner, B., & Meyer, W. B. (1991). Land use and land cover in global environmental change: considerations for study. *International Social Science Journal*, *43*(130), 669-679.

UM, & TNRB. (2001). University Malaya and TNB Research, Final Report: The Development of Hydroelectric Catchment Management Information System for Cameron Highlands-Badang Padang Scheme, University Malaya, Malaysia.

UNDP, E. P. (1997). A Guide to Participation, Guide Book on Participation: Oxford.

UNDP, H. (2003). Arab Human Development Report: Building a Knowledge Society. *New York, USA: UNDP*.

USGS. (2015). Water Properties: pH. In The USGS Water Science School . Retrieved from http://ga.water.usgs.gov/edu/ph.html.

Van der Ent, A., & Termeer, C. (2005). Study on river water quality of the Upper Bertam catchment. *Saxion University, Deventer, Institute of Spatial Planning and Environmental Science*.

Varol, M. (2013). Temporal and spatial dynamics of nitrogen and phosphorus in surface water and sediments of a transboundary river located in the semi-arid region of Turkey. *Catena*, *100*, 1-9.

Varol, M., Gökot, B., Bekleyen, A., & Şen, B. (2012). Spatial and temporal variations in surface water quality of the dam reservoirs in the Tigris River basin, Turkey. *Catena*, *92*, 11-21.

Vega, M., Pardo, R., Barrado, E., & Debán, L. (1998). Assessment of seasonal and polluting effects on the quality of river water by exploratory data analysis. *Water Research, 32*(12), 3581-3592.

Vieira, J. S., Pires, J. C., Martins, F. G., Vilar, V. J., Boaventura, R. A., & Botelho, C. M. (2012). Surface water quality assessment of Lis river using multivariate statistical methods. *Water, Air, & Soil Pollution, 223*(9), 5549-5561.

Von Sperling, M. (2017). *Basic principles of wastewater treatment*: IWA publishing.

Wadduwage, S., Millington, A., Crossman, N. D., & Sandhu, H. (2017). Agricultural Land Fragmentation at Urban Fringes: An Application of Urban-To-Rural Gradient Analysis in Adelaide. *Land, 6*(2), 28.

Wang, X., Cai, Q., Ye, L., & Qu, X. (2012). Evaluation of spatial and temporal variation in stream water quality by multivariate statistical techniques: A case study of the Xiangxi River basin, China. *Quaternary international, 282*, 137-144.

Wang, Y.-B., Liu, C.-W., Liao, P.-Y., & Lee, J.-J. (2014). Spatial pattern assessment of river water quality: implications of reducing the number of monitoring stations and chemical parameters. *Environmental Monitoring and Assessment, 186*(3), 1781-1792.

Wang, Y., Wang, P., Bai, Y., Tian, Z., Li, J., Shao, X., . . . Li, B.-L. (2013). Assessment of surface water quality via multivariate statistical techniques: a case study of the Songhua River Harbin region, China. *Journal of hydro-environment research, 7*(1), 30-40.

Ward, R. C., Loftis, J. C., & McBride, G. B. (1990). Design of Water Quality Monitoring Systems. 1-256.

Weng, T. K., & Mokhtar, M. B. (2013). LOCAL PERCEPTION ON JOINT MANAGEMENT TOWARDS INTEGRATED WATER RESOURCES MANAGEMENT IN CHINI LAKE, MALAYSIA. *Journal of Environmental Research and Development, 8*(2), 346.

Wheater, H., Jakeman, A., & Beven, K. (1993). Progress and directions in rainfall-runoff modelling.

WHO. (2011). Guidelines for drinking-water quality, Edition, Fourth. *WHO chronicle, 38*(4), 104-108.

Wilbers, G.-J., Becker, M., Sebesvari, Z., & Renaud, F. G. (2014). Spatial and temporal variability of surface water pollution in the Mekong Delta, Vietnam. *Science of the Total Environment, 485*, 653-665.

Wilkins, P. M., Cao, Y., Heske, E. J., & Levengood, J. M. (2015). Influence of a forest preserve on aquatic macroinvertebrates, habitat quality, and water quality in an urban stream. *Urban Ecosystems, 18*(3), 989-1006. doi:10.1007/s11252-015-0464-6

Williams, J. (1975). Sediment routing for agricultural watersheds. *JAWRA Journal of the American Water Resources Association*, *11*(5), 965-974.

Williams, J., & Berndt, H. (1977). Sediment yield prediction based on watershed hydrology. *Transactions of the ASAE, 20*(6), 1100-1104.

Williamson, D., Majule, A., Delalande, M., Mwakisunga, B., Mathé, P.-E., Gwambene, B., & Bergonzini, L. (2014). A potential feedback between landuse and climate in the Rungwe tropical highland stresses a critical environmental research challenge. *Current opinion in environmental sustainability, 6*, 116-122.

Wilson, C. O. (2015). Land use/land cover water quality nexus: quantifying anthropogenic influences on surface water quality. *Environmental Monitoring and Assessment, 187*(7), 424.

Wilson, C. O., & Weng, Q. (2011). Simulating the impacts of future land use and climate changes on surface water quality in the Des Plaines River watershed, Chicago Metropolitan Statistical Area, Illinois. *Science of the Total Environment, 409*(20), 4387-4405.

Wilson, P. C. (2010). Water quality notes: water clarity (turbidity, suspended solids, and color). *University of Florida*.

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

Wu, M.-L., Wang, Y.-S., Sun, C.-C., Wang, H., Dong, J.-D., & Han, S.-H. (2009). Identification of anthropogenic effects and seasonality on water quality in Daya Bay, South China Sea. *Journal of Environmental Management, 90*(10), 3082-3090.

Wu, Y., & Chen, J. (2013). Investigating the effects of point source and nonpoint source pollution on the water quality of the East River (Dongjiang) in South China. *Ecological Indicators, 32*, 294-304.

WWAP, U. (2012). World Water Assessment Programme: The United Nations World Water Development Report 4: Managing Water under Uncertainty and Risk: Paris: UNESCO.

Wyman, M. S., & Stein, T. V. (2010). Modeling social and land-use/land-cover change data to assess drivers of smallholder deforestation in Belize. *Applied Geography, 30*(3), 329-342.

Xu, X. (2013). Environmental Quality Assessment of Tibet Based on 3S. *Progress in Environmental Protection and Processing of Resource, Pts 1-4, 295-298*, 692-695. doi:10.4028/www.scientific.net/AMM.295-298.692

Xu, Y., Xie, R., Wang, Y., & Sha, J. (2015). Spatio-temporal variations of water quality in Yuqiao Reservoir Basin, North China. *Frontiers of Environmental Science & Engineering, 9*(4), 649-664.

Xue, C.-h., Yin, H.-l., & Ming, X. (2015). Development of integrated catchment and water quality model for urban rivers. *Journal of Hydrodynamics, Ser. B, 27*(4), 593-603.

Yao, H. (2013). Characterizing landuse changes in 1990–2010 in the coastal zone of Nantong, Jiangsu Province, China. *Ocean & coastal management, 71*, 108-115

Ye, L., Cai, Q.-h., Liu, R.-q., & Cao, M. (2009). The influence of topography and land use on water quality of Xiangxi River in Three Gorges Reservoir region. *Environmental Geology, 58*(5), 937-942.

Yu, S., Xu, Z., Wu, W., & Zuo, D. (2016). Effect of land use types on stream water quality under seasonal variation and topographic characteristics in the Wei River basin, China. *Ecological Indicators, 60*, 202-212.

Yvon-Durocher, G., Jones, J. I., Trimmer, M., Woodward, G., & Montoya, J. M. (2010). Warming alters the metabolic balance of ecosystems. *Philosophical Transactions of the Royal Society of London B: Biological Sciences, 365*(1549), 2117-2126.

Zaiha, A. N., Ismid, M. M., & Azri, M. S. (2015). Effects of logging activities on ecological water quality indicators in the Berasau River, Johor, Malaysia. *Environmental Monitoring and Assessment, 187*(8), 493.

Zaini, H., Che, Y. A., Ahmad, S., & Ab Khalik, W. (2014). Quantifying Soil Erosion and Deposition Rates in Tea Plantation Area, Cameron Highlands, Malaysia Using 137 Cs. *Malaysian Journal of Analytical Sciences, 18*(1), 94-106.

Zainudin, Z. (2010). Benchmarking river water quality in Malaysia. *Jurutera*, 12-15.

Zamani, M., Sadoddin, A., & Garizi, A. Z. (2012). Assessing land-cover/land-use change and its impacts on surface water quality in the Ziarat Catchment, Golestan Province-Iran.

Zampella, R. A., Procopio, N. A., Lathrop, R. G., & Dow, C. L. (2007). Relationship of Land-Use/Land-Cover Patterns and Surface-Water Quality in The Mullica River Basin. *JAWRA Journal of the American Water Resources Association, 43*(3), 594-604.

Zerga, B. (2015). Ecosystem Degradation Nexus in Ethiopia *Journal of Advances in Agricultural Science and Technology, Vol 3 (5)*, pp, 66-76

Zhang, Q.-L., Chen, Y.-X., Jilani, G., Shamsi, I. H., & Yu, Q.-G. (2010a). Model AVSWAT apropos of simulating non-point source pollution in Taihu lake basin. *Journal of hazardous materials, 174*(1), 824-830.

Zhang, X., Wang, Q., Liu, Y., Wu, J., & Yu, M. (2011). Application of multivariate statistical techniques in the assessment of water quality in the Southwest New Territories and Kowloon, Hong Kong. *Environmental Monitoring and Assessment, 173*(1), 17-27.

Zhang, X., Wenhong, C., Qingchao, G., & Sihong, W. (2010b). Effects of landuse change on surface runoff and sediment yield at different watershed scales on the Loess Plateau. *International Journal of Sediment Research, 25*(3), 283-293.

Zhang, X., Wu, Y., & Gu, B. (2015). Urban rivers as hotspots of regional nitrogen pollution. *Environmental Pollution, 205*, 139-144.

Zhang, Y., Wang, Y., Wang, Y., & Xi, H. (2009). Investigating the impacts of landuse-landcover (LULC) change in the pearl river delta region on water quality in the pearl river estuary and Hong Kong's coast. *Remote Sensing, 1*(4), 1055-1064.

Zhao, J., Fu, G., Lei, K., & Li, Y. (2011). Multivariate analysis of surface water quality in the Three Gorges area of China and implications for water management. *Journal of Environmental Sciences, 23*(9), 1460-1471.

Zhao, R., Chen, Y., Shi, P., Zhang, L., Pan, J., & Zhao, H. (2013a). Land use and land cover change and driving mechanism in the arid inland river basin: a case study of Tarim River, Xinjiang, China. *Environmental Earth Sciences, 68*(2), 591-604.

Zhao, R. F., Chen, Y. N., Shi, P. J., Zhang, L. H., Pan, J. H., & Zhao, H. L. (2013b). Land use and land cover change and driving mechanism in the arid inland river basin: a case study of Tarim River, Xinjiang, China. *Environmental Earth Sciences, 68*(2), 591-604. doi:10.1007/s12665-012-1763-3

Zhou, T., Wu, J., & Peng, S. (2012). Assessing the effects of landscape pattern on river water quality at multiple scales: a case study of the Dongjiang River watershed, China. *Ecological Indicators, 23*, 166-175.

Zhou, Z., & Li, J. (2015). The correlation analysis on the landscape pattern index and hydrological processes in the Yanhe watershed, China. *Journal of Hydrology, 524*, 417-426.

