INTEGRATED MODELLING OF LAND USE AND CLIMATE CHANGE IMPACT ON WATER QUALITY IN CAMERON HIGHLAND AREA, PAHANG, MALAYSIA

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ABSTRACT

(Key words: Water quality, physico-chemical parameters, climate change, Cameron Highland)

The research investigates the integrated assessment of landuse changes on water quality of Bertam River Catchment, Cameron Highlands, Malaysia. To accomplish the study, seasonal water sampling program was conducted from January 2014 to February 2015 to collect samples from selected 12 stations. A number of 15 (fifteen) physico-chemical parameters were analyzed to evaluate their spatio-temporal variability. Box and whisker plot of measured values of water quality parameters were used to interpret level and trend of the variations. Non-parametric statistical analysis as well as correlation matrix was performed to investigate the temporal and spatial variations of water quality. The water quality status and classes were also identified using the results of Water Quality Index (WQI) values. The land usage activity and changes in landuse pattern within the Catchment was analyzed and calculated over time (1984-2010). Georefencing, digitization, change detection and slope analysis techniques were applied to analyze the changing status and trends of these land usages using GIS approach. For water quality, non-parametric statistical analysis showed significant temporal and spatial differences ($p<0.05$) in most of the parameters across the Catchment. Parameters except DO and COD displayed higher values in rainy season. The higher concentration of total suspended solids was caused due to massive soil erosion and sedimentation. Seasonal variations in contaminant concentrations are largely affected by precipitation and anthropogenic influences. Untreated domestic wastewater discharge as well as agricultural runoff significantly influenced the water quality. WQI values indicated clean to polluted water quality status of the Rivers within the Catchment area. The analytical results of landuse changes 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 also observed in the study area. 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. Land use changes in the catchment area 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).All these changes were directly related to human impact and driven by socio-economic activities aided by favorable climatic condition. Rapid changes in agricultural activities (market gardening, floriculture) and urban expansion along with terrain features and poor agricultural practices resulted in a wide range of environmental impacts, including land and water quality degradation in the catchment area. The analytical results provided a

basis for protection of river environments and ecological restoration in mountainous Bertam Catchment. Moreover, sustainable landuse planning and management is urgent to handle the equilibrium between environmental conservation with land use development and utilization.

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ABSTRAK

Kajian ini menyiasat penilaian bersepadu perubahan guna tanah terhadap kualiti air Bertam Sungai Tadahan, Cameron Highlands, Malaysia. Untuk mencapai kajian itu, program persampelan air bermusim telah dijalankan dari Januari 2014 hingga Februari 2015 untuk mengumpul sampel dari 12 stesen terpilih. Sejumlah 15 (lima belas) parameter fiziko-kimia telah dianalisis untuk menilai kepelbagaian spatio-temporal tersebut. Teknik kotak dan rambut janggut lakaran nilai terukur parameter kualiti air telah digunakan untuk mentafsir tahap dan kecenderungan variasi. Analisis statistik bukan parametrik serta korelasi matriks telah dilakukan untuk menyiasat variasi temporal dan spatial kualiti air. Status kualiti air dan kelas juga dikenal pasti menggunakan hasil nilai Indeks Kualiti Air (WQI). Aktiviti penggunaan tanah dan perubahan dalam corak guna tanah dalam tadahan dianalisis dalam lingkungan julat masa tetap (1984-2010). Teknik georefencing, pendigitalan, pengesanan perubahan dan analisis cerun telah digunakan untuk menganalisis status perubahan dan kecenderungan penggunaan tanah dengan cara pendekatan GIS. Bagi kualiti air, analisis statistik bukan parametrik menunjukkan perbezaan temporal dan spatial yang signifikan ($p < 0.05$) dalam kebanyakan parameter seluruh kawasan tadahan. Parameter kecuali DO dan COD memaparkan nilai yang lebih tinggi pada musim hujan. Kepekatan yang lebih tinggi dalam jumlah pepejal terampai disebabkan akibat hakisan tanah besar-besaran dan pemendapan. Variasi bermusim dalam kepekatan bahan cemar sebahagian besarnya dipengaruhi oleh hujan dan pengaruh antropogenik. Jika pelepasan air sisa domestik tidak dirawat dengan rapi, air larian pertanian akan mempengaruhi kualiti air. Nilai WQI dinyatakan bersih untuk status kualiti air tercemar dari sungai dalam kawasan tadahan. Keputusan analisis perubahan gunatanah mendedahkan bahawa peningkatan kecenderungan perubahan positif untuk perkebunan pasaran diikuti dengan bunga-bungaan dan pembangunan bandar. Pengembangan besar perkebunan pasaran (16.37 km^2) dan kawasan bandar (4.15 km^2) telah berlaku dalam tempoh kajian menyebabkan penurunan ketara dalam kawasan hutan (22.85 km^2). Pengubahsuaian utama jenis tanah florikultur (8.04 km^2) dari perkebunan pasaran juga diperhatikan dalam kawasan kajian. Analisis cerun menunjukkan bahawa lebih daripada 40% kawasan di dalam kawasan tadahan mempunyai cerun dengan kecerunan antara sudut 10^0-30^0 darjah. Kadar ketara aktiviti pertanian yang dibangunkan di sepanjang cerun ini adalah dalam lingkungan kadar aktiviti menggantikan jenis tanah hutan dari semasa ke semasa. Perubahan gunatanah di kawasan tadahan telah disifatkan oleh pengembangan jenis penggunaan tanah dengan tekanan pembangunan yang lebih tinggi (aktiviti pertanian dan luar bandar) dan pengurangan beberapa jenis penggunaan tanah dengan nilai alam sekitar yang lebih tinggi (hutan dan tanah terpakai). Semua perubahan ini berkaitan secara langsung dengan kesan manusia dan didorong oleh aktiviti sosio-ekonomi serta dibantu oleh keadaan iklim yang menggalakkan. Perubahan pesat dalam aktiviti pertanian (perkebunan pasaran, florikultur) dan perkembangan bandar bersama-sama dengan ciri-ciri rupa bumi dan amalan pertanian yang tidak efektif telah menyebabkan pelbagai

kesan alam sekitar, termasuk degradasi tanah dan kualiti air di kawasan tadahan. Keputusan analisis yang disediakan menjadi asas bagi perlindungan persekitaran sungai dan pemulihan ekologi di pergunungan Bertam Tadahan. Selain itu, perancangan gunatanah mampan dan pengurusan adalah penting untuk mengendalikan keseimbangan antara pemuliharaan alam sekitar, pembangunan gunatanah serta penggunaan tanah.

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Water is an indispensable natural resource on earth, a crucial part of the environment and is one of the essentials that support all forms of plant and animal life (Vanloon and Duffy, 2005). Fresh water in the form of surface and ground is finite resource and also essential for agriculture, industry and even human existence.Without fresh water of adequate quantity and quality, sustainable development will not be possible (Kumar, 1997). Fresh water resource is becoming day-by-day at the faster rate of deterioration of the water quality is now a global problem (Mahananda et al, 2005). Therefore, the scarcity of clean and safe water has always been an issue of environmental concern throughout the world. 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. Thus, water quality degradation has now become a major concern all over the world. Water quality of surface water varies over space and time. It performs an important role on the health of aquatic ecosystems and human beings. In any region, it is influenced by both natural processes and anthropogenic changes through alteration of its hydrochemistry and damages their use for drinking, industrial, agricultural, reaction or other purposes. Hence, the assessment of water quality is one of the most important aspects in water resource studies that provide significant information for sustainable development and water resources management. (Bu, H. et al, 2010, Chen, Q. et al, 2012)

Worldwide deterioration of surface water quality is a combined effect of a number of factors, climate change and land use changes are being the most important ones. Any change of land use patterns by human activities, such as deforestation, urbanization, and agriculture practice modify the naturally occurring hydrological processes and the variables. These changing variables lead to soil erosion and deliver the sediments from modified land to the surface water bodies. This delivery of sediments is responsible for the supply of nutrients, pesticides and heavy metal contaminants and thus affects ultimately the water quality. Nowadays, the movement of pesticides and nutrients from agricultural lands into surface water is a great concern for degradation of water that affects the environment and subsequently agricultural products. (Ward, P. J., et al 2009, TDEC 2009, Seeboonruang, U. 2012). Climate change is an important factor that affectsthe water quality and quantity in streams of a watershed (Wilson and Weng, 2011).Like land cover change, climatic change can affect significantly the naturally occurring hydrological processes and variables and thus subsequent patterns of water quality. Climate change can affect water quality by directly changing the characteristics of water parameters or by affecting the hydrological cycle thus altering the urban or agricultural runoff over watersheds and the streamflow in rivers (Tu., 2009). It can also impact the quality by influencing land surface processes that regulate the production, release, and transport of natural materials and anthropogenic contaminants to ground and surface waters (Murdoch et al., 2000; Williams et al., 2008; Campbell et al., 2009). Many hydro climatic factors, including water and air temperature, precipitation amount and intensity, floods and droughts play important roles in land-water transport of chemicals affecting water quality. Water temperature changes can directly influence temperature-dependent water quality parameters including dissolved oxygen, redox potentials, pH, lake stratification and mixing, and microbial activity (Park et al., 2010). Therefore, unless addressed wisely, climate change adaptation challenges will adversely affect either water quality and aquatic ecosystem integrity, or the economic viability of agriculture, or both. (Adler, R. W. 2013).

Rivers in Malaysia have made immense contributions to the overall development of this country. In Malaysia, about 12 billion cubic meters of water are currently abstracted annually from the rivers, of which 22% is for water supply, 75% for irrigation and 3% for other uses. About 26% of the national electric power generated from hydropower. Unfortunately, the majority of the nation’s waterways are polluted by silt, due to soil erosion, unplanned land development activities, deforestation and mining activities (Abdullah. 1995). Moreover, current agricultural practices use agro-chemicals, particularly pesticides and fertilizers, creating problems for the environment - accumulating pesticide residues, as well as phosphates and heavy metals from both natural and chemical fertilizers in water. Hence, there is a need to control and maintain the quality of raw water in the river, to ensure better quality as deterioration of water quality will reduce usability (Fulazzaky et. al. 2010, Abdullah. 1995).

Like others, the river systems of Cameron Highlands play a vital role as a source of freshwater supply, agricultural activities, and hydroelectricity generation, as well as recreational activities. The area to be studied is one of the largest hill resorts in Malaysia and well known for its' agricultural and tourism activities. Agriculture is the largest land use (5,705.17 hectares), producing vegetables (47%), tea (44%), flowers (7%), fruit (1%) and other crops (1%). As the land is the center for vegetable farming, a huge dose of various types of fertilizers and pesticides are being used regularly. Moreover, uncontrolled deforestation, indiscriminate land clearing, and construction activities generate most of the eroded soils in the study area that lead to river bed sedimentation. Active deforestation in recent years has also affected the climatic condition - causing a negative impact on the tourism industry. Thus it is expected that these agricultural practice, land use changes, developments and climate change will cause tremendous pressure to the existing river system and its quality. (Yusof et. al. 2007, Toriman et al., 2010). Thus it is important to know the water quality status of the main river systems considering the combined effects of climate and land use changes in the study area.

1.2 Problem Statement

Cameron Highlands is a well-known highland resort famous for its cool pleasant climate, beautiful flower gardens and the variety of fruits and vegetables that flourish at its hillside farms. The economy of the highland is largely driven by its agricultural and tourism related activities.The river systems of the Highlands play a vital role as a source of freshwater supply, agricultural activities, and hydroelectricity generation, as well as recreational activities. Unfortunately, the water quality of River system has been deteriorated over time through the inclusion of increased point and non-point pollution loads as a result of rapid uncontrolled development, increased human activity and agricultural practices within the area (Aminu et al., 2014).

Over the years, the sensitive forest cover has drastically reduced in the upper catchment of 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 (Kumaran and Inuddin, 2004; Ismail et al., 2014). Therefore, the river system in the Highlands is under the severe threat of soil erosion and facing siltation problems (Toriman et al., 2010).With rapid growth of population and urbanization, the volume of solid waste generation in Cameron Highlands was increased to 46.05 tonne per day in 2013 from 22 tonne per day in 2000. A huge amount of wastes is dumped into open landfills due to shortage of existing treatment process (Ramli, 2014).The amount of wastewater discharge is released at random without the uses of a proper sewerage system due to inadequate sewage treatment plants. As a result, the river system receives domestic and municipal raw waste waters and leachate from garbage dumps from the main urban areas (Gasim et al., 2009). Increasing urban population also escalated the input of organic matter to the river system (Eisakhani and Malakahmad, 2009).In small settlement, latrine holes and direct releases into water courses are still practiced.

As the land is the center for vegetable farming, a huge dose of various types of fertilizers and pesticides are being used regularly also polluting the water quality. All the agricultural wastes were usually disposed in the hillside or near the river due to no specific places for their disposal in the highlands. Such wastes contain high chemical contents, flow into the river during heavy downpour.Nutrient losses are occurring due to the intensive farming practices within the catchment. The nitrate contents in both the runoff and leachate from vegetable farms were well above the acceptable limit of 10 ppm (Aminuddin et al., 2005).

Moreover, active deforestation in recent years has also affected the climatic condition - causing a negative impact on the tourism industry of the area. Rapid land use changes, most notably expansion of urban areas in recent decades have brought about climate change in the Highlands. Although the highland forests still provide a cooler climate regime, the rapidly changing land use is affecting this main tourist attraction (Chan et al., 2006). All these anthropogenic and natural activities significantly influenced the water quality of river system, leading to adverse effects on the aquatic environment of entire Highlands. Therefore, it is essential to find out the sources of pollution and the water quality trend that can generate important information for the authority concerned or policy maker to take proper action for better management.

1.3 Significance of the Study

The Cameron Highlands is experiencing rapid development as a popular tourist destination causing a rapid boost in construction and other tourism related activities.Agriculture is the main socio economies activity in the highlands of study area. The cold and temperate weather makes the area most suitable for many agricultural products. More importantly, the Highlands is a water catchment area, which provides fresh drinking water to households in both highlands as well as lowlands. The water is also used for other commercial utilizations of the Highlands. For portable water, 12.5 MLD was abstracted and processed in 2009 and the demand likely to be targeted 20.07 MLD by 2020 (NWRS, 2011). However, agricultural practice as well as development activities has led tremendous pressure to the existing river system and its quality. The highland areas are also particularly susceptible to climate change that change results in stress on the plant production capacities.

This research pinpoints the importance of local study to identify the current status of water quality as well as changing pattern of landuses in Bertam Catchment.The research would provide a technical support for the water quality improvement and management in Bertam River, which have a great significance for the sustainable economic development of Cameron Highlands, Malaysia. The result of this study can be used as baseline information on river water quality and can also be used as reference for further research.

1.4 Objectives

The aim of this research is to assess the combined effects of climate change and land use changes on the water quality of Bertam River in the Cameron Highlands area, Pahang, Malaysia.

The main objectives are;

i. To determine the spatio-temporal variation of surface water quality based on land use changes in the study area.
ii. To assess the potential effects of climate change and land use management on water quality in the study area.
iii. To perform the integrated approach of land use and climate changes impact on water quality.

1.5 Scope of the Study

In achieving the objectives of the present study, the scope of work is outlined as follows:

- Assessment of water quality status for adopting specific measure to preserve the desired water quality.
- Calculation of land use changes and their impact on surface water in the study area.
- Assessment of the impact of climate change on surface water quality to conserve the agro tourism and economic activities of the study area.
- Finally, development of an integrated approach that will help policy maker to manage and preserve the water resources environment.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Water is a crucial part of the environment that is common in nature and essential for all forms of lives. No life can survive without water. Although, the earth is like a water planet, fresh water that is essential for the environment as well as all living beings is becoming scarce. This scarce resource is under tremendous threat of pollution, as water quality degradation is now a universal problem partly due to uncontrolled natural and anthropogenic activities. Thus, water quality degradation has now become a major concern all over the world

Although more than 72% of the earth is covered by water (Beard, 2013; Rao, 2004), the available water is only about 2%, a rather small amount. The major source of available water is the surface water that comes mostly from the river basins. River plays a vital role in the surrounding environment of any locality exclusively for the hydrology and natural balance. It protects the aquatic community from several environmental problems and provides energy and nutrients (Losco et al., 2012). It also provides a wide range of services to the society by giving facilities of transportation and several terms of usages like water supply for drinking and irrigation, industrial uses, and recreational and spiritual activities (Losco et al., 2012). Moreover, rivers contribute substantially to industrial, agricultural and economic development along with potable water supply and provide opportunities for recreation and aesthetic. On the other way, rivers play a major role in assimilating or carrying industrial and municipal wastewater and manure discharges and runoff from agricultural fields, roadways, and streets, i.e., major sources of river pollution (Mouri et al., 2013). Thus, for effective and efficient water management it is important to have reliable information on water quality.

Water quality is affected by a combination of natural and anthropogenic factors, climate change and land use changes are being the most important ones. Climate change is an important factor that affectsthe water quality and quantity in streams of a watershed (Wilson and Weng, 2011).Climate change affects the hydrological cycle, thus changing the runoff over watersheds and the streamflow in rivers and also modifying the transformation and transport characteristics of water pollutants. Therefore, climate change is an important factor affecting water quantity and quality in streams. Climate change, including extremes, can affect water quality, not only by directly changing the characteristics of the water, but also by influencing land surface processes that regulate the production, release, and transport of natural materials and anthropogenic contaminants to ground and surface. (Murdoch et al., 2000; Williams et al., 2009; Campbell et al., 2009, Tu, J.,2009)

The growing population and increasing socio-economic essentials have accelerated the demand for landuse-land cover, and this pressure gives rise to the unplanned and uncontrolled changes in land use (Kibena, J et al 2013). These land use patterns also affect water quality through changing hydrological and chemical runoff processes in a watershed. When runoff carries pollutants from upland areas into a river system, the spatial patterns of the watershed modify the land use effect on the water quality of adjacent aquatic systems (Lee et al., 2009). Therefore, changes in land use and management practices can have considerable impact on water quality parameters. Water quality deterioration and water management are major concerns in sustainable development. To ensure sustainable development, it is essential to understand the impact of land use management and climate change on water quality.

2.2 Water quality studies

Water qualityis commonly defined by its physical, chemical, biological and aesthetic (appearance and smell) characteristics. For surface water, the physical characteristics of water quality constituents the on-site field parameters and generally include: dissolved oxygen (DO), conductivity, pH, temperature and stream flow. Conventional chemical parameters are typical water quality constituents that require laboratory analysis and generally include: COD, BOD, nutrients, total suspended solids, turbidity, hardness, chloride, and sulfate. Biological characteristics include generally E. coli, Total coliform and Fecal coliform.

2.2.1 Physical parameters

2.2.1.1 Temperature

The surface water temperature usually ranges between 0 ºC and 30 ºC. Water temperature effects on oxygen solubility as increased water temperature causes the depletion of the solubility of dissolved oxygen (DO). A water temperature above 27 °C is considered "unsuitable" for public use and above 32 °C it would be considered "unfit" for public use (Chapman, 2002). The aquatic ecosystems largely depend on water temperature, especially the metabolic rate of aquatic organisms that varies with fluctuation of temperature. Higher water temperature enhances respiration rates of aquatic organisms that lead to increased oxygen consumption. This results in more decomposition of organic matter followed by increase in water turbidity (Dallas, 2008) . Moreover, higher temperature (more than 26 °C) can make the toxic chemical more soluble and may cause more harm to the aquatic life including fish. Higher surface-water temperature can affect the biological productivity and can accelerate the growth of bacteria and fungi in the water and encourages algal blooms (Kundzewicz et al., 2007). This may create toxic contaminants that cause serious threats to human and aquatic ecosystem health (UNEP, 2010).

2.2.1.2 pH

The pH is one of the most important water quality parameters for all forms of water in the environment. It is a measure of hydrogen ion concentration that expresses the acidity or alkalinity of a solution on a scale of 0 to 14. pH for neutral water is 7, alkaline water has higher pH values (8-14), and acidic water has low pH values (0-6).It plays a critical role in the chemistry of river water quality. Fluctuation of pH from natural level may affectmany chemical and biological processes in the water.The pH range of 6.5 - 8.0 is favoured by the largest species of aquatic animals (Malallah and Daifullah, 2008).

Level of pH is influenced by several conditions, such as, presence and amount of organic matters, soil on which the water is moving, sources of water and so on. Higher organic matter leads to higher decomposition, which can affect the pH level. Similarly, soil pH also effect on water pH level. Generally, peat soil and the water peat soil can cause decline in water pH level largely (Euro-limpacs, 2009; Shrestha and Kazama, 2007). Biological decomposition of vegetation associated with humic acid also causes low pH in surface water (Yusuf, 2001).

2.2.1.3 Conductivity

Conductivity of water is one of the most important parameters for water quality analysis. It is largely affected by the presence of inorganic dissolved salts, such as, the anions of chloride, nitrate, sulphate, and phosphate or the cations of sodium, magnesium, calcium, iron, and aluminium. EC is the measurement of the total ions in the water. It is temperature sensitive and usually increases with temperature (Appelo and Postma, 2010; Balandin, 2011). Conductivity of water is an indirect measure of the TDS and can cause the corrosiveness of water, eye irritations, reduced portability, increase toxicity and reduce habitat suitability (Ali et al., 2012).

2.2.1.4 Dissolved oxygen (DO)

DO is an important indicator of water quality. It is the barometer for the river ecosystem and a key factor for the aquatic life (Kannel et al., 2007). It indicates whether the water is polluted or not. Biological and biochemical reaction in water depend on DO availability. The source of DO in river water is mostly natural. Oxygen can dissolve in river water freely from atmosphere by inducing air into water flow. DO concentration in water also depends on temperature largely. Besides atmosphere, photosynthesis of aquatic plants also contributes a considerable amount of DO in water (Moss, 2013). The DO concentration in water is directly related to the biological and biochemical process i.e. decomposition of organic matter and thus the amount of organic matter in water is a big factor for DO concentration (Moss, 2009). Effluents from industrial, residential and urban areas that contain a lot of organic matter ultimately cause depletion of DO in the adjacent water bodies. Therefore, the main causes of low DO levels in river water are the discharge of organic matter in the form of effluents or wastewater into rivers. The sources of these effluents or wastewater can be from treatment plants, multifarious industries, domestic and urban wastewater(Ahmed et al., 2012).

2.2.1.5 Turbidity

Turbidity is a visual quality of water, which indicates the deficiency of clearness of water and the degree of interfering of the straight-line transmission of light into it (Allen et al., 2008). Turbid water is unfit for industrial as well as homestead or recreational uses. Turbidity lessens the amount of light entering the water column that results in a decrease of photosynthesis of aquatic plants (Wilson, 2013). Anthropogenic activities increases turbidity and may lead to concerns about the impact on various fisheries species. Urbanization and residential areas contribute a lot to turbidity to the nearby water bodies through storm water pollution from paved surfaces such as, roads, bridges and parking lots. Forestry activities including timber harvesting, deforestation for new land use development and management cause huge soil erosions and runoffs that contribute to increased stream sediment followed by turbidity (Webb and Haywood, 2005).

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2.2.1.6 Total dissolved solids

A total dissolved solid (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, sulphates and nitrates, and cations of sodium, potassium, calcium and magnesium. On the other hand, organic sources include leaves, silt, and plankton, and industrial, domestic and 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 also release ion when water moves over them to consequently causing increase TDS level in surface water (Lawson, 2011;Wilson et al., 2013). Water with a TDS concentration above 1000 mg/L is usually considered unsuitable for human consumption as high TDS indicates the hardness of water. It can change the taste of water from normal taste to bitter, salty or metallic. High TDS also indicates the presence of toxic minerals such as, nitrates, sodium, sulfates, barium, cadmium, copper, and fluoride in water (Lawson, 2011)

2.2.1.7 Total suspended solids (TSS)

TSS are solids in water that can be trapped by a filter. Suspended solids usually occur naturally in river and lake water. However, the 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 newly construction sites are the potential sources of suspended solids in water. Excessive algal growths also contribute to the higher concentration of TSS in water (Akan et al., 2012; Lawson, 2011). A water body loses its capability to support a diversified aquatic life when TSS level increases in that water (Akan et al., 2012). 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.

2.2.2 Chemical parameters

2.2.2.1 Organic material (BOD and COD)

BOD is a measure of the amount of oxygen consumed in the biological process that breaks down organic matters in water. COD is a measure of oxygen required to oxidize all compounds (organic and inorganic) in water. Both BOD and COD provide an indirect measure of the concentration of biologically degradable and organic material present in water. Sources include plant decay, leaf fall, grass clippings and yard waste in water, pulp and paper mills, meat and food processing plants, vehicles (engine coolants/antifreeze), agricultural runoff, livestock operation, and treatment plant loading. Seasonal variation was also noticed that in the wet season due to increased water flow COD was recorded comparatively lower than the dry season (Varol et al., 2012).

2.2.2.2 Nutrients

Sources include residential and commercial lawns, agricultural and golf courses runoff (fertilizers), organic decomposition, decaying of human and animal waste, wastewater treatment plants, septic tanks, and the burning of fossil fuel and industrial waste (Barth, 1995). TN is organically and inorganically bound nitrogen (combination of ammonia, organic nitrogen and inorganic nitrogen). TP represents a combination of ortho phosphate, condensed phosphate, and organic phosphate. In a water body, ammonia exists in two forms, ionized ammonium (NH_4^+) and un-ionized ammonia (NH_3). The sum of these two forms of ammonia is referred to ammoniacal nitrogen (Ebeling et al., 2006). Free toxic ammonia may rapidly convert to non-toxic ammonium (NH_4^+) ion in acidic condition. Unpolluted fresh water generally contains small amount of ammonia and ammonia compound, normally < 0.1 mg/L and rarely contains >0.05 mg/L (EQMD, 2005).

The nitrate ion (NO_3^-) is the common form of combined nitrogen found in natural water. Nitrite (NO_2^-) ion rapidly oxidises to nitrate. Higher level of nitrate in surface water can affect phytoplankton growth (Hutchins, 2012). Excessive amount of nitrate can cause extreme growth of algae (Wang et al., 2008). The major source of nitrate concentration in surface water is the agricultural runoff (Cleophas et al., 2013; Gasim et al., 2006). Alike nitrogen, phosphate (PO_4^{3-})is one of the limiting factors of aquatic environment that controls the productivity of aquatic organisms (Howarth and Marino, 2006). It is an essential element for plants and aquatic organisms. Higher level of phosphate greatly stimulates the growth and production of algae that can cause eutrophication in water bodies. 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 (Wu et al., 2012).