APPENDIX A

HECTAREAGE, PRODUCTION AND VALUE OF PRODUCTION OF MAIN VEGETABLES, OTHER VEGETABLES AND CASH CROPS IN CAMERON HIGHLANDS DISTRICT, 2012

Product	Planted Area (Ha)	Harvested Area (Ha)	Production (Mt)	Production Value (RM '000)
Main Vegetables				
Spinach	146.84	146.84	2202.55	5616.50
Spring Onoin	375.23	375.23	6003.36	29416.46
Celery	558.82	558.82	11261.20	58220.40
Chinese Kale	111.12	111.12	1111.37	4334.34
Cabbage	3160.44	3160.04	88495.77	199115.48
Chinese cabbage	831.58	830.78	24918.73	61300.08
Lettuce	1722.30	1722.30	31666.60	158966.33
Leaf Mustard	2867.94	2867.94	36157.35	108472.05
Cilli	233.84	233.84	7707.08	51868.65
French Bean	242.66	242.06	2906.19	14966.88
Bottle Gourd	6.29	6.29	44.00	66.00
Pumpkin	33.61	33.61	235.20	352.80
Cucumber	273.00	273.00	16370.92	24556.38
Tomota	1692.37	1692.37	106384.89	310643.88
Brinjal	211.71	208.11	13759.01	44991.96
Carrot	31.88	31.88	604.65	1433.02
Reddish	149.12	149.12	2981.84	7305.51
Other vegetables				
Asparagus	0.53	0.53	7.86	111.22
Brocolli	306.50	292.44	3892.50	27052.88
Snow pea	81.99	81.99	655.74	4131.16
Chinese Box thorn	26.11	26.11	1,174.26	3,452.32
Lekol	195.74	195.74	4697.28	7045.92
Water Cress	90.29	90.29	1,896.09	6,636.32
Cauliflower	483.77	483.57	5,941.76	27,629.18
Sweet Pepper	381.17	381.17	27,820.80	185,008.32
Baby Corn	236.22	236.22	1,890.00	11,340.00
Chinese Parsley	210.96	210.96	2,531.13	16,199.23
Butter Bean	27.27	27.27	297.85	521.24
Spinach (Poh Choy)	273.89	273.89	4,108.86	18,078.98
Cash Crop				
Maize	460.9	460.9	13,135.71	55,169.98
Sweet Potato	53.73	53.73	1,075.32	2,107.63
Total	15,477.82	15,458.16	421,935.87	1,446,111.10

Source: Vegetable and cash crops statistic, Malaysia (Department of Agriculture, 2012)

HECTAREAGE, PRODUCTION AND VALUE OF PRODUCTION OF MAIN VEGETABLES, OTHER VEGETABLES AND CASH CROPS IN CAMERON HIGHLANDS DISTRICT, 2013

Product	Planted Area (Ha)	Harvested Area (Ha)	Production (Mt)	Production Value (RM '000)
Main Vegetables				
Spinach	146.84	146.84	2202.55	5616.50
Spring Onoin	375.23	375.23	6003.36	29416.46
Celery	558.82	558.82	11261.20	58220.40
Chinese Kale	111.12	111.12	1111.37	4334.34
Cabbage	3160.44	3160.04	88495.77	199115.48
Chinese cabbage	831.58	830.78	24918.73	61300.08
Lettuce	1722.30	1722.30	31666.60	158966.33
Leaf Mustard	2867.94	2867.94	36157.35	108472.05
Cilli	233.84	233.84	7707.08	51868.65
French Bean	242.66	242.06	2906.19	14966.88
Bottle Gourd	6.29	6.29	44.00	66.00
Pumpkin	33.61	33.61	235.20	352.80
Cucumber	273.00	273.00	16370.92	24556.38
Tomota	1692.37	1692.37	106384.89	310643.88
Brinjal	211.71	208.11	13759.01	44991.96
Carrot	31.88	31.88	604.65	1433.02
Reddish	149.12	149.12	2981.84	7305.51
Other vegetables				
Asparagus	0.53	0.53	7.86	111.22
Brocolli	306.50	292.44	3892.50	27052.88
Snow pea	81.99	81.99	655.74	4131.16
Chinese Box thorn	26.11	26.11	1,174.26	3,452.32
Lekol	195.74	195.74	4697.28	7045.92
Water Cress	90.29	90.29	1,896.09	6,636.32
Cauliflower	483.77	483.57	5,941.76	27,629.18
Sweet Pepper	381.17	381.17	27,820.80	185,008.32
Baby Corn	236.22	236.22	1,890.00	11,340.00
Chinese Parsley	210.96	210.96	2,531.13	16,199.23
Butter Bean	27.27	27.27	297.85	521.24
Spinach (Poh Choy)	273.89	273.89	4,108.86	18,078.98
Cash Crop				
Maize	460.9	460.9	13,135.71	55,169.98
Sweet Potato	53.73	53.73	1,075.32	2,107.63
Total	15,477.82	15,458.16	421,935.87	1,446,111.10

Source: Vegetable and cash crops statistic, Malaysia (Department of Agriculture, 2012)

APPENDIX B

RECORDS OF MONTHLY RAINFALL AMOUNT, CAMERON HIGHLANDS

Year	Month (millimetre)												Annual
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
1983				44.1	222.5	205.6	273.8	237.2	365.6	200.3	210.4	115.5	-
1984	193.7	209.8	264.1	354.3	356.8	159.6	272.9	110.2	196.4	385.2	294.5	244.9	3042.4
1985	67.4	182.2	257.2	88.9	300.0	56.6	133.1	154.8	195.6	468.9	531.6	195.7	2632.0
1986	101.7	49.1	137.7	317.0	284.3	141.5	84.4	56.1	244.5	456.2	281.9	181.3	2335.7
1987	60.7	48.1	110.1	247.6	242.4	93.2	106.1	382.8	377.9	463.9	187.1	203.0	2522.9
1988	33.5	188.3	137.9	166.8	311.7	233.5	178.1	479.3	407.5	121.9	402.1	234.3	2894.9
1989	83.7	62.7	251.3	294.4	210.5	150.6	226.5	135.6	361.5	360.9	337.0	154.2	2628.9
1990	112.6	35.4	112.9	141.4	360.1	130.2	211.2	124.4	343.4	357.9	263.9	88.6	2282.0
1991	53.5	110.3	202.7	292.4	554.2	181.1	105.7	129.7	243.0	392.3	277.2	145.5	2687.6
1992	46.2	205.4	140.1	166.7	260.2	136.6	154.6	138.7	192.7	403.4	299.9	193.6	2338.1
1993	119.1	188.0	203.0	366.9	319.7	151.9	214.9	231.1	410.8	443.3	252.5	293.5	3194.7
1994	38.6	240.0	281.1	231.3	316.4	230.5	55.2	256.5	354.0	328.2	182.5	192.5	2706.8
1995	129.0	70.3	221.5	327.2	108.6	261.4	160.5	429.5	288.6	461.1	330.4	245.3	3033.4
1996	141.2	47.3	223.6	416.3	270.8	166.7	155.9	289.9	140.6	522.6	461.9	267.8	3104.6
1997	32.7	254.1	196.6	237.9	146.3	289.4	205.9	202.9	149.6	369.3	386.9	237.5	2709.1
1998	63.1	22.1	96.6	81.7	201.9	204.7	278.1	292.5	182.8	400.5	384.3	190.2	2398.5
1999	161.8	365.1	496.1	365.1	263.2	146.3	196.1	332.0	357.5	390.3	329.4	304.2	3707.1
2000	214.4	190.2	437.6	517.4	224.5	220.8	127.9	176.6	221.8	204.2	313.5	323.1	3172.0
2001	141.5	137.2	245.4	310.7	197.2	89.7	50.2	99.2	274.8	429.2	413.7	242.9	2631.7
2002	26.0	8.9	84.9	421.5	301.6	254.5	167.0	282.4	366.2	412.3	334.0	157.3	2816.6
2003	102.0	118.0	266.6	185.7	235.4	300.7	289.0	362.0	157.0	470.4	313.5	175.5	2975.8
2004	44.2	102.4	248.9	256.4	262.2	75.6	213.8	161.9	444.9	322.9	175.3	103.1	2411.6
2005	24.5	99.3	190.4	217.9	199.8	227.2	235.0	137.1	157.4	450.4	401.2	551.6	2891.8
2006	208.8	149.2	181.4	223.8	365.3	209.2	150.4	177.2	291.4	328.0	322.0	170.4	2777.1
2007	110.6	117.2	252.0	361.8	223.2	280.6	260.6	218.4	220.0	418.4	311.9	197.6	2972.3
2008	235.6	120.4	408.0	448.2	248.2	284.8	389.8	340.4	330.4	330.2	560.2	255.4	3951.6
2009	229.4	230.8	345.6	178.6	300.0	193.0	187.6	282.3	265.9	384.2	327.0	126.8	3051.2
2010	146.8	153.2	139.2	175.8	179.6	225.8	176.8	295.2	285.4	100.8	352.2	220.2	2451.0
2011	173.6	65.4	377.2	410.0	430.2	135.4	109.8	443.4	240.6	359.4	388.9	176.2	3310.1
2012	213.6	168.6	321.2	324.0	241.8	30.2	277.6	272.8	165.6	224.2	411.2	210.6	2861.4
2013	242.0	80.6	105.8	463.2	191.2	121.8	170.8	150.0	226.8	419.0	343.8	255.8	2770.8
2014	91.8	33.6	136.6	391.0	311.4	106.8	49.8	244.6	433.4	335.4	420.6	339.6	2894.6
2015	166.0	59.8	128.6	187.6	341.4	121.8	239.0	270.2	224.4				

Source: JABATAN METEOROLOGI MALAYSIA

RECORDS OF NUMBER OF RAIN DAYS, CAMERON HIGHLANDS

Year	Month (days)												Annual
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
1983				9	22	19	21	22	28	21	20	25	187
1984	22	21	23	23	27	16	21	19	22	26	25	27	272
1985	10	20	24	23	20	6	15	18	25	25	30	17	233
1986	21	10	21	19	17	17	11	11	25	30	25	18	225
1987	12	7	17	16	23	11	16	26	25	28	24	21	226
1988	12	18	21	20	20	20	17	28	28	18	23	21	246
1989	18	7	21	23	19	17	17	19	24	27	21	14	227
1990	11	9	9	22	24	13	22	11	25	27	22	16	211
1991	18	9	21	25	25	13	13	16	23	23	24	23	233
1992	13	13	11	18	24	20	21	21	20	26	22	24	233
1993	18	17	16	22	23	16	20	17	28	30	24	27	258
1994	9	20	29	19	28	16	7	22	24	26	26	14	240
1995	22	11	19	20	22	23	24	26	21	24	24	22	258
1996	12	10	17	24	23	21	13	21	21	28	23	25	238
1997	8	19	16	18	15	19	16	16	18	25	23	22	215
1998	17	4	9	10	19	16	23	25	24	25	25	24	221
1999	25	16	24	18	23	14	16	21	25	29	24	23	258
2000	17	19	24	26	21	19	14	17	21	21	22	20	241
2001	26	12	20	28	18	10	11	16	20	26	29	18	234
2002	10	2	11	22	19	14	15	16	23	27	21	23	203
2003	16	15	19	21	13	22	17	22	22	28	27	17	239
2004	11	10	23	20	18	10	17	15	27	27	26	12	216
2005	9	7	12	18	24	14	17	16	17	30	24	27	215
2006	16	17	19	23	23	19	17	17	26	26	28	18	249
2007	18	13	16	22	24	20	21	18	19	28	21	18	238
2008	17	10	26	24	22	20	21	22	20	27	29	22	260
2009	13	19	25	21	21	14	17	25	22	23	26	16	242
2010	19	11	14	17	21	24	21	21	24	13	24	25	234
2011	19	12	27	24	22	14	12	24	21	26	26	22	249
2012	20	16	23	26	19	7	18	18	17	25	25	25	239
2013	20	16	18	25	22	13	15	21	18	28	25	22	243
2014	14	6	10	29	24	11	10	25	23	26	26	25	229
2015	16	6	12	18	26	11	18	19	21				

Source: JABATAN METEOROLOGI MALAYSIA

RECORDS OF 24 HOUR TEMPERATURE, CAMERON HIGHLANDS

Year	Month (°C)												Annual
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
1983				19.6	19.3	18.8	18.1	18.0	17.7	18.1	18.0	16.9	-
1984	16.8	17.1	18.0	18.4	18.3	18.0	17.7	17.7	17.5	17.4	17.9	17.3	17.7
1985	17.0	18.2	17.8	18.5	18.5	18.2	17.6	17.7	17.3	17.6	17.5	17.4	17.8
1986	16.8	17.4	17.8	18.7	18.8	18.6	18.2	18.0	17.7	17.9	17.6	17.4	17.9
1987	17.0	17.9	18.7	19.2	18.9	19.2	18.5	18.1	18.1	18.5	18.1	17.9	18.3
1988	17.9	18.4	18.9	19.2	19.2	18.3	18.3	17.9	17.7	17.5	17.7	16.5	18.1
1989	17.4	17.2	17.5	18.1	18.4	18.0	18.0	17.8	17.5	17.5	17.8	17.0	17.7
1990	17.3	18.1	18.7	19.3	18.8	18.6	17.8	18.1	17.6	17.8	17.4	17.0	18.0
1991	17.2	17.7	18.6	18.4	18.6	18.8	17.8	17.9	17.6	17.5	17.1	16.8	17.8
1992	16.8	17.7	18.6	18.9	18.7	18.4	17.6	17.5	17.7	17.1	17.0	16.8	17.7
1993	17.0	17.0	17.7	18.4	18.6	18.4	17.8	17.6	17.3	17.2	17.6	17.3	17.7
1994	17.1	17.7	17.6	18.4	18.2	18.2	17.9	17.5	17.3	17.6	17.4	17.3	17.7
1995	17.1	17.3	18.2	18.5	18.8	18.6	18.0	17.7	17.8	17.8	17.7	16.9	17.9
1996	16.7	16.8	18.3	18.5	18.5	18.6	18.2	17.8	17.7	17.2	17.5	17.1	17.7
1997	16.9	17.5	18.0	18.4	18.8	18.2	17.9	18.1	18.3	18.0	18.1	17.7	18.0
1998	18.3	19.0	19.3	20.0	19.9	18.8	18.5	17.9	17.9	17.6	17.6	17.4	18.5
1999	17.4	17.3	18.0	18.1	18.2	18.1	17.5	17.4	17.4	17.5	17.5	17.1	17.6
2000	17.1	17.4	17.9	18.3	18.5	17.9	18.0	17.6	17.9	17.6	18.0	17.9	17.8
2001	17.5	17.8	18.2	18.9	18.9	18.3	18.3	18.2	18.0	17.8	17.7	17.4	18.1
2002	17.1	17.8	18.5	18.9	19.0	18.6	18.4	18.0	17.7	17.9	18.1	18.1	18.2
2003	17.5	17.6	18.1	18.7	18.8	18.0	17.7	17.6	17.7	17.1	17.9	17.1	17.8
2004	17.5	18.0	18.4	18.6	18.9	18.3	17.6	18.0	17.7	17.6	17.8	17.3	18.0
2005	17.4	18.4	18.6	18.7	18.7	18.6	18.2	18.3	18.2	17.9	17.8	17.4	18.2
2006	17.5	17.7	18.3	18.4	18.4	17.9	18.0	17.8	17.4	18.0	18.2	17.8	17.9
2007	17.5	17.6	18.3	18.6	18.8	18.5	18.1	17.7	17.8	17.6	17.5	17.3	17.9
2008	17.7	17.2	17.9	18.2	18.1	17.9	17.7	17.6	17.5	18.0	18.0	17.3	17.8
2009	16.9	17.6	18.0	18.6	18.4	18.6	17.6	17.5	17.6	17.4	17.6	17.4	17.8
2010	17.5	18.3	18.5	19.2	19.4	18.2	17.9	18.1	17.8	18.0	17.8	16.9	18.1
2011	16.8	17.5	17.6	18.0	18.3	18.3	18.0	17.5	17.5	17.7	17.6	17.5	17.7
2012	17.4	18.1	17.8	18.3	18.7	18.5	18.0	18.2	17.8	18.0	18.5	18.1	18.1
2013	18.0	18.1	18.9	19.0	19.3	18.7	18.0	18.2	18.0	17.9	18.1	17.7	18.3
2014	16.9	17.9	18.6	18.6	19.0	19.4	18.9	18.2	18.0	18.2	18.2	17.9	18.3
2015	17.4	17.7	18.5	19.1	19.0	18.9	18.4	18.4	18.3				

Source: JABATAN METEOROLOGI MALAYSIA

RECORDS OF 24 HOUR MEAN RELATIVE HUMIDITY, CAMERON HIGHLANDS

Latitude: 4° 28' N Longitude: 101° 22' E Elevation: 1545.0 m m

Year	Month (%)												Annual
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
1983				88.0	90.3	88.3	92.0	92.1	92.8	90.9	89.3	92.6	-
1984	92.3	90.9	91.1	91.1	92.5	90.5	90.4	90.0	90.8	91.7	91.7	92.4	91.3
1985	87.3	88.9	88.9	89.9	92.6	79.9	87.2	89.6	92.0	93.1	94.5	90.5	89.5
1986	92.2	85.1	90.6	91.6	89.9	89.2	87.9	88.5	92.0	92.8	91.7	89.5	90.1
1987	86.2	87.3	88.4	88.9	91.9	88.4	89.5	92.5	92.3	93.3	92.8	91.6	90.2
1988	86.2	86.4	86.4	89.3	90.9	90.7	89.3	92.9	92.3	88.6	90.8	91.1	89.6
1989	87.3	84.7	89.8	93.6	91.7	88.5	87.9	89.7	92.1	93.2	90.7	87.6	89.7
1990	81.4	85.7	81.5	87.6	90.8	86.9	89.6	87.4	93.0	93.4	92.6	88.1	88.2
1991	86.7	84.2	88.6	92.5	93.3	89.6	90.6	91.3	92.5	91.9	92.3	92.5	90.5
1992	88.4	90.1	84.7	90.7	93.1	90.9	91.7	91.9	90.2	91.0	92.7	90.8	90.5
1993	89.3	89.4	86.6	92.4	93.5	91.1	91.6	91.2	93.4	94.6	93.0	95.8	91.8
1994	88.3	89.5	91.3	92.0	94.2	91.5	89.9	92.6	92.8	93.8	92.0	89.1	91.4
1995	90.7	87.9	87.5	89.9	91.3	91.4	89.2	94.8	91.7	93.4	93.8	92.0	91.1
1996	88.5	89.3	87.8	92.5	93.3	90.1	90.7	92.4	91.0	94.2	92.8	93.3	91.3
1997	89.0	90.1	88.3	90.3	88.1	92.2	90.3	92.2	Def.	91.6	91.3	91.0	-
1998	87.7	83.9	85.1	87.5	89.1	90.5	89.8	92.5	92.7	94.0	94.2	91.4	89.9
1999	92.4	88.1	92.9	91.1	92.5	90.0	91.8	92.9	93.1	93.8	92.7	93.6	92.1
2000	87.7	89.7	91.7	92.8	90.5	90.2	87.7	90.6	91.8	93.1	93.0	92.1	90.9
2001	92.5	89.4	91.3	93.5	92.1	91.1	89.9	91.0	91.5	94.0	95.2	92.9	92.0
2002	90.1	80.4	85.9	89.9	89.7	89.3	90.6	90.2	92.5	94.0	92.6	91.9	89.8
2003	90.9	90.3	90.7	91.6	89.1	92.4	91.9	93.4	93.2	96.3	93.5	92.6	92.2
2004	89.8	90.0	92.0	91.4	89.1	90.2	92.6	89.9	92.4	92.8	91.2	89.8	90.9
2005	89.3	86.6	87.7	88.1	90.1	87.8	86.6	86.8	87.2	91.9	91.4	91.5	88.7
2006	88.1	85.8	85.5	89.1	89.5	88.8	87.9	88.0	90.6	87.2	88.0	84.4	87.7
2007	86.9	87.8	88.3	88.0	88.6	88.0	87.6	88.0	89.0	91.2	90.7	88.3	88.5
2008	88.1	81.7	86.8	89.4	88.0	89.2	88.2	89.1	87.3	89.7	90.3	88.7	88.0
2009	86.6	86.4	87.2	86.5	88.7	86.3	90.4	92.8	91.4	92.0	92.3	88.9	89.1
2010	88.2	86.0	87.6	90.1	92.3	89.9	88.9	89.6	90.4	86.3	91.6	91.6	89.4
2011	91.3	87.3	91.2	91.2	91.7	89.1	88.6	91.5	92.0	90.7	91.3	90.4	90.5
2012	88.8	86.7	89.4	90.6	92.8	90.3	91.2	92.3	92.5	92.0	92.0	91.5	90.8
2013	90.9	90.5	90.7	93.0	89.0	87.7	86.6	89.0	87.5	90.3	90.4	90.0	89.6
2014	87.7	81.5	81.9	91.0	92.5	89.1	89.5	92.0	93.0	93.5	92.6	93.3	89.8
2015	89.7	88.1	86.2	89.4	93.5	90.8	91.6	91.9	92.0				

Source: JABATAN METEOROLOGI MALAYSIA. Def. - Defective Value

APPENDIX C

THE SUB-INDEX ESTIMATION EQUATIONS FOR THE LOCAL WQI

Parameter	Value[a]	Sub-index equation
DO	$x \leq 8\%$	$SI_{BOD} = 0$
(in % Sauration)	$8\% < x < 92\%$	$SI_{DO} = -0.395 + 0.03x^2 - 0.0002x^3$
	$x \geq 92\%$	$SI_{DO} = 100$
BOD	$x \leq 5$	$SI_{BOD} = 100.4 - 4.23x$
	$x > 5$	$SI_{BOD} = 108e^{-0.055x} - 0.1$
COD	$x \leq 20$	$SI_{COD} = -1.33x + 99.1$
	$x > 20$	$SI_{COD} = 103e^{-0.0157x} - 0.04x$
NH_3-N	$x \leq 0.3$	$SI_{AN} = 100.5 - 105x$
	$0.3 < x < 4$	$SI_{AN} = (94e^{-0.573x}) - \lvert x-2 \rvert$
	$x \geq 4$	$SI_{AN} = 0$
SS	$x \leq 100$	$SI_{SS} = 97.5e^{-0.00676x} = 0.05x$
	$100 < x < 1000$	$SI_{SS} = 71e^{-0.0016x}) - 0.015x$
	$x \geq 1000$	$SI_{SS} = 0$
pH	$x < 5.5$	$SI_{pH} = 17.2 - 17.2x + 5.02x^2$
	$5.5 \leq x < 7$	$SI_{pH} = -242 + 95.5x - 6.67x^2$
	$7 \leq x < 8.75$	$SI_{pH} = -181 + 82.4x - 6.05x^2$
	$x \geq 8.75$	$SI_{pH} = 536 - 77.0x - 2.76x^2$

[a] x is the concentration of the indicated parameter in mg/L, except for pH and DO. For DO, x refers to percentage saturation and for pH, x refers to pH value.