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 (Comber et al., 2013;Tyler et al., 2012). Phosphate is a common water quality parameter in agricultural areas because a substantial amount of phosphate fertilisers 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 (Tirado and Allsopp, 2012). 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 (Amist, 2010).

2.3 Impact of landuse

2.3.1 Introduction

Land use change is a general term to identify the human modification of Earth's terrestrial surface. Natural processes and both direct and indirect effects of human activities are major drivers of landuse change (GLP, 2005, Hopkins, 2009). The growing population and increasing socio-economic essentials have accelerated the demand for landuse-land cover, and this pressure gives rise to the unplanned and uncontrolled changes in land use (Kibena, J et al 2013), driving unprecedented changes in ecosystems and environmental processes at local, regional and global scales. These changes encompass the greatest environmental concerns of climate change, biodiversity loss and the pollution of water, soil and air. Land use patterns actually affect water quality through changing hydrological and chemical runoff processes in a watershed. When runoff carries pollutants from upland areas into a river system, the spatial patterns of the watershed modify the land use effect on the water quality of adjacent aquatic systems (Lee et al., 2009). Therefore, changes in land use and management practices can have considerable impact on water quality parameters.

Nowadays, Development activities such as agriculture, urbanization, forestry and industries often lead to more intensive landuse which modify the geomorphologic features, increases runoff and the consequent transport of pollutants directly into waterways is a great concern for degradation of water that ultimately affects the environment.Rivers are recipients of pollutants from adjacent landscapes, acting as integrators of land-water interactions. The quality of receiving waters is affected by these changes through point source pollution and non-point source pollution. (Schock, 2000, Ward et al., 2009, TDEC 2009, Zhou et al. 2012, Kibena et al. 2013). Advanced spatial tools (e.g., geographical information systems) combined with water quality assessment techniques make these studies convenient (Griffith, 2002; Tong et al. 2002; Bu et al. 2014).

2.3.2 Water pollution sources

Pollutants affecting water quality may come from point or nonpoint sources. Surface water impairment due to point source (PS) and nonpoint source (NPS) pollution threatens the aquatic ecosystems and water supply security. PS pollution mainly includes municipal sewage and industrial wastewater loads discharges mainly from urbanization areas from urban or highly residential areas and from a variety of manufacturers. Point source impurity enters the water resource at an easily identifiable, distinct location through a direct route. Point sources are relatively simple to measure and regulate, and can often be controlled by treatment at the source places.

NPS pollution occurs when rainfall, snowmelt water or irrigation water runs over land, carrying and depositing pollutants into rivers, lakes, and coastal waters. NPS pollution presents great challenges because of their dispersed origins and because they vary with the season and the weather. 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 different land surface, which carries the residues from the land and be enriched with different kinds of contaminants. It is therefore conceivable that the strong and immediate relationship exists between land use-land cover and water quality. These pollutants vary by the land -use source of the runoff. Different land uses may contribute different amounts and ratios of pollutants.

Agricultural activities have been identified as major sources of NPS pollutants like sediments, animal wastes, plant nutrients, crop residues, inorganic salts and minerals, pesticides and are known to have major impacts on water quality (Wu and Chen. 2013).

Urban areas have the potential to generate large amounts of NPS pollutants from storm-water discharge. The imperviousness of many urban areas increases their hydrological activities, and even small rains are capable of washing accumulated pollutants into surface waters. Pollutants that occur in urban areas vary by land-use source of runoff. The major pollutants found in urban runoff include sediments, nutrients, increased alkalinity, phosphorous, nitrate and nitrogen, metals and BOD (Tong et al., 2002, Dabrowski, 2013).

2.3.3 Relationship between landuse and water quality

It is widely known that watershed hydrology is dependent on many factors, such as land use and land cover, climate, soil conditions. In fact, there is a long history of such studies, and many of them have documented the significant relationships between landuse and water quality. The effects of specific land use on surface water quality were summarized in this literature review. The three non-point source landuses that have received the most attention are forested (harvested) land, agricultural land and urban land. The relationships between land use and water quality may also be impacted by the analysis scale (e.g., watershed, sectioned-watershed, buffer and site), which determines the area used to link the land use types with a water sampling site's physical and chemical properties (Carey et al., 2011; Pratt and Chang, 2012, Kibena et al, 2013).

2.3.3.1 Agricultural impact on water quality

Agriculture activities indicate a human alteration of natural Earth environment, which can often lead to the increasing erosion and water quality degradation. Agriculture has long been considered the leading non-point source contributor to water quality impairment (Carpenter et al., 1998). Agricultural activities can have many adverse effects on streams and rivers, such as increased nutrients, total suspended solids (TSS), and pesticides. The application of both nitrogen and phosphorus fertilizers and manure to agricultural lands combined with disturbed soils contributes to the large nutrient loads from these landscapes (Carpenter et al., 1998). Excessive inputs of nutrients (especially, nitrogen and phosphorus) cause increased growth of nuisance algae, which leads to more rapid eutrophication, eventually lowering dissolved oxygen (DO) levels and threatening water quality for human consumption. An excess amount of phosphorus generally results in eutrophication in freshwater streams, while excessive nitrogen often causes eutrophication in estuaries. Siltation as a prominent source of NPS pollution results from agricultural which is capable of altering aquatic habitat, suffocating fish eggs and other benthic community, drinking water treatment and the recreational use.

Some researchers concluded that agricultural coverage strongly influenced water nitrogen (Fisher et al., 2000; Ahearn et al., 2005, Kibena et al., 2013), phosphorus (Kibena et al., 2013, Hill, 1981, Mouri et al., 2013), total suspended solids (Kibena et al., 2013, Ahearn et al., 2005, Mouri, G et al, 2013) and sediments (Glavan et al., 2013, Zhang et al, 2013). A number of authors, Tong and Chen (2002) examined the relationships of land use and water quality on a regional scale in the watersheds of the Ohio State, USA. They found that TN (total nitrogen), TP (total phosphorus), conductivity, and fecal coliform were significantly positively related to agricultural lands as well as sodium and heavy metals had significant strong negative relationships with agricultural land, but non-significant relationships but a non-significant with agricultural land. 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. Bu et al (2014) showed a seasonal relationship between land use patterns and water quality of Taizi river basin. The authors demonstrated that agricultural and built-up land uses have significant effects on most water quality variables during rainy season whereas built-up landuse more significantly influences on nutrient variables than agricultural land uses during dry season. Kibena et al (2013) studied that expansion of agriculture areas by 24.4% affecting the nutrients and sediment loads in the water quality in Upper Manyame River, Zimbabwe. Result showed that Increased agricultural area have a strong positive relationship with TN, TP and TSS indicative of extensive use of fertilizers from upstream urban agricultural activities and of poor agricultural activities. Glavan et al (2013) explained historical agricultural land use situations (1787, 1827, 1940, and 1984) have demonstrated very adverse effects on the water quality, as all showed increase in the quantity of pollutants in watercourses, especially significant is increase in sediments.

2.3.3.2 Urban impact on water quality

Urban land cover, incorporating the effects of increased population, domestic water use, and industrial wastewater, was positively associated with increases in water pollution and was included as an important explanatory variable for the variations in all water quality parameters. Urban land use, through alterations of physical and hydrologic features of watersheds and the production of additional anthropogenic nutrient sources (i.e., lawn fertilizers, pet waste, septic tank effluent, accelerated erosion), is thought to be an important cause of lake and stream water quality degradation (Carpenter et al.,1998, Mouri et al., 2013). 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. Thus, increasing nitrogen load might be associated with land development in watersheds. Increases in nitrogen load or concentration caused by urban development have been reported in watersheds around the world (Tong and Chen, 2002; Tu. 2009).

In addition to imperviousness surface, runoff from urbanized surfaces as well as municipal and industrial discharges carried greater sources of pollutants, which resulted in the increased loading of nutrients (Praskievicz, S., & Chang, H. 2009*,* Rose, 2002), heavy metals (Callender and Rice, 2000), sediment loadings (Praskievicz, S., & Chang, H. 2009) and other contaminants to the stream waters. Therefore, when land development occurring, maintenance of stream water quality, is critical for the protection of drinking water and biotic integrity (Schoonover and Lockaby, 2006).In many developed watersheds, agriculture land occupied a large proportion of the total land area, whereas urban land covered relatively smaller fraction. However, the urban land area containing high density of population had the significant influence on water quality from human activities. A number of documents illustrated increasing impervious surface coverage within urban catchment, altered the hydrology and geomorphology of urban streams and gave the negative impacts on urban stream ecosystems (Morse *et al,* 2003, Wu and Chen 2012). Mouri et al (2013) examined the impact of urban areas and of forest and agricultural areas on stream nutrient and sediment concentrations in the humid northwest region of Shikoku Island, Japan. Relationships among land use and water quality - urban land cover positively influenced BOD, TP and SS. Kibena et al (2013) 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.

2.3.3.3 Forest impact on water quality

Compared to agricultural and urban landscapes, nutrient loads from harvested forested landscapes are quite low (Ye et al., 2009). While the loss of forest cover reduces the recycling and uptake of nutrients and increases the possibility of soil erosion, these landscapes do not typically receive additional nutrient inputs from fertilizers or anthropogenic sources which greatly reduce the amount of nutrients that they supply to nearby river systems.Different from urban and agriculture land covers, forest was observed as the smallest contributor to water quality degradation in all cases. In the study of Basnyat et al (2000), the results indicated that, forest or grassland were acting as a "sink" or active transformation zone; the water quality represented the health status when forest and grassland were located adjacent to the streams, while agricultural or urban area located adjacent to stream had the significantly negative impact on water quality. Similar conclusion had also suggested in the Ruvu river watershed (Ngoye et al, 2004), the author demonstrated that stretches of the river in forest land had lower nutrients concentration compared to the areas close to human activities. A recent study conducted by Luo et al (2010) confirmed the earlier studies that forest and grassland were the nitrogen sinks while dry land and residential area exported significant amount of nitrogen in Hujiashan watershed. In surface areas covered by forest or rangeland, the terrestrial and aquatic environments are in dynamic equilibrium (Rogers, 1994). Hence, forest and rangeland have minimal effects on water quality.

2.3.3.4 Far field landuse vs near field landuse

The effect/influence of land use on stream water quality is scale dependent and varies over time and space. The scale dependence of the relationship between landscape pattern and water quality has important implications for watershed research and management as well as restoration.

Through numerous documents have determined the significant relationships between water quality and land cover characteristics found within a watershed drainage area, some other studies suggested that the clear influences from land cover on water quality only existed within a shorter distance of the receiving water body (Barling and Moore, 1994). Tran et al (2010) demonstrated the importance of considering the proximity to assess the influence of land use in water quality in New York State; the result suggested that land use of near-field (200-m buffer on each side of the stream) had the larger impact on water quality than the influence of far-field land use encompassing a watershed drainage area. Basnyat et al (2000) also suggested the importance of stream-side management zones which was important to maintain the stream water quality in the Fish River, and the authors further demonstrated that maintaining adequate stream-side buffers could mitigate the water quality problems due to land use activities, and the buffer width might differ from one watershed to another based on community objectives for water quality. Zhou et al (2012) also analyzed the relationship of water quality in multiple spatial scales and found that most water quality variables (Cl−, EC, NH3–N, and NO3–N) are strongly correlated at the sub-watershed scale than at the catchment and buffer scales at Dongjiang River in China. Gyawali et al (2013) studied on the relationship of land use patterns of 100m riparian zone of the river and water quality parameters and showed that Urban land showed significant positive correlation with TEMP, SS and dissolved solid (DS) and negative correlation with pH. Similarly, agriculture showed significant positive correlation with SS and DS and negative correlation with TEMP and DO.

2.4 Impact of climate changes

2.4.1 Introduction:

Climate change is an important factor that affectsthe water quality and quantity in streams of a watershed (Wilson and Weng, 2011). Climate change can affect water quality by directly changing the characteristics of water parameters or by affecting the hydrological cycle thus altering the urban or agricultural runoff over watersheds and the streamflow in rivers (Tu. 2009). It can also impact the quality by influencing land surface processes that regulate the production, release, and transport of natural materials and anthropogenic contaminants to ground and surface waters (Murdoch et al., 2000; Williams et al., 2008; Campbell et al., 2009).

Many hydro climatic factors, including water and air temperature, precipitation amount and intensity, floods and droughts play important roles in land-water transport of chemicals affecting water quality. Higher water temperatures result in lower levels of dissolved oxygen, increased concentrations of phosphorus and other pollutants, increased algal blooms, and high levels of bacteria and fungi. Areas receiving more precipitation and more intense storms generate more and more intense runoff, which increase loadings of sediment, nutrients, pesticides, animal wastes, pathogens, and other contaminants. Increase temperature and rainfall affect the river flows hence influence on the mobility and dilution of nutrients and other pollutants. Water temperature changes can directly influence temperature-dependent water quality parameters including dissolved oxygen, redox potentials, pH, lake stratification and mixing, and microbial activity (Park et al., 2010).