DOE WATER QUALITY INDEX CLASSIFICATION

Parameters	Unit	Water Quality Classes				
		I	II	III	IV	V
Ammoniacal Nitrogen	mg/L	<0.1	0.1-0.3	0.3-0.9	0.9-2.7	>2.7
Biochemical Oxygen Demand	mg/L	<1	1-3	3-6	6-12	>12
Chemical Oxygen Demand	mg/L	<10	10-25	25-50	50-100	>100
Dissolved Oxygen	mg/L	>7	5-7	5-7	1-3	<1
pH		>7	6-7	5-6	<5	>5
Total Suspended Solids (TSS)	mg/L	<25	25-50	50-150	150-300	>300
Water Quality Index (WQI)		>92.7	76.5-92.7	51.9-76.5	31.0-51.9	<31

DOE WATER QUALITY CLASSIFICATION BASED ON WATER QUALITY INDEX

Parameters	**Index Range**		
	Clean	Slightly Polluted	Polluted
SIBOD	91 – 100	80 – 90	0 – 79
SIAN	92 – 100	71 – 91	0 – 70
SISS	76 – 100	70 – 75	0 – 69
WQI	81 – 100	60 – 80	0 – 59

WQ CLASS AND STATUS CALCULATION

WQC	Water Status	Water Use
I	Very Good	Conservation of natural environment. Water Supply I - Practically no treatment necessary Fishery I - Very sensitive aquatic species.
II	Good	IIA. Water Supply II - Conventional treatment required Fishery II - Sensitive aquatic species IIB. Recreational use with body contact
III	Average	Water Supply III - Extensive treatment required. Fishery III - Common, of economic value and tolerant species; livestock drinking
IV	Polluted	Irrigation
V	Very Polluted	None of the above

Source: Department of Environment, Malaysia, (DOE, 2010); Zainudin (2010)

APPENDIX D

MEASUREMENT OF TEMPERATURE OF WATER SAMPLES AT DIFFERENT STATIONS ALONG THE MAIN BERTAM RIVER AND ITS TRIBUTARIES

Parameter: Temperature (^{0}C)

Station	2014															2015		
	January			March			June			September			October			February		
	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd
Main River																		
UB-1	16.35	16.35	16.35	16.21	16.21	16.23	17.23	17.33	17.32	16.68	16.67	16.70	17.15	17.16	17.16	16.01	16.00	16.01
UB-2	17.91	17.92	17.92	18.47	18.47	18.47	18.51	18.52	18.53	19.05	19.06	19.08	20.30	20.28	20.28	17.38	17.39	17.40
UB-3	18.45	18.45	18.46	18.55	18.56	18.56	18.92	18.92	18.93	18.80	18.85	18.91	20.17	20.13	20.13	17.90	17.89	17.90
UB-4	19.85	19.74	19.93	18.69	18.67	18.66	19.74	19.63	19.62	19.93	19.95	19.95	20.33	20.28	20.27	19.29	19.23	19.19
UB-5	20.27	20.25	20.16	20.02	20.04	20.11	20.19	20.25	20.23	20.94	20.88	20.90	20.84	20.85	20.83	19.05	19.06	19.10
LB-1	26.61	26.48	26.92	24.50	24.42	24.30	25.66	25.62	25.46	26.32	26.37	26.25	22.47	22.50	22.52	26.25	26.21	26.31
LB-2	24.60	24.61	24.62	22.67	22.66	22.70	24.81	24.75	24.73	23.57	23.61	23.64	24.18	24.14	24.14	23.48	23.45	23.42
Tributaries																		
TB-1	17.23	17.23	17.24	17.95	17.96	18.01	18.09	18.11	18.12	17.50	17.49	17.50	20.27	20.25	20.29	17.01	17.00	17.00
TB-2	18.25	18.26	18.26	18.26	18.26	18.29	18.42	18.41	18.45	18.76	18.81	18.94	18.89	18.87	18.87	17.80	17.79	17.79
TB-3	20.36	20.40	20.31	19.16	19.16	19.19	20.27	20.29	20.30	20.61	20.59	20.56	19.66	19.62	19.58	20.33	20.35	20.40
TB-4	21.72	21.74	21.75	20.09	20.10	20.13	20.73	20.72	20.74	21.70	21.70	21.68	21.61	21.62	21.64	21.21	21.21	21.22
TB-5	21.59	21.53	21.64	20.05	20.04	20.03	20.72	20.73	20.72	21.52	21.58	21.55	21.31	21.30	21.30	19.89	19.91	19.93

MEASUREMENT OF PH OF WATER SAMPLES AT DIFFERENT STATIONS ALONG THE MAIN BERTAM RIVER AND ITS TRIBUTARIES

Parameter: pH

Station	2014															2015		
	January			March			June			September			October			February		
	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd
Main River																		
UB-1	6.80	6.67	6.31	6.59	6.31	6.31	6.24	6.89	6.49	7.72	7.91	7.48	6.01	5.46	5.47	6.05	6.07	6.09
UB-2	6.79	6.72	6.69	7.23	7.22	7.21	8.06	7.73	7.54	7.89	7.71	7.60	5.60	5.42	5.45	6.25	6.35	6.47
UB-3	6.23	6.15	6.25	7.15	7.10	7.06	7.17	7.07	7.06	6.93	6.65	6.62	5.97	5.72	5.71	6.16	6.46	6.52
UB-4	6.31	6.27	6.17	7.25	7.16	7.10	7.94	7.30	7.11	7.62	7.52	7.59	6.20	5.86	5.83	6.05	6.07	6.08
UB-5	5.91	5.77	5.73	7.24	6.94	6.73	7.50	7.11	7.01	6.55	6.44	6.29	6.46	6.22	6.16	5.66	5.60	5.73
LB-1	7.22	7.22	7.22	7.45	7.28	7.17	7.30	7.15	7.06	8.17	7.60	7.45	6.84	6.69	6.67	6.39	6.55	6.58
LB-2	6.42	6.46	6.45	6.92	6.88	6.86	6.35	6.38	6.35	7.01	6.89	6.87	6.73	6.70	6.72	5.96	6.17	6.25
Tributaries																		
TB-1	6.33	6.27	6.29	7.48	7.19	7.50	8.12	7.72	7.63	7.86	7.67	7.61	6.20	5.61	5.41	6.20	6.28	6.42
TB-2	6.76	6.67	6.53	7.25	7.14	7.04	8.03	7.41	7.17	8.96	8.90	8.61	6.63	5.90	5.76	5.72	5.65	5.66
TB-3	6.45	6.46	6.30	7.02	6.93	6.93	7.70	6.90	6.69	6.75	6.54	6.45	6.34	5.98	5.90	6.17	6.27	6.32
TB-4	6.61	6.27	6.25	7.30	6.95	6.87	7.60	7.17	6.94	7.82	7.55	7.26	6.30	6.29	6.32	5.91	5.99	6.09
TB-5	5.67	5.69	5.63	7.48	7.19	7.05	6.88	6.55	6.51	6.75	6.69	6.62	6.67	6.65	6.68	6.03	6.07	6.11

MEASUREMENT OF CONDUCTIVITY OF WATER SAMPLES AT DIFFERENT STATIONS ALONG THE MAIN BERTAM RIVER AND ITS TRIBUTARIES

Parameter: Electrical Conductance (µS/cm)

Station	2014															2015		
	January			March			June			September			October			February		
	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd
Main River																		
UB-1	13.00	13.00	13.00	8.00	13.00	8.00	9.00	13.00	15.00	17.00	17.00	17.00	17.00	9.00	9.00	14.00	6.00	14.00
UB-2	66.00	65.00	36.00	85.00	85.00	87.00	73.00	75.00	73.00	90.00	90.00	91.00	69.00	68.00	69.00	65.00	65.00	65.00
UB-3	46.00	45.00	39.00	69.00	70.00	59.00	63.00	62.00	32.00	70.00	70.00	70.00	55.00	66.00	62.00	59.00	59.00	59.00
UB-4	59.00	57.00	57.00	71.00	69.00	67.00	70.00	69.00	68.00	72.00	73.00	75.00	69.00	67.00	66.00	64.00	62.00	60.00
UB-5	51.00	46.00	46.00	53.00	53.00	54.00	69.00	68.00	71.00	65.00	65.00	65.00	56.00	56.00	56.00	56.00	56.00	56.00
LB-1	202.00	152.00	201.00	98.00	162.00	163.00	152.00	183.00	185.00	170.00	172.00	164.00	130.00	157.00	160.00	172.00	172.00	173.00
LB-2	133.00	133.00	133.00	69.00	131.00	131.00	84.00	135.00	163.00	124.00	124.00	124.00	110.00	110.00	110.00	127.00	127.00	127.00
Tributaries																		
TB-1	53.00	53.00	35.00	64.00	61.00	35.00	64.00	64.00	64.00	73.00	71.00	71.00	61.00	61.00	61.00	62.00	62.00	62.00
TB-2	27.00	30.00	18.00	42.00	44.00	45.00	44.00	45.00	44.00	34.00	33.00	51.00	22.00	30.00	46.00	20.00	21.00	26.00
TB-3	100.00	79.00	56.00	60.00	60.00	62.00	60.00	40.00	119.00	88.00	46.00	50.00	86.00	85.00	45.00	66.00	106.00	109.00
TB-4	46.00	46.00	45.00	53.00	53.00	52.00	50.00	53.00	54.00	67.00	62.00	66.00	35.00	36.00	36.00	52.00	52.00	51.00
TB-5	49.00	53.00	49.00	59.00	59.00	59.00	55.00	54.00	53.00	66.00	67.00	66.00	56.00	56.00	56.00	44.00	44.00	44.00

MEASUREMENT OF TDS OF WATER SAMPLES AT DIFFERENT STATIONS ALONG THE MAIN BERTAM RIVER AND ITS TRIBUTARIES

Parameter: TDS (mg/L)

Station	2014															2015		
	January			March			June			September			October			February		
	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd
Main River																		
UB-1	10.00	10.00	10.00	8.00	10.00	7.00	6.00	10.00	10.00	11.00	11.00	11.00	11.00	6.00	6.00	9.00	5.00	9.00
UB-2	44.00	43.00	24.00	57.00	58.00	58.00	47.00	47.00	47.00	59.00	59.00	59.00	45.00	45.00	45.00	42.00	42.00	41.00
UB-3	35.00	38.00	30.00	53.00	51.00	46.00	41.00	40.00	38.00	45.00	45.00	46.00	40.00	43.00	41.00	37.00	38.00	38.00
UB-4	42.00	41.00	41.00	53.00	52.00	50.00	46.00	45.00	44.00	47.00	48.00	46.00	45.00	43.00	43.00	41.00	23.00	39.00
UB-5	33.00	33.00	33.00	38.00	38.00	38.00	44.00	45.00	45.00	42.00	42.00	42.00	37.00	37.00	37.00	37.00	36.00	36.00
LB-1	127.00	126.00	129.00	61.00	107.00	107.00	89.00	131.00	129.00	110.00	111.00	106.00	91.00	103.00	105.00	112.00	112.00	112.00
LB-2	87.00	87.00	87.00	89.00	89.00	48.00	106.00	56.00	106.00	80.00	81.00	81.00	71.00	72.00	71.00	83.00	83.00	83.00
Tributaries																		
TB-1	40.00	40.00	22.00	44.00	46.00	24.00	42.00	42.00	42.00	47.00	46.00	46.00	40.00	40.00	40.00	40.00	40.00	40.00
TB-2	17.00	24.00	15.00	32.00	33.00	33.00	29.00	29.00	29.00	33.00	38.00	35.00	20.00	18.00	30.00	28.00	18.00	30.00
TB-3	70.00	67.00	46.00	44.00	44.00	45.00	50.00	30.00	70.00	57.00	33.00	41.00	56.00	55.00	30.00	69.00	69.00	44.00
TB-4	32.00	32.00	32.00	38.00	38.00	38.00	35.00	35.00	35.00	43.00	43.00	43.00	28.00	29.00	29.00	34.00	33.00	33.00
TB-5	34.00	33.00	34.00	42.00	42.00	42.00	36.00	36.00	36.00	43.00	43.00	43.00	36.00	37.00	37.00	28.00	28.00	28.00

MEASUREMENT OF TDS OF WATER SAMPLES AT DIFFERENT STATIONS ALONG THE MAIN BERTAM RIVER AND ITS TRIBUTARIES

Parameter: TDS (mg/L)

Station	2014															2015		
	January			March			June			September			October			February		
	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd
Main River																		
UB-1	10.00	10.00	10.00	8.00	10.00	7.00	6.00	10.00	10.00	11.00	11.00	11.00	11.00	6.00	6.00	9.00	5.00	9.00
UB-2	44.00	43.00	24.00	57.00	58.00	58.00	47.00	47.00	47.00	59.00	59.00	59.00	45.00	45.00	45.00	42.00	42.00	41.00
UB-3	35.00	38.00	30.00	53.00	51.00	46.00	41.00	40.00	38.00	45.00	45.00	46.00	40.00	43.00	41.00	37.00	38.00	38.00
UB-4	42.00	41.00	41.00	53.00	52.00	50.00	46.00	45.00	44.00	47.00	48.00	46.00	45.00	43.00	43.00	41.00	23.00	39.00
UB-5	33.00	33.00	33.00	38.00	38.00	38.00	44.00	45.00	45.00	42.00	42.00	42.00	37.00	37.00	37.00	37.00	36.00	36.00
LB-1	127.00	126.00	129.00	61.00	107.00	107.00	89.00	131.00	129.00	110.00	111.00	106.00	91.00	103.00	105.00	112.00	112.00	112.00
LB-2	87.00	87.00	87.00	89.00	89.00	48.00	106.00	56.00	106.00	80.00	81.00	81.00	71.00	72.00	71.00	83.00	83.00	83.00
Tributaries																		
TB-1	40.00	40.00	22.00	44.00	46.00	24.00	42.00	42.00	42.00	47.00	46.00	46.00	40.00	40.00	40.00	40.00	40.00	40.00
TB-2	17.00	24.00	15.00	32.00	33.00	33.00	29.00	29.00	29.00	33.00	38.00	35.00	20.00	18.00	30.00	28.00	18.00	30.00
TB-3	70.00	67.00	46.00	44.00	44.00	45.00	50.00	30.00	70.00	57.00	33.00	41.00	56.00	55.00	30.00	69.00	69.00	44.00
TB-4	32.00	32.00	32.00	38.00	38.00	38.00	35.00	35.00	35.00	43.00	43.00	43.00	28.00	29.00	29.00	34.00	33.00	33.00
TB-5	34.00	33.00	34.00	42.00	42.00	42.00	36.00	36.00	36.00	43.00	43.00	43.00	36.00	37.00	37.00	28.00	28.00	28.00

MEASUREMENT OF TSS OF WATER SAMPLES AT DIFFERENT STATIONS ALONG THE MAIN BERTAM RIVER AND ITS TRIBUTARIES

Parameter: TSS (mg/L)

Station	2014															2015		
	January			March			June			September			October			February		
	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd
Main River																		
UB-1	3.00	11.00	9.00	7.00	6.00	7.00	5.00	2.00	5.00	7.00	3.00	2.00	5.00	3.00	3.00	6.00	2.00	2.00
UB-2	23.00	11.00	25.00	22.00	21.00	21.00	83.00	86.00	74.00	35.00	49.00	20.00	22.00	16.00	23.00	20.00	13.00	11.00
UB-3	62.00	64.00	55.00	167.00	175.00	143.00	130.00	157.00	166.00	451.00	486.00	506.00	540.00	510.00	560.00	150.00	134.00	151.00
UB-4	84.00	91.00	93.00	56.00	60.00	50.00	110.00	108.00	99.00	334.00	319.00	303.00	188.00	210.00	195.00	142.00	114.00	134.00
UB-5	311.00	309.00	289.00	1049.00	1246.00	1299.00	39.00	48.00	58.00	420.00	372.00	472.00	420.00	435.00	384.00	154.00	221.00	221.00
LB-1	143.00	171.00	143.00	77.00	80.00	80.00	105.00	78.00	104.00	564.00	571.00	591.00	323.00	352.00	365.00	830.00	801.00	750.00
LB-2	173.00	203.00	170.00	244.00	237.00	217.00	102.00	133.00	94.00	392.00	420.00	365.00	2012.00	2084.00	1988.00	357.00	359.00	357.00
Tributaries																		
TB-1	13.00	42.00	25.00	20.00	15.00	17.00	110.00	112.00	132.00	22.00	63.00	26.00	16.00	15.00	12.00	26.00	16.00	26.00
TB-2	40.00	32.00	38.00	480.00	675.00	528.00	178.00	170.00	179.00	4780.00	4040.00	4078.00	1722.00	1688.00	1705.00	1036.00	1260.00	1250.00
TB-3	165.00	100.00	128.00	102.00	71.00	108.00	53.00	75.00	76.00	338.00	349.00	95.00	249.00	194.00	123.00	11.00	58.00	32.00
TB-4	73.00	62.00	51.00	104.00	164.00	115.00	96.00	188.00	215.00	157.00	122.00	74.00	2152.00	2130.00	2098.00	20.00	36.00	132.00
TB-5	14.00	15.00	47.00	32.00	41.00	30.00	14.00	4.00	8.00	6.00	26.00	6.00	840.00	834.00	812.00	29.00	30.00	30.00

MEASUREMENT OF TURBIDITY OF WATER SAMPLES AT DIFFERENT STATIONS ALONG THE MAIN BERTAM RIVER AND ITS TRIBUTARIES

Parameter: Turbidity (NTU)

Station	2014															2015		
	January			March			June			September			October			February		
	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd
Main River																		
UB-1	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.05	0.05	0.05	0.05	0.05	0.04
UB-2	7.10	6.80	6.80	15.40	15.70	13.70	53.00	56.10	55.30	24.50	24.70	26.40	9.90	9.10	9.60	9.00	9.80	9.20
UB-3	30.50	30.70	28.60	98.00	88.00	93.00	81.50	78.50	80.20	560.20	542.20	515.20	210.10	211.40	207.60	67.40	74.60	74.90
UB-4	44.00	35.30	33.70	49.00	46.00	48.00	86.00	83.00	78.10	280.50	278.80	275.90	145.90	147.50	138.30	94.20	89.20	85.20
UB-5	179.20	182.40	183.00	950.00	915.00	889.50	79.80	78.20	78.90	330.80	344.80	341.70	215.80	202.50	195.30	113.10	113.90	89.50
LB-1	79.50	71.90	73.60	78.90	68.30	70.70	60.60	62.10	56.00	557.10	554.30	573.80	347.20	297.50	255.20	817.90	720.00	716.90
LB-2	109.98	103.30	102.30	189.40	194.00	182.40	70.50	65.90	55.40	356.80	363.90	368.90	1292.20	1292.00	1291.80	261.00	240.00	257.00
Tributaries																		
TB-1	5.00	5.50	5.20	10.40	13.00	10.10	85.30	87.20	78.30	16.30	18.00	15.00	9.70	10.00	10.30	11.40	12.50	10.80
TB-2	20.30	19.50	19.30	336.00	328.00	240.00	173.00	151.30	134.60	1241.20	1241.40	1242.70	1242.20	1242.10	1241.90	570.00	547.00	609.00
TB-3	153.00	98.70	95.30	79.70	76.00	52.40	43.10	55.30	89.50	200.20	53.00	83.40	118.50	82.50	59.00	61.20	61.00	29.50
TB-4	23.00	24.49	25.80	30.00	34.70	35.30	68.10	64.50	65.10	52.30	52.10	50.70	1267.50	1267.70	1259.90	14.40	11.70	10.60
TB-5	9.90	8.30	8.80	23.50	23.00	23.40	35.30	12.20	18.90	11.00	33.40	52.10	650.90	654.10	657.20	22.60	22.10	23.40

MEASUREMENT OF DO OF WATER SAMPLES AT DIFFERENT STATIONS ALONG THE MAIN BERTAM RIVER AND ITS TRIBUTARIES

Parameter: DO (mg/L)

Station	2014															2015		
	January			March			June			September			October			February		
	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd
Main River																		
UB-1	7.88	7.84	7.70	7.56	7.44	7.58	7.47	7.40	7.40	7.46	7.42	7.42	7.34	7.44	7.45	7.78	7.77	7.80
UB-2	7.30	7.24	7.22	7.26	7.28	7.23	7.27	7.20	7.14	7.10	7.04	6.98	6.95	6.85	6.82	8.22	8.20	8.19
UB-3	7.21	7.04	7.07	7.16	7.13	7.08	7.12	7.07	7.06	6.88	6.83	6.82	6.62	6.56	6.54	8.10	8.00	8.03
UB-4	6.30	6.41	6.58	6.52	6.38	6.36	6.45	6.37	6.40	6.38	6.30	6.34	6.21	6.28	6.33	7.21	7.92	8.02
UB-5	8.20	8.32	8.29	8.40	8.36	8.42	8.39	8.53	8.57	8.15	8.10	8.09	7.89	7.9	7.85	8.89	9.33	9.25
LB-1	5.27	5.22	5.13	5.25	5.27	5.38	5.05	5.31	5.64	5.95	5.83	6.10	6.42	6.25	6.31	6.04	5.93	5.96
LB-2	7.32	7.33	7.31	7.26	7.28	7.25	7.23	7.20	7.22	7.19	7.19	7.15	7.16	7.16	7.15	7.97	7.88	7.93
Tributaries																		
TB-1	7.66	7.58	7.52	7.49	7.60	7.55	7.61	7.49	7.47	7.15	7.35	7.55	7.13	7.2	7.22	7.85	7.87	8.17
TB-2	7.51	7.48	7.49	7.45	7.42	7.38	7.40	7.36	7.36	7.28	7.28	7.30	7.2	7.19	7.19	7.96	7.94	8.02
TB-3	5.96	5.93	5.91	5.47	5.36	5.35	5.36	4.66	4.57	5.46	5.26	5.89	6.22	6.05	5.9	5.76	5.70	5.76
TB-4	7.68	7.69	7.69	7.71	7.63	7.75	7.72	7.73	7.75	7.70	7.65	7.75	7.66	7.66	7.66	8.38	8.58	8.59
TB-5	7.45	7.54	7.57	7.58	7.65	7.46	7.63	7.65	7.65	7.68	7.66	7.66	7.72	7.72	7.72	8.45	8.48	8.49

MEASUREMENT OF BOD OF WATER SAMPLES AT DIFFERENT STATIONS ALONG THE MAIN BERTAM RIVER AND ITS TRIBUTARIES

Parameter: Biological Oxygen Demand (mg/L)