2.4.2 Climate change variables

The climate change determinants affecting water quality are mainly the ambient (air) temperature, rainfall and the increase of extreme hydrological events. Regional precipitation patterns and air temperature play a significant role in the dynamics of water quality, particularly for surface waters. Solar radiation increase may also be considered (Delpha et al. 2009).

First of all, temperature, in general, must be viewed as the main factor affecting almost all physico-chemical equilibriums and biological reactions. Most chemical reactions and bacteriological processes run faster at higher temperatures. It is well known that all physico-chemical “constants” vary with temperature, and frequently increasing endothermic reactions. Consequently, several transformations or effects related to water will be favoured by water temperature increase such as dissolution, solubilisation, complexation, degradation, evaporation, etc. This phenomenon globally leads to the concentration increase of dissolved substances in water but also to the concentration decrease of dissolved gases, importantly, the dissolved oxygen in water. Increased water temperatures will affect chemical reaction kinetics and, combined with deteriorations in quality, freshwater ecological status (Whitehead et al. 2009). Remind that, whatever the IPCC scenario, the average global air temperature should increase between 1.8 and 4.0 °C (Bates et al., 2008) during the 21st century. Moreover, a drying tendency in summer is expected, particularly in subtropics, low and mid-latitudes, in addition with an extreme events increase in general. Arise in surface water temperatures was observed since the 1960s in Europe, North America and Asia (0.2–2 °C), mainly due to atmospheric warming in relation to solar radiation increase (Bates et al., 2008).

Higher temperatures imply higher potential evapotranspiration, which might result in increased actual transpiration and thus also changes in percolation and drain flow. In addition, temperature governs processes such as freezing and thawing, as well as the partitioning of precipitation into rainfall and snow. Higher temperatures also enhance diffusion rates, which would tend to increase rates of equilibration of pesticide concentrations between micropores and macropores, and thereby lead to reduced leaching by preferential flow. For heavy rain falls and strong hydrologic conditions, runoff and solid material transportation are the main consequences. Intensity of precipitation can lead to change the runoff over a watershed and the streamflow in rivers and consequently modify the transformation and transport characteristics of water pollutants (Tu., 2009). With increased flows there will be changes in stream power and, hence, sediment loads with the potential to alter the morphology of rivers and the transfer of sediments to lakes, thereby impacting freshwater habitats in both lake and stream systems. Increased rainfall could affect river flows and, hence, the mobility and dilution of contaminants (Whitehead et al., 2009).

Solar irradiation increase could also alter water quality and especially characteristics of natural organic matter in freshwaters systems both by warming and UVB radiation (increasing photolysis) (Soh et al., 2008). Floods and droughts will also modify water quality by direct effects of dilution or concentration of dissolved substances. For low river flow rates, the main effect on water quality is as for a temperature increase, a concentration increase of dissolved substances in water but a concentration decrease of dissolved oxygen (Prathumratana et al., 2008; Van Vliet and Zwolsman, 2008). A correlative positive effect is the concentration decrease of some pollutants due to a low water velocity (aquatic plants assimilation of nutrients and adsorption/complexation of heavy metals on suspended matter and settling). Storms that terminate drought periods will flush nutrients from urban and rural areas or generate acid pulses in acidified upland catchments. (Delpla et al., 2009, Whitehead et al, 2009). These climate variability, including extreme events such as floods and droughts, have been suggested to have significant impacts on and hydrology water quality around the world (Murdoch et al., 2000; Worrall et al., 2007). Potential impacts on water supply and hydrology have received much attention, but relatively little is known about the concomitant changes in water quality.

2.4.3 Impact on hydrology

Many previous studies have assessed the impact of climate change on hydrology (Delpla et al., 2009; Stulina, & Eshchanov. 2013). These studies found that streamflow variability is closely associated with climate change. Ficklin et al (2009) predicted an increase in water yield by 36.5%, and stream flow by 23.5% compared to the present-day climate in the highly agricultural San Joaquin watershed in California for averaged over 50 simulated years due to an increase in CO2 concentration, temperature and Precipitation. Zarghami et al (2011) found that changes in temperature and precipitation patterns by scenario analyses have serious impacts on the quantity and quality of water supply in Tabriz city, East Azerbaijan. The research outcomes, based on the scenario, show an average annual temperature rise of ~2.3 °C and an annual precipitation reduction of ~3% will convert the study area from semi-arid to arid, and the permanent rivers will change to seasonal rivers.

2.4.4 Impact on water quality

Few scientific works have been published until recently on the impacts of climate change on water quality modification. Zwolsman and van Bokhoven (2007) and VanVliet and Zwolsman (2008) observed an average increase in water temperature of around 2 °C respectively in Rhine and Meuse rivers after the severe drought of 2003, with a pH increase and a decrease in dissolved oxygen (DO) solubility reflecting a lower DO solubility under higher water temperatures. In the same study dealing with the surface water quality in the lower Mekong River, negative significant correlations were generally found between precipitation (or discharge flow) and DO, pH and conductivity (from 0.2 to 0.9) (Prathumratana et al., 2008). It was finally shown in the study that COD (Chemical Oxygen Demand), used as an indicator of Natural Organic Matter (NOM), have weak to fair correlations with precipitations (0.295–0.426) and discharge flows (0.312–0.324). Cox & Whitehead (2009) show that, under a range of UKCIP scenarios, DO in the River Thames will be affected in the 2080s by enhanced BOD, and by the direct effects of temperature which reduces the saturation concentration for DO.

Water quality is subjected to weather seasonality which has an important impact on their nutrient patterns (Zhu et al., 2005). A warmer climate will create indirect impacts on water bodies like an increase nutrients load in surface and groundwater (Van Vliet and Zwolsman, 2008). Indeed, higher temperatures will increase mineralization and releases of nitrogen, phosphorus and carbon from soil organic matter. Moreover, an increase in runoff and erosion due to greater precipitations intensity should result in an increase in pollutants transport, especially after a drought period. Higher ammonium concentrations could be observed in rivers with a reducing dilution capacity caused by droughts (Zwolsman and van Bokhoven, 2007; Van Vliet and Zwolsman, 2008). Correlations between precipitations, air temperature, discharge flow and phosphates, nitrates and Total Phosphorus (TP) in the Mekong River have also been observed (Prathumratana et al., 2008). Drewry et al (2009) also found positive correlations between TP, total nitrogen, suspended solids and flow. P increases in the surface layer, fueling phytoplankton growth (Jackson et al., 2007), leading to algal blooms and a deterioration of water quality (Komatsu et al., 2007).

Ducharne et al (2007) predict an increase in nitrate concentration in the Seine basin aquifer layers for the years 2050 and 2100 due to an increase in precipitations and consequently in soil leaching. Kaste et al (2006) and Arheimer et al (2005) respectively predict a 40–50% increase in nitrate flux by 2070–2100 in a Norwegian river basin, and an increase in phosphorus (50%) and nitrogen (20%) in a lake. Bouraoui et al (2004) studied the impact of climate change on nutrients and suspended solids using 34 years of historic climate data. By removing the trends in temperature and precipitation, they found that observed climate change has resulted in increased annual and winter nutrient transport.

2.4.5 Combined impact

Very few studies have analyzed the combined effects of climate and land use changes on streamflow and water quality (Tu., 2009; Wilson et al., 2011, Wu et al., 2012). Tu (2009) studied on combined impact of climate and land use changes on streamflow and water quality by using a GIS-based watershed simulation model, AVGWLF, to simulate the future changes in streamflow and nitrogen load under different climate change and land use change scenarios in watersheds of eastern Massachusetts. The results show that climate change and land development have more impact on changing the seasonal distributions of the streamflow and nitrogen load than on altering average annual amounts of the streamflow and nitrogen load. Wu et al (2012) studied on integrated impacts of climate and land-use changes on the migration of non-point source nitrogen and phosphorus during rainfall-runoff in the Jialing River Watershed, China and assessed the impact of climate change on hydrological behavior considering future land-use types and rural residential area and their propagation to NPS pollution loads.

2.5 Conclusion

The impact of water quality studies due to land use pattern and climate change in local, national and global contexts have been reviewed in this chapter. The reviewed studies suggest that the surface water deterioration was due to the organic substances and inorganic nutrients, suspended solids, dissolved solids, heavy metals and pesticides. They were induced by natural and anthropogenic activities. Combined land use patterns and climate change were one of the major reasons for deteriorating the water quality. In Cameron highlands, there had been no in-depth, long-term and comprehensive water quality study covering most of the important water quality parameters and other important aspects. However, no study was performed on water quality assessment in the area with view to landuse management and climate change in detailed. Moreover, as the study area is the center for vegetable farming, a huge dose of various types of fertilizers and pesticides are being used regularly also polluting the water quality. Therefore, it is prime require to monitor the pesticide information in a regular basis.

Therefore, this study will employ an integrated approach involving Geographic Information System (GIS), Statistical and Spatial Analysis to conduct a comprehensive study on the relationship between land use, climate variables and water quality in Bertam River in Cameron Highlands, Malaysia.It would provide a technical support for the water quality improvement and management in Bertam River, which have great significance for the sustainable economic development of Cameron Highlands, Malaysia.

CHAPTER 3

MATERIALS AND METHODS

3.1 Introduction

This chapter describes about the study area, the methodologies and procedures used to establish the monitoring stations for water quality assessment, calculation of water quality index, landuse and climate change. This chapter also includes the monitoring stations selection techniques, procedures for measurement of parameters, plan for sampling approach, methods of laboratory analyses and data analysis with statistical software.

3.2 Description of the study area

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 District on the south-east (Fig.3.1). The Highlands is 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°35’ E and latitude 4°19’ to 4°31’ N.

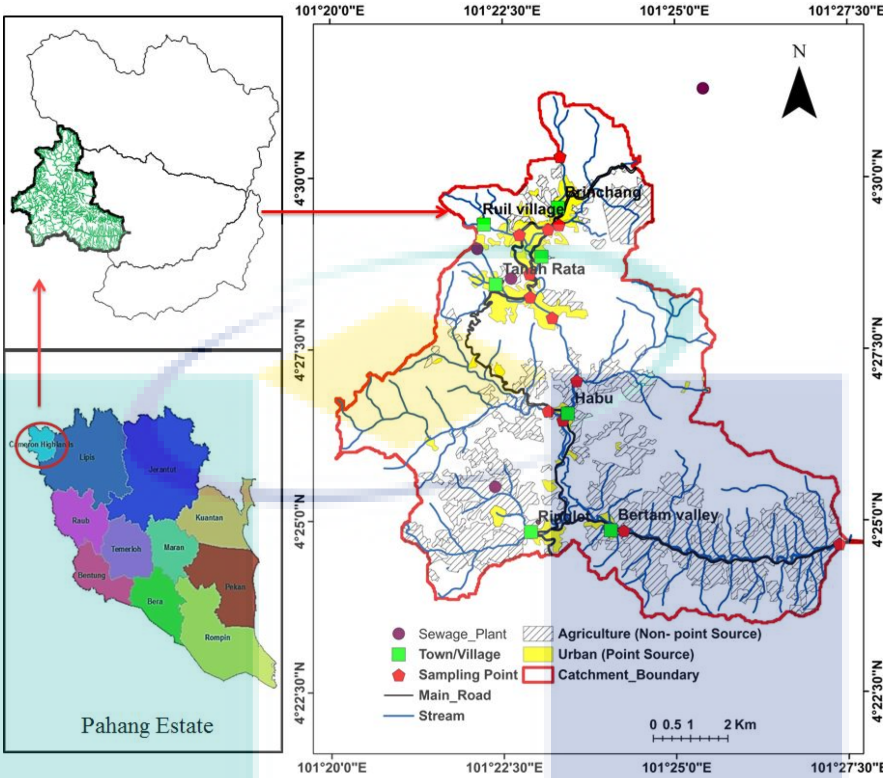


Fig 3.1: Location map of the study area

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 and its terrain height varying in range from 1000 m at the river valley on the eastern boundary to 2031 m on the western boundary. The average elevation of the area is 1180 m and the highest peak is Mountain Brinchang at 2032m (Tenaga National Berhad Research, 2009; Kumaran and Inuddin, 2004). About 75% of the area is located above the elevation of 1000 m above mean sea level (Kumaran and Inuddin, 2004). Generally the mountainous terrain is strongly dissected with 10^0-35^0 slopes. More than 66 per cent of the land has a gradient of more than 20° (Abdullah et al., 1998). Much of the Cameron Highlands, however, embodied in areas greater than 40 degree slope (Leong, 1992) (Table 3.1).