Station	2014															2015		
	January			March			June			September			October			February		
	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd
Main River																		
UB-1	5.95	5.80		3.00	3.20		1.85	4.00	0.35	0.85	0.80		3.55	2.99	1.85	2.15	2.65	2.80
UB-2	10.90	10.40	10.95	11.05	9.60	8.05	8.50	9.45	10.15	5.10	3.00	2.90	13.90	10.89	9.60	15.80	24.80	8.95
UB-3	11.85	11.50	10.80	8.60	7.95	7.50	6.30	5.50	5.80	10.10	10.15	9.30	10.85	10.15	11	8.65	12.15	9.15
UB-4	13.95	13.30	13.95	6.30	6.05	7.65	8.05	8.80	5.95	2.90	0.90	2.45	19.15	15.78	13.32	10.50	3.70	8.30
UB-5	10.05	10.10	10.45	5.90	5.90	4.65	1.25	1.65	2.90	5.00	4.55	4.05	8.40	8.50	7.96	4.35	5.40	3.80
LB-1	15.50	15.20	21.45	14.55	7.95	9.15	10.85	11.05	11.05	13.00	11.80	13.25	11.2	12.00	1.56	9.85	9.30	9.00
LB-2	6.65	7.35	7.30	4.40	4.80	2.25	2.10	2.15	4.40	8.25	7.90	6.70	10.60	8.50	8.90	4.95	2.95	4.70
Tributaries																		
TB-1	8.45	7.55	9.20	5.75	10.55	6.05	19.20	17.80	18.15	3.10	1.90	3.20	13.55	14.00	13.33	3.60	4.30	3.90
TB-2	6.20	6.85	4.90	3.05	3.65	3.25	8.00	12.50	10.05	4.40	0.45	2.60	13.05	12.56	10.7	5.15	5.70	3.50
TB-3	13.95	13.70		15.10	14.75	13.20	11.20	12.55	13.50	24.70	14.15	24.00	32.35	34.09	31.11	35.00	35.30	35.50
TB-4	9.75	10.00	10.10	2.20	2.70	2.20	0.40	0.75	0.90	3.65	2.45	4.90	9.50	8.50	8.76	1.45	1.45	1.30
TB-5	10.15	9.05	9.70	2.10	2.65	0.90	1.50	1.35	6.40	4.30	2.75	5.15	8.65	7.99	7.65	1.65	1.15	3.90

MEASUREMENT OF COD OF WATER SAMPLES AT DIFFERENT STATIONS ALONG THE MAIN BERTAM RIVER AND ITS TRIBUTARIES

Parameter: Chemical Oxygen Demand (mg/L)

Station	2014															2015		
	January			March			June			September			October			February		
	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd
Main River																		
UB-1	13.00	17.00	9.00	11.00	14.00	12.00	12.00	15.00	19.00	6.00	7.00	6.00	5.00	6.00	5.00	13.00	15.00	19.00
UB-2	16.00	21.00	18.00	26.00	38.00	19.00	17.00	16.00	16.00	39.00	42.00	43.00	19.00	19.00	16.00	23.00	44.00	42.00
UB-3	18.00	22.00	19.00	25.00	35.00	20.00	15.00	8.00	13.00	18.00	8.00	23.00	13.00	21.00	16.00	50.00	42.00	42.00
UB-4	19.00	25.00	20.00	27.00	41.00	22.00	17.00	13.00	23.00	13.00	18.00	14.00	5.00	8.00	14.00	6.00	45.00	55.00
UB-5	13.00	22.00	11.00	36.00	40.00	38.00	8.00	12.00	13.00	16.00	12.00	8.00	10.00	15.00	11.00	36.00	37.00	34.00
LB-1	30.00	30.00	28.00	31.00	27.00	41.00	17.00	16.00	27.00	32.00	33.00	41.00	10.00	12.00	9.00	29.00	45.00	47.00
LB-2	16.00	13.00	22.00	21.00	15.00	15.00	11.00	11.00	12.00	14.00	13.00	4.00	13.00	10.00	12.00	37.00	35.00	41.00
Tributaries																		
TB-1	19.00	15.00	13.00	23.00	24.00	20.00	14.00	13.00	13.00	23.00	16.00	18.00	15.00	13.00	15.00	46.00	44.00	40.00
TB-2	11.00	11.00	10.00	18.00	23.00	26.00	13.00	18.00	14.00	57.00	59.00	55.00	12.00	13.00	11.00	44.00	42.00	51.00
TB-3	35.00	35.00	35.00	63.00	62.00	60.00	36.00	34.00	34.00	22.00	27.00	29.00	19.00	29.00	26.00	63.00	60.00	64.00
TB-4	11.00	14.00	12.00	18.00	19.00	22.00	8.00	12.00	7.00	8.00	10.00	12.00	12.00	10.00	8.00	38.00	30.00	40.00
TB-5	12.00	10.00	10.00	22.00	30.00	18.00	14.00	13.00	8.00	7.00	7.00	8.00	17.00	15.00	12.00	37.00	24.00	40.00

MEASUREMENT OF NH4-N OF WATER SAMPLES AT DIFFERENT STATIONS ALONG THE MAIN BERTAM RIVER AND ITS TRIBUTARIES

Parameter: Ammonical Nitrogen (mg/L)

Station	2014															2015		
	January			March			June			September			October			February		
	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd
Main River																		
UB-1	0.03	0.05	0.04	0.03	0.02	0.05	0.06	0.06	0.04	0.09	0.11	0.11	0.17	0.06	0.10	0.01	0.01	0.01
UB-2	1.00	0.87	0.86	2.12	2.09	2.12	1.06	1.13	1.12	1.29	1.4	1.40	0.69	0.72	0.67	0.71	0.61	0.68
UB-3	0.95	0.85	0.76	1.95	1.80	2.20	1.02	1.00	1.03	1.56	1.61	1.61	0.70	0.85	0.93	0.88	0.71	0.85
UB-4	0.55	0.75	0.63	1.36	1.20	1.36	0.82	0.78	0.68	1.17	1.21	1.22	0.53	0.65	0.73	0.96	0.62	0.72
UB-5	0.76	0.86	0.80	1.84	1.94	1.92	0.23	0.26	0.28	0.92	0.87	0.92	0.11	0.32	0.43	0.66	0.59	0.67
LB-1	1.34	1.38	1.39	0.90	0.97	0.89	1.77	1.79	1.95	1.34	1.32	1.37	0.85	0.90	0.97	1.86	1.82	2.04
LB-2	0.56	0.44	0.47	1.23	0.60	0.82	0.29	0.28	0.29	0.95	0.88	0.99	0.53	0.60	0.55	0.95	0.53	0.91
Tributaries																		
TB-1	0.70	0.74	0.68	1.02	1.08	1.04	0.67	0.68	0.65	0.9	0.92	0.96	0.50	0.60	0.57	0.37	0.30	0.29
TB-2	0.92	0.81	0.50	1.56	1.35	1.48	0.63	0.62	0.64	2.38	2.28	3.72	0.95	0.75	0.93	2.14	1.30	1.60
TB-3	2.14	2.13	2.20	3.38	3.28	3.26	3.30	3.04	1.76	0.63	1.00	1.04	1.30	1.50	1.80	2.20	1.94	1.91
TB-4	0.27	0.27	0.24	0.23	0.20	0.29	0.25	0.28	0.33	0.34	0.32	0.38	0.18	0.20	0.19	0.07	0.05	0.09
TB-5	0.10	0.12	0.14	0.28	0.25	0.35	0.11	0.10	0.11	0.17	0.15	0.16	0.22	0.11	0.14	0.06	0.08	0.08

MEASUREMENT OF NO3-N OF WATER SAMPLES AT DIFFERENT STATIONS ALONG THE MAIN BERTAM RIVER AND ITS TRIBUTARIES

Parameter: Nitrate Nitrogen (mg/L)

Station	2014															2015		
	January			March			June			September			October			February		
	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd
Main River																		
UB-1	0.10	0.09	0.10	0.10	0.10	0.10	0.08	0.20	0.10	0.10	0.10	0.10	0.20	0.10	0.20	0.10	0.10	0.10
UB-2	0.70	0.90	0.80	0.40	0.60	0.30	0.60	0.80	0.70	0.90	0.80	0.80	0.70	0.70	0.80	0.50	0.50	0.40
UB-3	0.58	0.50	0.68	0.40	0.60	0.50	0.30	0.50	0.30	0.50	0.70	0.60	0.50	0.60	0.65	0.30	0.30	0.30
UB-4	0.70	0.70	0.80	0.50	0.80	1.20	0.50	0.50	0.80	0.80	0.90	0.60	0.80	0.70	0.90	0.30	0.50	0.50
UB-5	0.90	1.00	0.90	0.70	1.00	1.20	0.90	0.70	0.60	1.10	0.90	0.80	0.90	0.90	1.00	1.10	0.80	0.50
LB-1	3.00	3.30	2.90	1.90	2.90	2.90	2.40	2.70	2.10	2.20	2.50	2.00	2.10	2.30	2.40	1.20	2.50	2.80
LB-2	3.30	3.20	3.40	2.80	3.40	3.00	3.00	3.70	2.80	1.90	2.10	3.10	2.80	2.60	2.50	2.00	1.80	2.10
Tributaries																		
TB-1	0.90	1.20	1.00	0.60	0.40	0.70	0.90	0.90	0.80	0.80	1.00	0.90	0.90	0.90	1.10	0.40	0.60	0.30
TB-2	0.20	0.10	0.20	0.20	0.10	0.10	0.20	0.10	0.20	0.20	0.30	0.30	0.20	0.20	0.20	0.10	0.10	0.10
TB-3	0.30	0.30	0.30	0.10	0.40	0.20	0.10	0.10	0.70	0.60	0.50	0.40	0.20	0.20	0.25	0.50	0.60	0.20
TB-4	0.80	1.00	0.90	0.50	0.50	1.20	0.80	0.60	0.60	1.20	0.60	0.70	1.00	0.80	0.90	0.70	0.50	0.60
TB-5	0.70	0.60	0.80	0.50	0.50	0.50	0.50	0.40	0.50	0.40	0.70	0.70	0.60	0.70	0.70	0.40	0.70	0.50

MEASUREMENT OF TN OF WATER SAMPLES AT DIFFERENT STATIONS ALONG THE MAIN BERTAM RIVER AND ITS TRIBUTARIES

Parameter: Total Nitrogen (mg/L)