Table 3.1 Slope Class Distributions

Class	Slope degree	Percentage	Total area (h)
Class I	<15	30.31	21,539.56
Class II	16-25	28.75	20.444.39
Class III	26-35	32.11	22,952.05
Class IV	>35	8.82	6,281.99
Total		100	72,218

- Source: Cameron Highland Local Plan, 2003-2015

3.2.3 Geology

The geology of the Cameron Highlands is related to the tectonic, structure and rock types of the main mountain range as it entirely located at the eastern part of the main mountain range of Peninsular Malaysia. The Main Range of Peninsular Malaysia was formed as a result of the collision between the oceanic Indo-Australian and continental Eurasian tectonic plates. The convergence forced the heavier oceanic plate below the lighter continental plate. The main range, Titiwangsa, was formed from this mountain building episode and its granite bedrock is driven from such magma. Generally, two main types of bedrock prevail along the middle section of the main range. About 90% of the main range is underlain by primarily acidic intrusive Granite rocks formed in the Late Triassic period.Geologically, the main range is composed of granite with scattered outliers (roof pendants) of Lower Palaeozoicschists of mainly Ordovician to Silurian Age. The thickness of this bedrock varies considerably from approximately 5m to over 25m. The main textural classification of granite is classified as being a medium to coarse grained, porphyritic, biotite-granite. Metasediments are also mapped in the area. They were listed to consist of schist, phyllite, slate and limestone. Minor intercalations of sandstone and volcanics are said to occur as well.

3.2.4 Soil

The Soils in the Cameron Highlands are mainly derived from two parent materials: (a) acid intrusives, 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 (Paramanathan, 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/cm3, 4.3 per cent organic carbon, and a pH of 4.9. The metamorphic soil has an average bulk density of 0.78 g/cm3, 3.2 per cent of organic carbon and a pH of 4.6. Both soils are classified as sandy clay loam with average silt 16 per cent, clay 32 per cent and sand 52 per cent (Abdullah et al., 2001, Abdullah et al., 2005).

Humus in virgin soils in the north of the Highlands reaches 80–100 cm deep (Gunung Brinchang series), falling to 40 cm in the Tanah Rata Series, and to a negligible layer of humus in the Ringlet series of the south where altitude is less and temperatures higher. The Gunung Brinchang series (altitude >1600 m above sea-level) have been classified as a Typic Troposaprist over a Tropaquod, which is loamy, siliceous and isomesic. The mineral soils are acid, and have low CEC (<10 cmol/kg). The mineralogy is dominated by kaolonite, halloysite and some gibbsite, reflecting aggressive weathering under a perudic moisture regime.The Tanah Rata series (altitude 1200–1600 m) has been classified as an Aeric Ultic Troaquod, which is loamy, siliceous and isothermic. The soil has low base saturation, low CEC and is acidic. The mineralogy is dominated by kaolonite, halloysite and gibbsite.The Ringlet series (altitude 300–1200 m) has been classified as Orthoxic Tropohumult, clayey, kaolinitic, isohyperthermic. At this elevation, paludisation and podsolisation are no longer apparent and are replaced by humification and illuviation. The humified organic matter migrates down the soil profile enriching the mineral layers with organic carbon. The characteristics of three soil series for undisturbed land under forests are shown in Table. Soil properties under cultivated land show a different result, especially for pH and organic carbon (Table 3.2 and 3.3). It shows the influence of agricultural activities on some of the soil properties.

Table 3.2: Soil characteristics under forest

Series	Horizon depth (cm)	pH	Clay (%)	Silt (%)	Sand (%)	Organic Carbon (%)	Nitrogen (%)
Brinchang	A2: 10-16	4.4	19.9	12.7	62.4	0.38	0.04
	Bhir: 16-36	4.5	6.6	26.4	67.0	0.82	0.06
Tanah Rata	A2: 0-10	4.1	4.5	6.4	89.2	0.63	0.04
	Bhir: 32-75	4.7	23.0	17.9	59.1	0.71	0.06
Ringlet	A2: 0-7	4.4	22.2	32.9	44.9	2.05	0.18
	B21 t: 39-60	4.9	42.5	20.9	36.6	0.79	0.07

Table 3.3: Soil characteristics under cultivated land

Crop	pH	Organic Carbon (%)	Nitrogen (%)
Cabbages	6.5	3.17	0.34
Chrysanthemums	6.2	2.40	0.33
Carnations	6.2	2.98	0.36
Roses	6.2	2.45	0.33

Source: MARDITECH (1998) and Lim *et al.* (1987).

3.2.5 Hydrology and water resources

The Cameron Highlands is endowed with a very complex drainage system due to its rugged terrain.

3.2.5.1 River network

The system is mainly controlled by three main Rivers namely Telom River, Bertam River and Lemoi River alongwith many small tributaries that drain the northern, middle and southern parts of the Highlands, respectively. 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 utilizations of the Highlands. The exploitation of water is expected to rise from an estimated amount of 12.5 million litres per day (MDL) in 2009 to 20.07 MLD by 2020 (NWRS, 2011). Water abstracted at several intake points from these rivers originating from mountain forests in Cameron Highlands for drinking water supply.

The river systems, specially, within the Telom and Bertam Catchment areas play a vital role in Cameron Highlands as sources of water for freshwater supply, irrigation water for agricultural activities, for hydroelectricity generation and for recreational activities.Initially the rivers and streams of Cameron Highlands were categorized as fast flowing with cool, clean and clear water having high oxygen content and supporting sensitive aquatic invertebrates (Kumaran and Ainuddin 2004). The commercial sector which comprises mostly of hotels and restaurants, together with the industrial sector are the largest water consumers. It is important to note that, water supply for agricultural use does not come from the District's water supply network. More importantly, the forest covering area (79% of total 712 km^2 area) of Highlands are mainly form the important headwater catchment for two major rivers of Malaysia that drain down to the lowland areas namely Pahang River and Perak River .(WWF Malaysia, December 2001; Fortuin, 2006, Hashim and Rahaman, 2006). The Department of Environment (DOE) has been responsible for water quality monitoring of the rivers since 1987 through a network of ten stations (ASMA-CH01 to ASMA-CH10) initially and later another 64 new stations (designated as WR5 to WR74) were added, covering all the three catchments of the Telom, Bertam and Lemoi Rivers.

3.2.5.2 Ringlet reservoir

The ringlet reservoir is a man-made lake created upstream of the concrete dam on 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.

3.2.6 Climate

The climatic conditions of the Cameron Highlands significantly differ from the present Malaysia's lowlands because of a difference in elevation. The higher elevation of the highlands results in lower temperatures, higher relative humidity and lower solar radiation. The increasing altitudinal factors significantly decreased the temperature in the Cameron Highlands with the mean temperature drop by 0.613°C for every 100 meters elevation. The average temperate at Tanah Rata is about 18^0 C while the mean maximum temperature and mean minimum temperature are about 22^0 C and 15^0 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 (streams).The annual rainfall of the area is very high, averaging between 2,500 and 3,000 mm per annum. Meteorological records show that the study area received an average rainfall of 2,800 mm, with the western foothill areas receiving higher precipitation compared to that at the higher mountainous areas. In the hill station, Rainfall coincides with the two maxima of April-May and that of October-November. Rainfall is higher during the wettest periods towards the end of the year. There is none remarkably annual dry season and no month is without rainfall (Midmore et al., 1996; Van der Ent and Tarmeer, 2006).

In the Cameron Highlands rainfall is quite uniform through the year. 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 (Hasim et al., 2003). Other months have about 150-250 mm of rainfall. The rainfall regime is characterized by a large number of intensive rainstorms, especially in the periods of April-May and October-November.

3.2.7 Agriculture

Agriculture is the major socio-economics' activity in Cameron Highlands although about 86% of the total land is still under forest (Roslan et al. 1997). Although the topography of the Highlands is steep and highly dissected, the relatively cold and temperate weather (14-24°C) with plenty of rain and sunshine all-round the year has allowed the Highlands area most suitable for the cultivation of many subtropical crops, temperate vegetables and flowers. It is also the most important temperate agricultural area in the whole country of 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. The total land use for agriculture is 5251 hectare (16.4%) in Cameron Highlands. Out of the land used, land cultivated with vegetables is the most extensive (47%), followed by tea (44%), flowers (7%), and fruits (1%) (Table 3.4).

- **Table 3.4:** Main crops in the Cameron Highlands

Crops	**Area (ha)**
Vegetables	2492
Tea	2309
Flowers	368
Fruits	59
Other food crops	19
Total	**5251**

Source: Anon, 1997 [Abdullah et al., 2001]

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 40^0 (Midmore et al. 1996). Vegetables and flowers are also cultivated intensively on terraces and platforms. Regarding the slope gradient (<25^0) and suitable soil type, only 3,292 ha of the total 71,218 ha is suitable for agriculture in Cameron Highlands (Van der Ent, 2005). Two types of agriculture practices are common in the highlands area as open and rain shelter farm. Rain-shelters are often used for the cultivation of high-value vegetables and many species of flowers. This is due to the heavy rainfall experienced throughout the year.

3.2.8 Agro-tourism

Next to agriculture as the primary source of income, tourism is the second major economic force. 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 and well known as one of the oldest and largest hill resorts in Malaysia (Khairulmani, 1998; Leong, 1992 and Allen, 2005). After Malaysian independence in 1957, the highland was promoted as a tourist destination. At the same time, more agricultural land has been developed into resorts (Leong, 1992), and since the 1970's many vacation homes and hotels have been built in the area.The Malaysian government, through the 9th Malaysian Plan, has opened opportunities for farmers to expand and diversify agricultural products and their related industries, such as agro tourism.

The appealing cool climate attracts a lot of people who wants to escape the high temperatures in Malaysia's lowland areas. The tea plantation landscape is the most preferred scene in Cameron Highlands (Jamilah *et al*., 2006). The scenic view of the tea plantation has been known ever since tea was introduced to Cameron Highlands in 1929. So, this land use has maintained as the main scenic icon of Cameron Highlands. Most of the tea plantations were established in the 1930s, by planting tea seedlings on slopes. The plantations are managed by large private companies. However cultivation tea is in decline because of increasing labour costs, and it is being replaced by vegetable production. Cameron Highlands is one of the main regions with large areas of intensive vegetable cultivation in Malaysia. It has a long history of intensive horticulture especially vegetable and flower cultivation as well as tea plantations.

3.3 Sampling site selection

A reconnaissance field survey was conducted to point out the possible locations for the collection of surface water prior to seasonal water samplingin December, 2013. Selection of sampling stations was 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 main stream of the Bertam River (UB1-UB5 and LB1-LB2) and five stations at different tributaries namely BurungRuil, Jasar, Uluh and BatuPipih (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 sited at the source point of the main River in mountainous forest area .The stations were named as per Catchment areas and tributaries and numbered from upstream to down within the study area (Fig. 3.2). Sampling stations alongwith their coordinate, elevation and selection criteria are presented in Table 3.5.

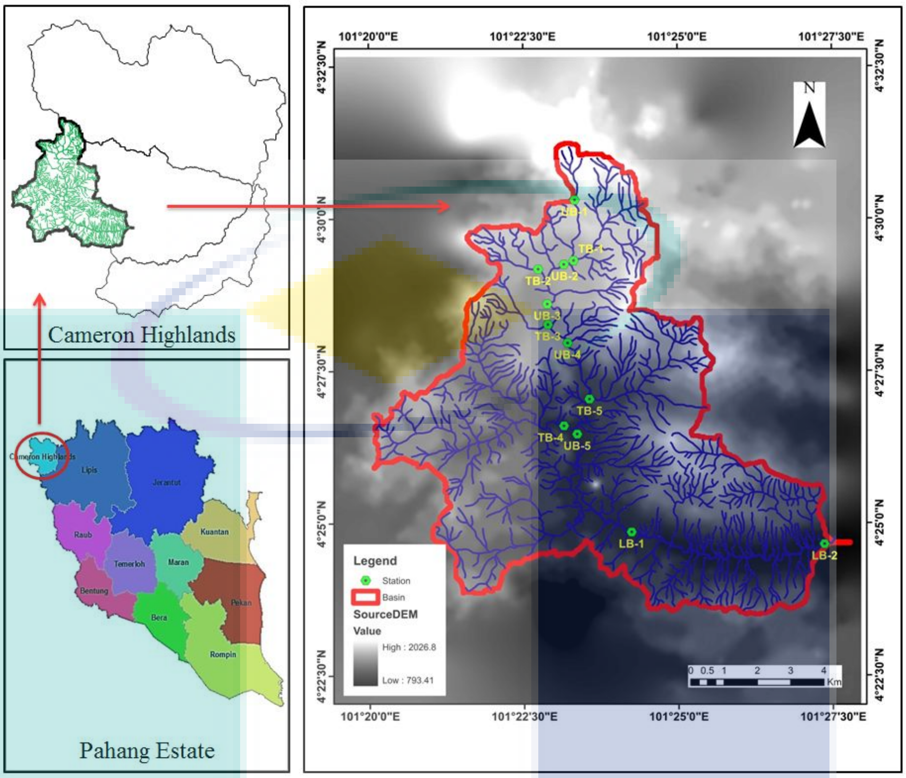


Fig 3.2: Location of sampling stations in the study area

Table 3.5: Description of sampling locations in Bertam Catchment area

Catchment	Station	Latitude	Longitude	Elevation (m)	Station Description and Selection Criteria
Upper Bertam (Main River)	UB-1	04^{0}30'18.4"	101^{0}23'19.9"	1635	Sloppy mountainous and forest area. Source area of the river.
	UB-2	04^{0}29'15.0"	101^{0}23'09.3"	1463	Adjacent to Brinchang town and after confluence of Sungai Burung (tributary).
	UB-3	04^{0}28'36.0"	101^{0}22'53.1"	1450	Adjacent to Taman Sedia residential area and after confluence of Sungai Ruil (tributary).
	UB-4	04^{0}27'57.6"	101^{0}23'12.7"	1443	After Tanah Rata town and confluence of Sungai Jasar.
	UB-5	04^{0}26'27.9"	101^{0}23'21.8"	1079	Before Ringlet Reservoir, after confluences of Sungai BatuhPipih and Sungai Uluh.
Upper Bertam (Tributaries)	TB-1	04^{0}29'18.8"	101^{0}23'18.8"	1469	Sungai Burung; farming and residential area.
	TB-2	04^{0}29'10.3"	101^{0}22'44.3"	1459	Sungai Ruil; village area.
	TB-3	04^{0}28'15.7"	101^{0}22'53.6"	1428	Sungai Jasar; impact of residential area and sewage treatment plant
	TB-4	04^{0}26'36.0"	101^{0}23'09.0"	1125	Sungai BatuhPipih; around tea plantation and agricultural area
	TB-5	04^{0}27'02.3"	101^{0}23'33.8"	1087	Sungai Uluh; around tea and farming area
Lower Bertam	LB-1	04^{0}24'51.3"	101^{0}24'14.5"	1019	Intensive farming and residential area
	LB-2	04^{0}24'39.1"	101^{0}27'21.9"	915	Farming area

3.4 Sampling program

Sampling program was conducted from January 2014 to February 2015 to collect water sample 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 at 15 cm depth from the water surface following the grab method. Three replicate samples were collected at each sampling station using 1L HDPE bottles for physico-chemical analysis and 300mL black BOD bottles with glass robotic stoppers (Wheaton, USA) for BOD test. Sampling bottles were pre-cleaned with chromic acid and rinsed with distilled water prior to sample collection, and all bottles were again rinsed with river water before sampling was carried out. All samples were then stored in a cooler box filled with ice packs to keep the temperature below 4^0C before transferring to the laboratory, in a cold room at 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).