Station	2014															2015		
	January			March			June			September			October			February		
	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd
Main River																		
UB-1	0.50	0.40	1.00	0.20	0.20		0.30	0.20	0.40	0.50	1.00	0.60	0.55	0.63	0.58	0.20	0.30	0.50
UB-2	1.90	2.80	2.40	2.00	3.10	2.90	2.80	3.90	2.70	4.00	3.60	3.50	2.00	2.60	2.80	2.70	3.30	4.20
UB-3	2.70	2.50	2.70	2.20	3.20	3.00	2.30	2.80	2.50	3.10	2.90	2.80	2.50	2.50	2.80	1.80	2.30	3.00
UB-4	3.30	4.70	2.80	2.50	4.80	3.40	3.00	3.50	2.70	3.50	3.60	4.20	3.00	3.30	3.10	2.00	2.40	3.80
UB-5	3.50	2.30	4.00	3.90	3.70	4.50	3.00	2.60	2.80	3.60	3.50	4.20	3.00	3.40	3.50	2.80	2.50	1.60
LB-1	4.90	4.80	7.80	3.80	10.90	5.10	6.40	6.20	5.80	5.40	5.20	5.00	4.80	4.60	4.80	8.20	6.10	8.00
LB-2	5.30	5.00	3.20	3.70	4.10	5.80	5.20	6.80	5.10	5.60	4.90	4.80	4.30	3.40	3.80	6.00	6.90	6.90
Tributaries																		
TB-1	2.40	2.00	2.60	1.80	1.40	2.30	3.30	2.90	2.70	4.00	3.60	3.60	2.90	1.80	2.50	2.30	2.70	3.50
TB-2	1.30	1.60	1.50	2.10	1.90	2.30	1.70	2.20	1.80	4.40	3.80	4.00	2.80	1.80	1.90	1.50	3.70	3.40
TB-3	4.40	4.80	3.70	3.80	3.50	3.80	4.40	5.20	5.50	3.90	3.50	4.00	3.10	2.20	2.90	5.20	5.20	4.10
TB-4	2.90	3.30	2.40	1.80	2.40	1.60	2.90	2.80	2.00	3.70	3.50	3.20	3.20	3.10	2.80	2.00	1.60	1.50
TB-5	4.80	3.50	0.50	3.70	1.70	2.20	3.10	2.20	2.10	2.50	3.00	3.10	2.70	2.60	3.00	1.40	1.50	2.00

MEASUREMENT OF PO_4-P OF WATER SAMPLES AT DIFFERENT STATIONS ALONG THE MAIN BERTAM RIVER AND ITS TRIBUTARIES

Parameter: Phosphate Phosphorous (mg/L)

Station	2014															2015		
	January			March			June			September			October			February		
	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd
Main River																		
UB-1	0.12	0.10	0.15	0.10	0.12	0.12	0.12	0.15	0.18	0.22	0.13	0.16	0.19	0.17	0.15	0.14	0.12	0.10
UB-2	0.68	0.80	1.01	0.99	0.73	0.79	0.55	0.72	0.68	0.85	0.73	1.31	1.39	0.84	0.85	0.80	0.70	0.48
UB-3	0.78	0.83	0.93	0.86	0.75	0.77	1.08	0.52	0.48	1.25	0.80	0.43	0.98	1.00	0.56	0.36	0.21	0.47
UB-4	0.65	0.76	0.43	0.68	0.55	0.40	0.34	0.37	0.37	0.54	0.84	0.29	0.92	0.59	0.62	0.42	0.34	0.24
UB-5	0.92	0.73	0.71	0.97	0.74	0.75	0.67	0.72	1.00	0.74	1.19	1.28	0.98	1.49	0.91	0.30	0.31	1.67
LB-1	1.27	1.03	0.92	0.79	0.70	0.89	1.00	0.95	1.01	1.40	1.00	0.88	1.53	1.32	1.54	1.03	0.53	0.63
LB-2	1.77	1.55	1.30	1.26	1.39	0.93	1.03	1.17	1.51	0.86	2.22	1.03	1.92	1.48	2.12	1.09	0.60	0.90
Tributaries																		
TB-1	0.88	0.76	0.67	0.53	0.59	0.85	0.58	0.82	0.42	1.00	1.01	0.99	1.51	0.66	0.94	0.36	0.50	0.80
TB-2	0.49	0.26	0.32	0.41	0.27	0.24	0.12	0.42	0.16	0.40	0.31	0.64	0.59	0.43	0.69	0.10	0.10	0.10
TB-3	0.70	0.72	0.54	0.87	0.75	0.69	0.50	0.59	0.75	0.21	0.31	0.30	0.23	0.35	0.39	0.44	0.60	0.77
TB-4	0.48	0.39	0.37	0.58	0.83	0.44	0.29	0.36	0.27	1.00	1.26	0.87	0.99	0.92	1.10	0.34	0.54	0.90
TB-5	0.82	0.57	0.49	0.87	0.85	0.70	1.18	0.68	0.60	1.38	1.68	1.33	2.20	2.16	1.80	0.91	0.32	0.59

MEASUREMENT OF TP OF WATER SAMPLES AT DIFFERENT STATIONS ALONG THE MAIN BERTAM RIVER AND ITS TRIBUTARIES

Parameter: Total Phosphate (mg/L)

Station	2014															2015		
	January			March			June			September			October			February		
	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd
Main River																		
UB-1	0.31	0.27	0.24	0.17	0.32	0.28	0.12	0.40	0.22	0.23	0.21	0.40	0.32	0.30	0.25	0.22	0.26	0.20
UB-2	1.01	0.86	1.00	2.01	0.98	1.35	0.84	1.06	0.98	0.97	1.14	1.50	1.50	1.50	1.47	0.84	0.68	0.63
UB-3	1.20	0.89	1.05	1.30	1.10	1.25	0.98	0.77	0.53	0.72	1.24	1.51	1.54	0.86	1.62	0.56	0.50	0.59
UB-4	1.24	0.83	0.78	0.98	1.06	1.21	0.66	0.88	0.76	1.04	0.98	0.98	1.56	0.89	1.98	0.47	0.49	0.45
UB-5	1.27	1.21	1.30	2.08	1.86	1.87	0.73	1.02	2.10	1.76	1.06	1.39	1.84	1.87	1.86	0.65	1.25	0.56
LB-1	1.15	1.00	1.01	2.80	2.65	1.46	1.24	1.35	2.10	1.37	1.56	2.02	2.81	2.98	1.40	1.30	1.32	1.22
LB-2	1.25	1.32	0.98	2.09	2.35	1.83	2.04	0.95	1.85	1.62	1.70	2.22	2.98	3.03	2.96	1.34	1.00	1.04
Tributaries																		
TB-1	0.81	0.79	0.82	1.57	1.48	1.89	0.74	0.88	0.64	1.68	1.35	1.02	1.40	1.98	1.87	0.58	0.67	0.60
TB-2	0.42	0.44	0.45	0.38	0.40	0.51	0.38	0.93	0.48	1.20	0.88	0.54	1.37	1.20	0.70	0.56	0.59	0.73
TB-3	1.25	1.05	1.48	1.68	1.89	1.85	0.86	1.32	1.52	0.55	0.43	0.40	0.66	0.70	0.65	0.90	0.83	0.71
TB-4	0.89	0.83	0.85	0.95	0.93	0.85	0.53	0.74	0.63	0.64	1.87	1.56	1.61	1.60	1.48	0.97	0.99	1.02
TB-5	0.92	0.94	0.94	1.45	0.64	1.71	1.40	0.93	0.86	1.03	1.97	1.68	3.20	3.00	2.80	0.62	0.58	0.79

APPENDIX E

QUESTIONNAIRE (ENGLISH VERSION)

Impact of Landuse Change on Water Quality and People Perception in Bertam River, Cameron Highlands

Survey conducted by
Md. Golam Rasul (Ph. D. Candidate, Universiti Malaysia Pahang)
Contact : 010-9050246

A. Demographic Information of Respondent

1. Age
   20-35 ☐ 36-45 ☐ 46-55 ☐ 56-65 ☐ > 65 ☐

2.Gender
   Male ☐ Female ☐

3. Race/Ethnicity
   Malay ☐ Chinese ☐ Indian ☐ Orang Asli ☐

3. Occupation
   Farmer ☐ Business ☐ Service ☐ Resident ☐ student ☐ Other ☐

4. Educational Level
   Illiterate ☐ Primary ☐ Secondary ☐ Diploma ☐ Academic ☐

5. Where you live ....
6. No. of family members ____________________
7. How long have you been here ____________________

B. Environmental Change

B1: Water Quality

1. How would you rate the quality of surface water of Bertam River?
   Good ☐ Poor ☐

2. Do you agree that the water quality has been degraded over time?
   Strongly agree ☐ Agree ☐ Neutral ☐ Disagree ☐ Strongly disagree ☐

3. What are the activities that you believe affect water quality? (You can tick more than one option)

Excess Sedimentation for soil erosion	☐	poor solid waste management	☐
Poor agricultural practice	☐	Sewage treatment plants/domestic discharge	☐
low awareness of local community	☐	Land clearing for development	☐

Others ____________________

4. What are the main obstacle/ limitations to protect the river pollution of Bertam river? (You can tick more than one option)

Lack of awareness	☐	Lack of strict enforcement	☐
Uncontrolled land clearing	☐	Poor agricultural practices	☐
poor solid waste management	☐	Rapid urbanization	☐

Others ______________________________

5. How important is to minimize the potential impacts of pollution sources (soil erosion, runoff) on the water environment? [protection the environment]

Very Important ☐ Somewhat important ☐ Neutral ☐ Not very imp ☐ Not at all important ☐

B2: Landuse Change

1. Did you observe that in your locality there was land pattern change with the passage of time?

   Yes ☐ No ☐

2. How you rate its change?

   Low ☐ Moderate ☐ High ☐

3. In your opinion, what was the main cause of land pattern change in the catchment (You can tick more than one option)?

Tourist development ☐ Rapid Urbanization ☐ Intensive farming activities ☐

Suitable for agro product ☐ Others ------------------------------

4. Consequences (You can tick more than one option)?

Loss of Biodiversity ☐ Environmental change ☐ Climate change ☐

Deforestation ☐ Others ------------------------------

B3: Soil Erosion

1. Did you observe that in your locality there is soil erosion with the passage of time??

   Yes ☐ No ☐

2. How you rate its change?

   Mild ☐ Moderate ☐ Severe or Rapid ☐

3. Did you know that which was the main source of Erosion in your locality? (You can tick more than one option)?

Farming ☐ Cleaning of Slopes ☐ Heavy rain ☐

Deforestation ☐ Others

4. What you think, what are the major consequences of soil erosion in Cameron Highlands? (You can tick more than one option)?

Pollution of river water ☐ Flooding ☐

Soil degradation ☐ Landslide ☐

Deforestation ☐ Loss of biodiversity ☐

If any other (Please specify here) ______________________________

C: Awareness about the Environmental Change

1. Do you agree that it is your responsibility to keep the water resource healthy in this area?

Strongly agree ☐ Agree ☐ Neutral ☐ Disagree ☐ Strongly disagree ☐

2. How dangerous do you think that the pollution of river is for you and your family?

Very danger ☐ Somewhat anger ☐ Neutral ☐ Not very danger ☐ Not at all danger ☐

3. Do you agree that protection of river pollution will provide a better health for you and your family?

Strongly agree ☐ Agree ☐ Neutral ☐ Disagree ☐ Strongly disagree ☐

4. Do you agree that protection of river pollution will provide a better health and offer benefit for the people in your community?