3.5 Water quality analysis and stream flow measurement

Physicochemical parameters were measured from water samples of the study area. A total of 15 (fifteen) parameters were measured from the water samples consisting of 6 (six) physical parameters and 9 (nine) chemical parameters. Hydrological measurements (water velocity, depth and width of the river) were done to determine the specific stream flow values (Table 3.6).

Table 3.6 List of measured water quality parameters and hydrological variables

Physical Parameters	**Chemical Parameters**	**Hydrological variables**
Temperature	Dissolved Oxygen	Water level
pH	Total nitrogen	Flow rate
Electrical Conductance	Ammonical-nitrogen	Width
Turbidity	Nitrate-nitrogen	
Total dissolve solids	Nitrite-nitrogen	
Total suspended solids	Total phosphorus	
	Orthophosphate-phosphorus	
	Bio-chemical oxygen demand	
	Chemical oxygen demand	

3.5.1 In-situ measurements

In-situ measurement of water quality parameters were 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. Application of the portable instrument was almost similar. The sonde was placed under the water and the readings were taken from the display window. To avoid errors and to get a stable results measurement was repeated thrice. The sonde was calibrated in the laboratory before each sampling program.

3.5.2 Hydrological parameters

Hydrological measurements (water velocity, depth and width of the river) were done in a systematic way to determine the specific stream flow values (Table 3.7). The cross section width, depth and flow velocity were measured at each station using a range finder and a flow meter respectively. These parameters were measured to determine specific stream flow values. Measured width, depth and velocity were plotted on the square graphic paper and thus the cross section of the river has done. From the cross section water flow (m^3/s) was calculated using the method.

Stream flow value (Q) is the product of average velocity (V) and cross section area (A) or Q=VA. Cross section area is derived from the product of depth (d) and width (w).

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

$$= \text{Area } (m^2) \text{ x Velocity of flow } (msec^{-1})$$

Monthly precipitation data of the study period collected from the Meteorological Department of Malaysia for the station of Cameron highlands.

Table 3.7 Instruments used for *in-situ* measurement of water quality and hydrological parameters

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	
Salinity	Sal	ppt	
Turbidity	Turb	NTU	
Total dissolve solids	TDS	mg/L	
B. Hydrological			
River width	d	m	Measuring tape
Water velocity	w	m/s	SWOFFER 300 Flow meter
Depth of the river	V	m	CMI 5m measuring staff

3.5.3 Laboratory analysis (ex-situ)

Laboratory analyses were carried out to measure 9 chemical parameters in the water samples collected from the study area. Methods of analysis and required equipment those were used to analyze the parameters are given in Table 3.8. Selective 9 (nine) chemical parameters included a 5-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 were analyzed following the standard methods of analysis (APHA, 2012). Except 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 done by 5 days incubator method. Total suspended solid (TSS) was determined using gravimetric method.

For, BOD_5, initial DO analysis was done as reach to the laboratory and the samples were kept to the incubator for 5 days. Phosphate analysis was done within 48 hours of sample collection to avoid interference of other parameters. All other laboratory analyses were done within 7 days of sample collection. The list of physical and chemical parameters that was analysed in the laboratory is shown in Table 00 along with the methods and instruments adopted for analysis.

Table 3.8: Methods and Equipments for laboratory analysis

Parameter/ Variables	**Abbreviation**	**Unit**	**Analytical Method/ Instrument**
Total Suspended Solid	TSS	mg/L	Gravimetric methods
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 ReductionMethod HACH DR 5000 spectrophotometer
Nitrite-nitrogen	NO_2-N	mg/L	
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
Bio-chemical 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

3.6 Water quality index (WQI)

The DOE-WQI index was used to classify stretches of the studied water bodies into classes, according to the system adopted by the DOE (DOE 1994; DOE 1998). Six water quality parameters i.e. DO, BOD, COD, TSS, ammonia-N and pH was used in the calculation of the DOE-Water Quality Index (DOE-WQI) as described by Norhayati et al. (1997) and Norhayati (1981).The index was established based on the results of an opinion–poll of a panel of experts who determined the choice of the parameters and weightages assigned to each chosen water quality parameter (DOE 1994). Calculations are performed not on the parameters themselves but on their sub-indices, the values of which are obtained from a series of equations. These are the best-fit equations obtained from the rating curve (Norhayati 1981). The sub-indices for these parameters are named SIDO, SIBOD, SICOD, SIAN, SITSS and SIpH. The formula will be used to calculate the WQI is as follows:

$$WQI = 0.22\ (SIDO) + 0.19\ (SIBOD) + 0.16(SICOD) + 0.15\ (SIAN) + 0.16(SI\ SS) + 0.12\ (SI\ pH)$$

Where SI refers to the sub index function for each of the given parameters and the coefficients are the weighting factors derived from the opinion poll.

3.7 Statistical methods

Prior to statistical analysis, water quality parameters were examined for normality of distribution using the Shapiro-Wilk's test ($p > 0.05$) (Shapiro and Wilk. 1965; Rajili and Wah, 2011), visual inspection of their histogram, normal Q-Q plots and box-plots. A non-parametric Lavene's test was used to verify the equality of variances ($p > 0.05$) (Nordstokke et al., 2011, Martin and Bridgmon, 2012). Moreover, the Kruskal-Wallis test (Ai et al., 2015, Mei et al 2014) was performed to estimate the significance differences in water quality parameters under different sampling stations and seasons ($p < 0.05$), due to non-normal distributions of the parameters. Correlations among the parameters were also tested as well using Spearman's correlation coefficients (r) with statistical significances at $p < 0.01$ and $p < 0.05$ levels (2-tailed), respectively. All statistical analyses were conducted using IBM SPSS Statistics version 20 (SPSS,Inc.,USA).

3.8 Analysis of land use map

For landuse evaluation of the study area, topographic map with a scale of 1:50,000 (1995) 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 raster data (administrative boundary, river network, sub basin boundary) of Cameron Highlands district were collected from JPS, Cameron Highlands, Malaysia. Each of the lnduse maps georeferenced individually by matching control points (40 to 50 control points) on the landuse map to the same features within prepared georeferenced topographic map as well as 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.

Using watershed delineation tool of ArcSWAT (extension software of ArcGIS 9.3), the boundary of study catchment was delineated as the region of interest. A Digital Elevation Model (DEM) of the area has been generated from the topographic map (30m interval contour map) as an input data source for this purpose. All the final layout of landuse maps for the study prepared according to the region of interest. After digitization, the area of each newly made polygon was calculated using the Calculate Areas tool under the Spatial Statistics Tools in ArcToolbox. The landuse types were reclassified into following 10 landuse classes (viz) forest, urban, market gardening, orchards, horticulture, floriculture, tea, scrub, open land and water body over a total study area of 97.36 km^2.

The slope map and shaded relief map were computed from the DEM using the 3D Spatial Analysis tool of GIS software (Fig 3.3). 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. For this calculation, all agriculture land types except tea was considered as market gardening land type. The ranges of slope classes and areal percentages were considered same for the whole study period.

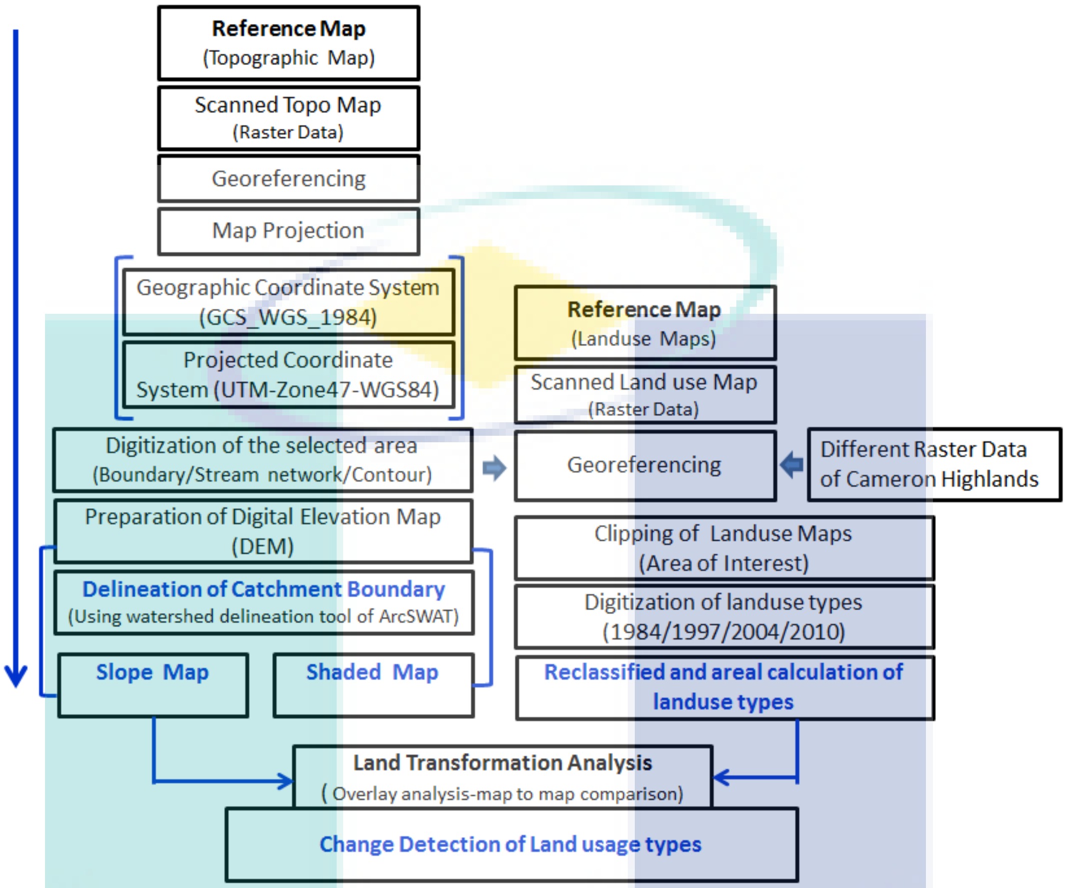


Fig.3.3 Flow chart for Landuse Data Processing using GIS Approach is given below:

3.9 Trends in climatic variables (1984-2014)

Climatic variables data on rainfall, rain days, temperature and humidity were collected from the Meteorological Department of Malaysia for the station Cameron Highlands. The data was collected monthly basis for the period of 1984 to 2014.

A relative change approach was applied to generate the trend analysis of the climatic variables.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Water quality assessment

4.1.1 Introduction

Surface water quality is very important and sensitive issue as it plays vital role on the 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 has become an essential aspect due to the seasonal and regional characteristics of river water quality. (Bu et al., 2010, Chen et al., 2012, Wang et al., 2013)

Worldwide deterioration of surface water quality has been attributed to both natural processes and anthropogenic activities. Anthropogenic changes like intensive agricultural development, lands clearing for agriculture and excessive utilization of commercial inorganic fertilizers have become major non-point source issues that lead to increase erosion and nutrient additions (Carpenter et al., 1998; Wu and Chen, 2013; Glavan et al., 2013 and Bu et al.,2014). Furthermore, urban and industrial developments with increased population, untreated domestic, municipal and industrial waste discharge as well as land development for infrastructure are the major point sources of anthropogenic changes (Xue et al., 2015; Hu and Cheng, 2013). 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 (Hubbard et al., 2011; Ai et al., 2015; Pratt et al., 2012; Wang et al., 2012; Ogwueleka et al., 2015). As all the changes seriously degrade the aquatic environments, accurate assessment of water quality conditions is pre-requisite to achieve sustainable management as well as remediation degradation.

In this study, the Bertam River, with a number of tributaries was selected for water quality evaluation as it reflects typical drainage patterns of a mountainous Catchment in the Cameron Highlands, Malaysia.

4.1.2 Hydrology of The Bertam Catchment

4.1.2.1 Rainfall

In the study area, rainfall is quite uniform through the year. 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 (Hasim et al., 2003). Other months have about 150-250 mm of rainfall. The rainfall regime is characterized by a large number of intensive rainstorms, especially in the periods of April-May and October-November. The average monthly rainfall is shown in Fig 4.1.

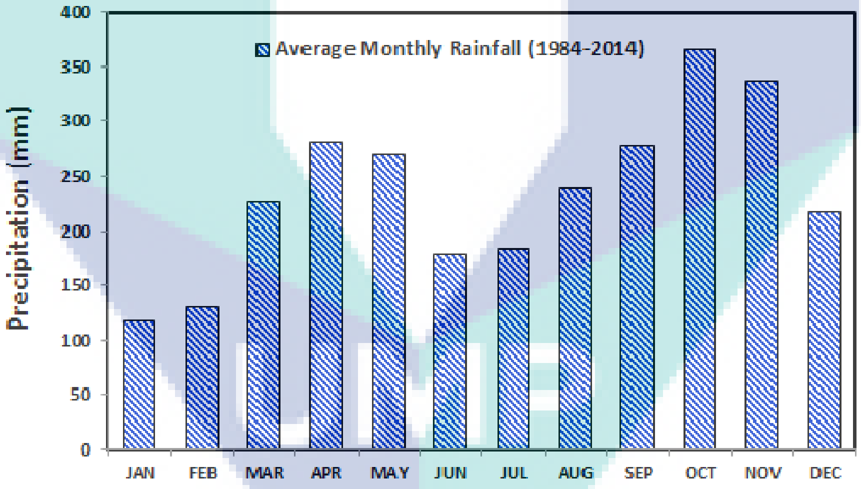


Fig 4.1: Average monthly rainfall of the study area.

4.1.2.2 Stream flow

The stream flow at different stations in the Catchment depends mainly on the rainfall pattern of the area. The high flow was observed during the wet period in September and October'14 and the low flow was measured dry period in January, March, May'2014 and February'2015 (Fig 4.2A).

According to the observed data, the stream flow ranged from 0.04 to 4.80 m^3/s with an average of 0.74 m^3/s in dry season and 0.11 to 6.44 m^3/swith an average of 1.16 m^3/sin rainy season respectively (Fig 4.2B). The lowest and the highest stream flows were observed at stations UB1 and UB5 along the main Bertam in both the seasons. Among the tributaries, the Batuh Pipih showed the higher flow (0.85 m^3/s in dry and 2.47 m^3/s in rainy) compared to others. The average stream flow of Upper Bertam (0.81 m^3/s in dry and 1.28 m^3/s in rainy) was considerably higher than that of the Lower Bertam (0.41 m^3/s in dry and 0.54 m^3/s in rainy). The observed reduction of flow at Lower Bertam mainly as a result of water storage and regulation in the upstream Ringlet reservoir (Othman Jaafar et al., 2010)

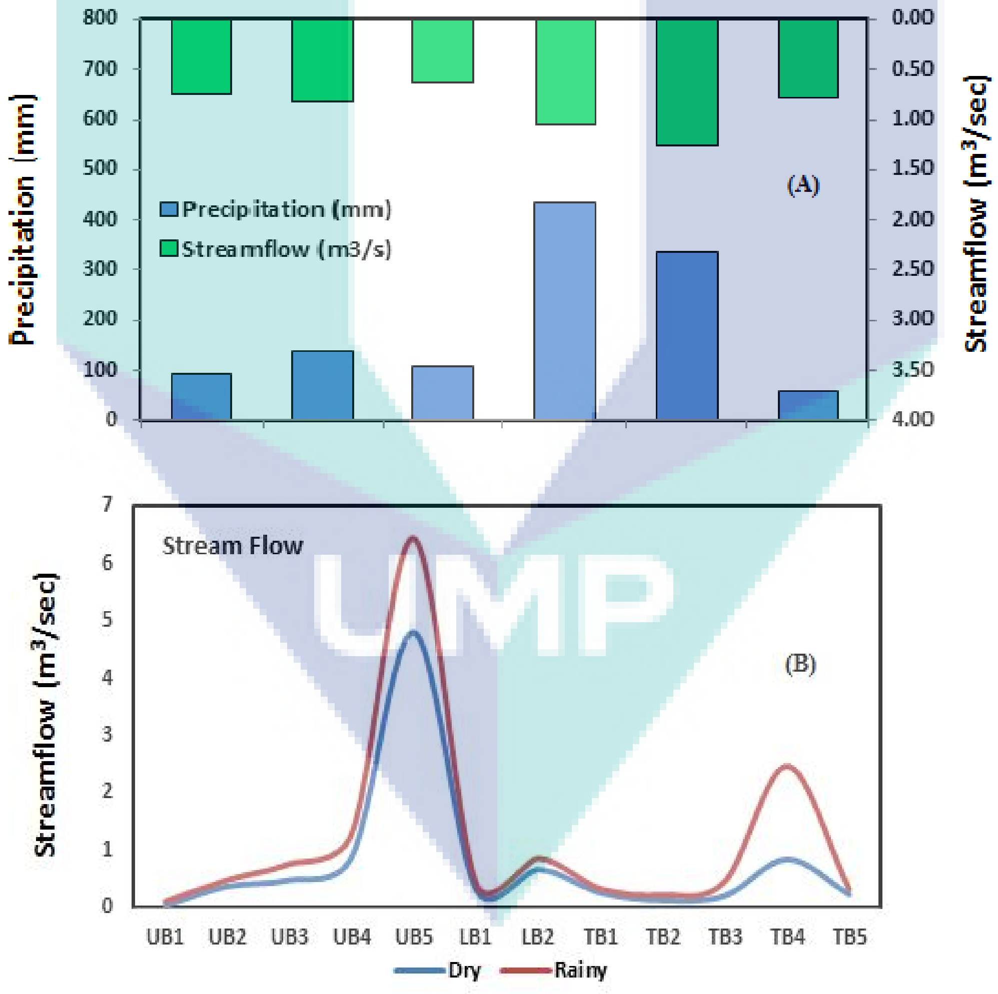


Fig 4.2: The relationship between monthly recorded precipitation and measured average streamflow in the catchment during the sampling periods (A) and Average stream flow distribution at different sampling stations during the dry and rainy seasons.

4.1.3 Water quality status of Bertam Catchment

A total of 14 (Fourteen) physicochemical parameters were analyzed to assess the status of surface water quality of Bertam River and major tributaries of Cameron Highlands, Malaysia. The detailed results of the parameters are discussed in the following sections.

4.1.3.1 Descriptive statistical summary

The statistical summary of physical and chemical parameters for all sampling stations along the Bertam River and its main tributaries is presented in Table 4.1 and Table 4.2 respectively**.** The results showed that the average concentrations of turbidity, TSS, BOD, COD, NH_3-N, and PO_4-P exceeded the Malaysian National Water Quality Standards (NWQS) level for Class I, Class IIA and 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. The level of variability of different stations and seasons are compared by using box and whisker plots (95% confidence interval) in Fig 4.3 and Fig 4.4 respectively. Results from the non-parametric Kruskil Walis test showed significant spatial differences for all parameters ($p<0.05$) at the 12 (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 6 (six) sampling times over the study period (January 2014 to February 2015). Such spatial and seasonal variability of water quality parameters are related to heterogeneous characteristics of watershed in respect of space and season (Ai et al., 2015).

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 (DoE)	Normal (I) Normal+2(IIB)	6.5-8.5 (I) 6-9 (IIB)	7.00 (I) 5.00-7.00 (IIB)	1000.00 (I) 1000.00 (IIB)	500.00 (I) 1000.00 (IIB)	5.00 (I) 50.00 (IIB)	25.00 (I) 50.00 (IIB)
All	**Average**	**20.13**	**6.70**	**7.18**	**69.03**	**46.65**	**195.15**	**321.59**

No. of Samples: 216

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**

4.1.4 Spatial variation of the water quality parameters

Surface water temperature ranged from 16.00 °C to 26.92 °C with a mean value of 20.13 ºC and 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 (Fig. 4.3A). Sampling time, decreased flow with low depth might cause such exception at these two stations (Shuhaimi-Othman et al., 2007). The present data of temperature is more or less similar to the atmospheric condition of Cameron Highlands.

The pH and DO plays an important role in quality measurement of any surface water. 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 DO values varied from 4.57 mg/L to 9.33 mg/L with an average of 7.18 mg/L. The lowest average concentration of DO was observed at station LB1 (5.68 mg/L) and at TB3 (5.59 mg/L) which is indicative to discharge of domestic wastewater from the two main towns namely Tanah Rata and Ringlet of Bertam Catchment into the river stream (Perrin et al., 2014) (Fig. 4.3C). DO values mainly decrease due to decomposition of organic matter and nitrification of ammonia introduced from human and industrial wastes (Bailey et al., 2014).

EC and TDS values displayed a similar spatial trend among the sampling stations with a range of 6.00 to 202.00 µS/cm and 5.00 to 131.00 mg/L respectively. Low values of EC and TDS recorded at station UB1, which is the source point of the Bertam River which is located at the undisturbed mountainous forest and free from the influences of human activities (Singh and Mishra, 2014). Low values also occur in the source water originated from local precipitation. The composition of granitic bank could be another reason of the low EC and TDS values. The highest mean values of EC and TDS at station LB1 (164.89 µS/cm and 109.33 mg/L, respectively) was mainly caused by the combined effect of point and non-point sources of domestic discharge from Ringlet town and agricultural activities along Lower Bertam Valley. Among the tributaries, Jasar River exhibited the highest mean EC and TDS values (73.17 µS/cm and 51.11 mg/L, respectively) due to the direct discharge of untreated municipal waste water from the Tanah Rata town and from water resources recovery facility. 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. Results of correlation analysis (Table 4.3) showed positive correlations between EC and TDS and among all nutrient parameters. Such relations might reflect in the variations of EC and TDS concentrations within the Catchment (Fig. 4.3D and 4.3E).

Concentrations of TSS and turbidity were found within a range of 2.00 to 4780.00 mg/L and 0.00 to 1292.20 NTU, respectively and displayed a similar pattern of spatial variation. Along the Bertam River, the highest mean values of TSS (550.39 mg/L) and turbidity (377.60 NTU) were recorded towards downward station at LB2, whereas the lowest mean values of TSS (4.89 mg/L) and turbidity (0.02 NTU) was found near origin, at station UB1. Among the tributaries, station TB2 (Ruil River) showed the highest concentrations while station TB1 (Burung River) showed the lowest values of turbidity and TSS (Fig. 2F and 2G). Moreover, the values of TSS and turbidity at most of the stations of Bertam River and its tributaries showed higher values than the limit (25 mg/L) of Malaysian standard.Correlation matrix showed a strong positive correlation (r=0.95) between TSS and turbidity (Table 4.3). 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 (Toriman et al., 2010). Present agricultural activities on steep and gentle slopes, hilltops, valley floor as well as construction activities were the main reasons for such increment during study period (Aminuddin et al., 2005). Similar results have been focused by other studies, which stated that agricultural activities and land pattern development strongly influenced the total suspended solids and sediments in the river water (Duan et al., 2013; Mouri et al., 2013 and Glavan et al., 2013).

Standard concentrations of nutrient variables are essential elements for any aquatic ecosystems. In the studied Catchment, the concentrations of nitrate nitrogen (NO_3-N), ammonia nitrogen (NH_3-N) and total nitrogen (TN) ranged from 0.08 to 3.70 mg/L, 0.01 to 3.38 mg/L and 0.20 to 10.90 mg/L, respectively. The concentrations of phosphate phosphorous (PO_4-P) and total phosphorous (TP) were recorded within the ranges of 0.10 to 2.22 mg/L and 0.12 to 2.80 mg/L respectively. Among these parameters, mean concentrations of NH_3-N (1.32 mg/L) and PO_4-P (0.74 mg/L) showed higher values than the guided value of NQWS of Malaysia. Spatially, all nutrient parameters (NO_3-N, NH_3-N, TN, PO_4-P and TP) showed higher concentrations at sampled stations of Lower Bertam than that of Upper Bertam along the Bertam River (Fig. 4.3H-L). In the Upper Bertam, like other physical parameters, the lowest values of all nutrient parameters were also observed at mountainous station UB-1. Ye et al. (2009) found that similar forest dominated region had low concentration of most nutrient variables in Xiangxi basin, China. Next to UB1, the stations UB2 and UB3 showed increased concentrations of NH_3-N, PO_4-P and TP. These pollutants could be originated from decomposition of nitrogen containing organic compounds as well as detergents occurring in municipal wastewater discharges from Brinchang town and residential area of Taman Sedia in the study area (Vega et al.1998, Ai et al., 2015). The higher concentration could be due to influences of the Burong and Ruil tributaries as well. High TN values were observed at stations UB4 and UB5 due to combined effect of point and non-point sources influenced by Jasar (TB3), Batu Pipih (TB4) and Uluh (TB5) tributaries Mei et al. (2014) showed that similar impact of TN influenced by tributaries at Wen-Rui Tang River watershed of eastern China. In the Lower Bertam, high concentrations of NO_3-N, TN, PO_4-P and TP were found at the stations LB-1 and LB-2. These might be attributed to agricultural runoff containing nitrogenous and phosphorous fertilizers from vegetable farming areas around the 'Lower Bertam Valley' (Shrestha and Kazama, 2007; Huang et al., 2010) as well as runoff from upward eroded land (Bu et al., 2010). In addition, higher value of NH_3-N at station LB1 could be the reason of direct discharge of wastewater from the Ringlet town. Higher TN values at station LB1 could occur as a result of combined effect of point and non-point sources from the aforementioned agricultural farming areas and residential wastewater. Similar findings were reported that the diversification of the agriculture practices, involving the use of fertilizers as well as the residential waste-water and the sewage treatment plant were the potential sources of high nitrogen concentrations (Kilonzo and Obando, 2012, Kibena, J.et al, 2014). 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 (Fig. 4.3I-K-L). Agricultural runoff containing fertilizers could be the major causes for such concentrations (Wu et al., 2009; Mouri et al., 2013). The higher concentration of NH_3-N was observed at stations TB3 (Jasar River) and TB2 (Ruil River) located around Tana Ratah town and small Ruil villages (Fig. 4.3H). The discharge of untreated domestic sewage to the river might be the reason behind such increment (Zhang et al., 2015). TN showed increased concentrations at station TB-3 (Jasar River) and TB-4 (Batu Pipih River) relating to their higher concentrations of NH_3-N and NO_3-N respectively.