Strongly agree ☐ Agree ☐ Neutral ☐ Disagree ☐ Strongly disagree ☐

5. Do you agree to willingly contribute to protect the water quality environment?

Strongly agree ☐ Agree ☐ Neutral ☐ Disagree ☐ Strongly disagree ☐

6. Do you agree that degradation of water quality will destroy the ecosystem of this area over time?

Strongly agree ☐ Agree ☐ Neutral ☐ Disagree ☐ Strongly disagree ☐

7. To what extant you agree that, land pattern change/Land type change affect the ecosystem and environment of the locality

Strongly agree ☐ Agree ☐ Neutral ☐ Disagree ☐ Strongly disagree ☐

8. To what extent you agree that, soil erosion is the main cause behind pollution of surface water and flooding

Strongly agree ☐ Agree ☐ Neutral ☐ Disagree ☐ Strongly disagree ☐

9. To what extent you agree that public authorities should consult with local communities to start any venture which can affect the environment

Strongly agree ☐ Agree ☐ Neutral ☐ Disagree ☐ Strongly disagree ☐

10. If public authorities want that you should participate in river water protection programs (Integrated Catchment Management) as volunteer in collaboration with authorities. Would you join the programs

Yes ☐ No ☐

D: Sources of information

1. Is there any regular awareness program to protect water quality of Bertam river?

Yes ☐ No ☐ Very less ☐

2. Is there any regular awareness program regarding precaution to environmental consequences (Flooding/ Landslide)?

Yes ☐ No ☐ Very less ☐

3. Is there any regular awareness discussion on your religious place regarding environmental pollution/Land pattern change and its consequences? [like for Muslims during khudba]

Yes ☐ No ☐ Very less ☐

4. What are the sources of information for you regarding water quality awareness program/ land change/ soil erosion? (You can tick more than one option)

Through local authority	☐	Through community	☐
REACH [Awareness program]	☐	Media [Television/ Newspaper]	☐
Classroom teaching	☐	Internet	☐
Friends	☐	Seminar and conferences	☐

Others ______________________

5. Do you feel that Government or public authorities should arrange periodic programs for community awareness for their volunteer participation in water/ environmental protection?

Yes ☐ No ☐

6. What is you opinion regarding water quality management program for better future? [How to improve the river environment]

____

QUESTIONNAIRE (MALAY VERSION)

Kesan Kegunaan Tanah Terhadap Penukaran Kualiti Air dan Persepsi Orang Awam Di Bertam Valley River, Cameron Highlands

Dikaji Oleh:
Golam Rasul (Ph. D. Candidate, University Malaysia Pahang)
Contact : 010-9050246

A. Demographic Information of Respondent/ Maklumat Demografik Responden

1. Umur
   20-35 ☐ 36-45 ☐ 46-55 ☐ 56-65 ☐ > 65 ☐
2. Jantina
   Lelaki ☐ Perempuan ☐
3. Etnicity/ Kaum
   Melayu ☐ Cina ☐ India ☐ Orang Asli ☐
3. Pekerjaan
   Petani ☐ Peniaga ☐ Service ☐ Penduduk ☐ Pelajar ☐ lain ☐
4. Tahap Academik
   Tidak Sekolah ☐ Rendah ☐ Menengah ☐ Diploma ☐ Academik ☐
5. Where you live ....
6. No. of family members ____________________
7. How long have you been here ____________________

B. Perubahan Alam Sekitar (Kualiti Air)

B1: Kualiti Air

1. Bagaimana anda menilai kualiti air permukaan Bertam River?
   Baik ☐ | Lemah ☐
2. Adakah anda bersetuju bahawa kualiti air telah dihina dari masa ke masa?
   Sangat bersetuju ☐ Setuju ☐ Neutral ☐ Tidak Bersetuju ☐ Sangat tidak setuju ☐
3. Apakah aktiviti-aktiviti yang anda percaya menjejaskan kualiti air?
   (Anda boleh menandakan lebih daripada satu pilihan)

Pemendapan berlebihan untuk hakisan tanah	☐	kelemahan pengurusan sisa pepejal	☐
Kelemahan amalan Pertanian	☐	Loji rawatan kumbahan / pelepasan domestik	☐
kesedaran yang rendah masyarakat tempatan	☐	Pembukaan tanah untuk pembangunan	☐

Lain-lain ____________________

4. Apakah halangan / had utama untuk melindungi pencemaran sungai di sungai Bertam? ((Anda boleh menandakan lebih daripada satu pilihan)

Kekurangan kesedaran	☐	Kekurangan Penguatkuasaan ketat	☐
Pembukaan tanah tidak terkawal	☐	Kelemahan amalan pertanian	☐
Kelemahan pengurusan sisa pepejal	☐	Perbandaran yang pesat	☐

Lain-lain ____

5. Berapa pentingkah untuk mengurangkan kesan potensi punca pencemaran (hakisan tanah, air larian) di persekitaran air? [Perlindungan alam sekitar]

Sangat penting ☐ Agak penting ☐ Neutral ☐ Tidak Penting ☐ Tidak penting sekali ☐

B2: Landuse Change/ Perubahan Penggunaan Tanah

1. Adakah anda perhatikan bahawa di tempat anda ada perubahan pola tanah dengan peredaran masa?

Yes ☐ | No ☐

2. Bagaimana anda menilai perubahannya?

Rendah ☐ Sederhana ☐ High ☐

3. Apakah punca utama perubahan kegunaann tanah di kawasan tadahan air?
(Anda boleh menandakan lebih daripada satu pilihan)

Pembangunan pelancongan ☐ Pembandaran Pesat ☐ Aktiviti pertanian intensif ☐

Sesuai untuk produk agro ☐ Lain-lain

4. Akibat perubahan penggunaan tanah (Anda boleh menandakan lebih daripada satu pilihan)

Kehilangan Biodiversiti ☐ Perubahan alam sekitar ☐ Perubahan iklim ☐

Penebangan hutan ☐ Lain-lain ....

B3: Soil Erosion/ Hakisan tanah

1. Adakah anda perhatikan bahawa di kawasan anda ada hakisan tanah dengan peredaran waktu ?

| Ya ☐ | Tidak ☐

2. Bagaimana anda menilai perubahannya?

Ringan ☐ Sederhana ☐ eruk atau Pantas ☐

3. Adakah anda tahu bahawa sumber Eraion utama di tempat anda? (Anda boleh menandakan lebih daripada satu pilihan)?

Berkebun ☐ Pembersihan Lereng ☐ Hujan lebat ☐

Penebangan hutan ☐ Lain-lain ....

4. Apakah kesan utama hakisan tanah di Cameron Highlands? (Anda boleh menandakan lebih daripada satu pilihan)

Pencemarn air sg ☐ Banjir ☐

Degradasi tanah ☐ Tanah Runtuh ☐

Penebangan hutan ☐ kehilangan biodiveisiti ☐

Lain-lain ____

C: Awareness about the Environmental Change/ Kesedaran mengenai Perubahan Alam Sekitar

1. Adakah anda bersetuju bahawa ia adalah tanggungjawab anda untuk memastikan sumber air yang sihat di kawasan ini?

Sangat bersetuju ☐ Setuju ☐ Neutral ☐ Tidak Bersetuju ☐ Sangat tidak setuju ☐

2. Bagaimana berbahaya yang anda fikir bahawa pencemaran sungai adalah untuk anda dan keluarga anda?

Sangat bahaya ☐ Agak bahaya ☐ Neutral ☐ Tidak sangat bahaya ☐ Tidak bahaya sekali ☐

3. Adakah anda bersetuju bahawa perlindungan pencemaran sungai akan memberikan kesihatan yang lebih baik untuk anda dan anda keluarga?

Sangat bersetuju ☐ Setuju ☐ Neutral ☐ Tidak Bersetuju ☐ Sangat tidak setuju ☐

4. Adakah anda bersetuju bahawa perlindungan pencemaran sungai akan memberikan kesihatan dan menawarkan faedah yang lebih baik untuk rakyat dalam komuniti anda?

Sangat bersetuju ☐ Setuju ☐ Neutral ☐ Tidak Bersetuju ☐ Sangat tidak setuju ☐

5. Adakah anda bersetuju dengan rela menyumbang untuk melindungi alam sekitar kualiti air?

Sangat bersetuju ☐ Setuju ☐ Neutral ☐ Tidak Bersetuju ☐ Sangat tidak setuju ☐

6. Adakah anda bersetuju bahawa degradasi kualiti air akan memusnahkan ekosistem di kawasan ini dari masa ke masa?

Sangat bersetuju ☐ Setuju ☐ Neutral ☐ Tidak Bersetuju ☐ Sangat tidak setuju ☐

7. Sejauh mana anda bersetuju bahawa, perubahan pola tanah / Perubahan jenis tanah mempengaruhi ekosistem dan persekitaran tempat tinggal

Sangat bersetuju ☐ Setuju ☐ Neutral ☐ Tidak Bersetuju ☐ Sangat tidak setuju ☐

8. Sejauh mana anda bersetuju bahawa, hakisan tanah adalah punca utama pencemaran air permukaan dan banjir

Sangat bersetuju ☐ Setuju ☐ Neutral ☐ Tidak Bersetuju ☐ Sangat tidak setuju ☐

9. Setakat mana anda bersetuju bahawa pihak berkuasa awam perlu berunding dengan komuniti tempatan untuk memulakan usaha yang boleh menjejaskan alam sekitar

Sangat bersetuju ☐ Setuju ☐ Neutral ☐ Tidak Bersetuju ☐ Sangat tidak setuju ☐

10. Sekiranya pihak berkuasa awam mahu anda mengambil bahagian dalam program perlindungan air sungai (Pengurusan Pengawalan Bersepadu) sebagai sukarelawan dengan kerjasama pihak berkuasa. Adakah anda menyertai program ini

Ya ☐ Tidak ☐

D: Sources of information/ Sumber maklumat

1. Adakah terdapat mana-mana program kesedaran biasa untuk melindungi kualiti air sungai Bertam?

Ya ☐ Tidak ☐ Sangat kurang ☐

2. Adakah terdapat mana-mana program kesedaran biasa mengenai langkah berjaga-jaga untuk kesan alam sekitar (Banjir / Tanah Runtuh)?

Ya ☐ Tidak ☐ Sangat kurang ☐

3. Adakah terdapat mana-mana perbincangan kesedaran biasa di tempat agama anda mengenai pencemaran alam sekitar dan akibatnya? [seperti untuk kain kasa semasa khudba]

Ya ☐ Tidak ☐ Sangat kurang ☐

4. Apakah sumber maklumat untuk anda mengenai program kesedaran kualiti air/ perubahan tanah / hakisan tanah? (Anda boleh menandakan lebih daripada satu pilihan)

Melalui pihak kerajaan tempatan	☐	Melalui komuniti	☐
REACH [Program Kesedaran]	☐	Media [Television/ Akhbar]	☐
Pengajaran di bilik darjah	☐	Internet	☐
Kawan-kawan	☐	Seminar dan persidangan	☐
Lain-lain			

5. Adakah anda merasakan bahawa Kerajaan atau pihak berkuasa awam harus mengatur program berkala untuk kesedaran komuniti untuk penyertaan sukarelawan mereka dalam perlindungan air / alam sekitar?

Ya ☐ Tidak ☐

6. Apakah pandangan anda mengenai program pengurusan kualiti air untuk masa depan yang lebih baik? [Cara untuk menambah baik persekitaran sungai]

APPENDIX F

PUBLICATION

1. Rasul, M. G., Islam, M. S., Alam, L., & Mokthar, M.B (2015). **Effects of Anthropogenic Impact on Water Quality in Bertam Catchment, Cameron Highlands, Malaysia**. *International Journal of Ecology and Environmental Sciences*, *41*(1-2), 75-86.

2. Rasul, M. G., Islam, M. S., Yunus, R. B. M., Mokhtar, M. B., Alam, L., & Yahaya, F. M. (2017). **Spatial and Temporal Variation of Water Quality in the Bertam Catchment, Cameron Highlands, Malaysia**. *Water Environment Research*, *89*(12), 2088-2102.

3. M.G. Rasul, Mir Sujaul Islam, Rosli Bin Mohd Yunus, Mazlin Bin Mokhtar, Md Yasir Arafat (2018) "**Adverse Impact of Land Use Changes on Degrading Environment in Bertam River Catchment, Cameron Highlands, Malaysia**". *International Journal of Ecology and Environmental Sciences,* Vol 44, No 2, 171-184.