COD and BOD are two important parameters to analyze the organic contamination of the study area. The concentrations of BOD and COD ranged from 0.35 to 35.50 mg/L and 5.00 to 64.00 mg/L with an average of 8.95 mg/L and 22.51 mg/L respectively (Table 4.2). Both the parameters showed higher values than the acceptable limit for Malaysian National Water Quality Standard at stations UB2, TB2, TB3 and LB1 within the catchment (Fig. 4.4). The average values of BOD and COD showed a wide range of spatial variation among the stations without following any specific trend (Fig 4.3M-N). In the Bertam River, the highest BOD and COD were found at station LB1 while the lowest of those were recorded at station UB1. Among the tributaries the highest BOD and COD values were recorded at station TB-3 (Jasar River) while lowest value was found at station TB4 (Batu Pipih River). The higher values of BOD and COD at station UB2, TB2, TB3 and LB1 might be attributed to domestic wastewater discharged from residential areas of Brinchang, Tana Ratah and Ringlet towns into the river stream. A number of researchers have mentioned that water quality deterioration caused by the discharges of municipal wastewater is indicated by high BOD and COD value (Ogwueleka, 2015; Mei et al., 2014; Kibena et al., 2013).

Finally, it could be concluded that the lowest values of all parameters were found at UBl, located at the mountainous forest area in the Upper Bertam region. The least quality water was observed in Lower Bertam at station LB1 and LB2 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 station UB2, UB3, TB3, LB1 located around the urban areas. The results demonstrated that the influence of untreated domestic sewage discharge and water resources recovery facilities from the three main towns, namely Brinchang, Tanah Rata, Ringlet and small settlement areas that includes most of the population of the Highlands. In addition, the housing at Brinchang, Tanah Rata and Ringlet (17%, 32% and 12% of total housing of the Highlands) were mainly equipped with septic tank sewage facilities. In small settlement, latrine holes and direct releases into water courses are still practiced. Moreover, no adequate sewage treatment plants are operational in the study area (Van der and Termeer., 2005). Thus, the amount of wastewater discharge was difficult to estimate, however, the wastewater in these areas is released at random without the use of a proper sewerage system. On the other hand, the high concentrations of the nutrient variables (NO3-N, TN, PO4-P and TP) were mainly observed at stations TB2, TB4, TB5, LB1 and LB2 around Burong, Batuh Pipih, Ulu River, Ringlet and Lower Bertam Valley. These concentrations are influenced by agricultural runoff from the agricultural practiced areas. Approximately 68 % of market gardening areas (vegetables and flowers) are located at Ringlet and Bertam Valley region in the lower catchment. The finding results of the present study are well supported by the previous published results of Eisakhani et al. (2009) except forest land type. They studied on the non-point sources pollution and their pollution loads in river system of Cameron Highlands based on different land uses and found considerable amounts of nitrogen (2.34 x 10^5 kg/yr), phosphorus (6.91 x 10^4 kg/yr) and BOD (2.13 x 10^5 kg/yr) load based on agricultural activities. Urban development causes highest BOD load (1.31 × 106 kg/yr) in the river system.

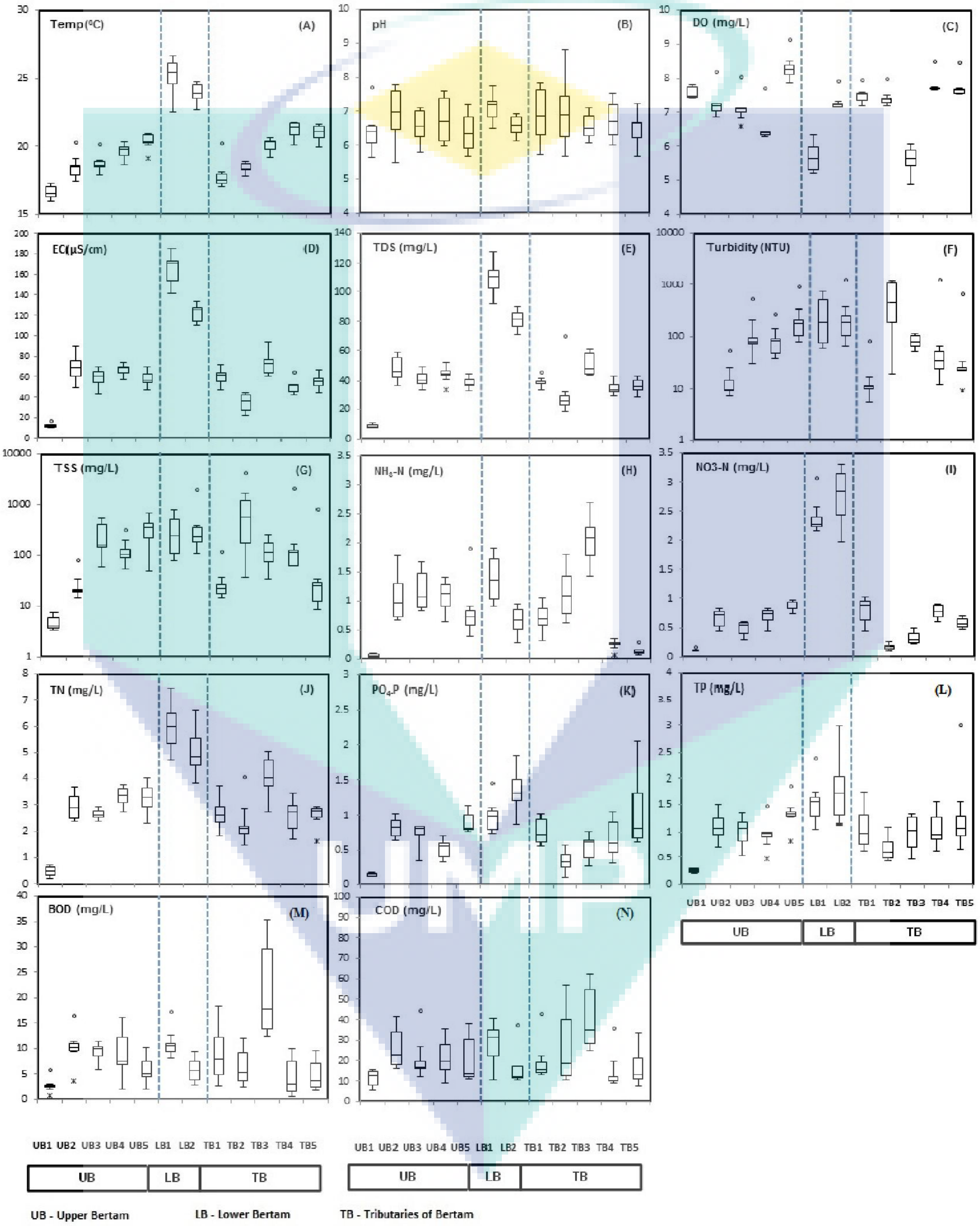


Fig 4.3: The spatial variations of physico-chemical parameters in Bertam Catchment area (o and x denote outliers).

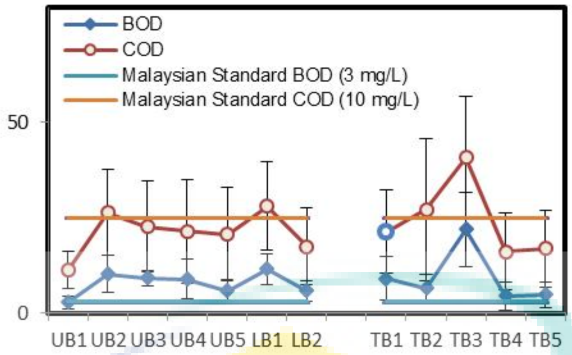


Fig 4.4: The trend of BOD and COD concentrations comparison with Malaysian Standard

Table 4.3: Spearman's Correlation coefficient for water quality parameter in the Bertam Catchment area^{a}

	Temp	pH	EC	TDS	Turbidity	TSS	DO	BOD	COD	NH3-N	NO2-N	NO3-N	TN	PO4-P	TP
Temp	1.000														
pH	-.008	1.000													
EC	**.574****	.283**	1.000												
TDS	**.565****	.334**	**.965****	1.000											
Turbidity	**.467****	.101	.331**	.336**	1.000										
TSS	**.442****	.062	.256**	.260**	**.951****	1.000									
DO	-.231**	-.229**	**-.466****	-.538**	-.143*	-.099	1.000								
BOD	.192**	-.190**	.269**	.293**	.177**	.165*	**-.541****	1.000							
COD	-.074	.032	.194**	.238**	.067	.064	-.111	.193**	1.000						
NH3-N	.060	.271**	**.429****	**.502****	.413**	.372**	**-.566****	**.482****	**.534****	1.000					
NO2-N	.134*	.049	**.376****	**.413****	.004	-.043	-.267**	.303**	.370**	**.420****	1.000				
NO3-N	**.686****	.080	**.646****	**.621****	.324**	.330**	-.119	.115	-.070	.065	.230**	1.000			
TN	**.632****	.228**	**.698****	**.724****	.500**	.435**	**-.407****	**.284****	**.263****	**.485****	.299**	**.598****	1.000		
PO4-P	**.582****	.070	**.546****	**.530****	.313**	.282**	-.144*	.183**	-.129	.051	.052	**.632****	**.470****	1.000	
TP	**.641****	.075	**.551****	**.569****	.436**	.388**	-.195**	.218**	-.045	.145*	.104	**.624****	**.522****	**.792****	1.000

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

Abbreviations for the water quality variables are mentioned in method section

^{a}The bold-faced numerical values indicate a significant relationship at a level of $p < 0.01$

4.1.5 Temporal variation of the water quality parameters

The temporal variation of physico-chemical parameters and their average values during dry and rainy season at different stations are presented in Fig 4.5 (A-N) and Fig 4.6 (A-N). The ranges of these parameters, by months, were reasonably different during the study period. Temperature, turbidity and TSS showed higher values in the months of September and October while those were lower values in the months of January, February and March. Therefore, these three parameters showed a general increasing trend of variation from dry to rainy season (Fig. 4.5A, 4.5F and 4.5G). Comparatively higher temperature in the rainy season resulted from the specific climatic conditions during this period (Chen et al., 2014). The values of turbidity and TSS were greatly influenced by erosion from agricultural activities cultivated on the hill slopes of the Catchment area during the rainy season (Kilonzo et al., 2014). Conversely, DO showed higher values in January and February and lower values in September and October (Fig. 4.5C). The values of DO showed a decreasing trend towards the rainy season caused by decomposition of organic compound (Ai et al., 2015). The pH, EC and TDS showed higher values in the month of September but slightly dropped in October (Fig. 4.5B, 4.5C and 4.5E). This could occur due to dilution effect because of continuous rainfall within catchment. Therefore, pH, EC and TDS values showed a minor increasing trend during the dry season while the highest values observed in rainy season. The values gradually decreased with constant rainfall.

By months, the average higher values of NO_3-N, TN, PO_4-P and TP were observed in September and October during rainy season (Fig 4.5I-L). The rainfall washed dissolved nutrients out from the eroded sediments and discharged into the water body that caused the differences in water quality between dry and rainy season. The overland runoff from agricultural and urban areas was suspected for such temporal variation in the concentration of these nutrients within the Catchment (Vega et al., 1988, Wu et al., 2009). The ranges of NH_3-N varied all the year and showed the highest value in March during dry season and the lowest value in October during rainy season, probably due to dilution effect of heavy rainfall (Fig. 4.5H). Similar reason impacts for decreasing the TN Values in October with constant rainfall in rainy season (Mei et al., 2014). By months, BOD and COD showed in consistent variation in the study area (Fig. 4.5M-N).

Results of seasonal variation revealed that the values of temperature, pH, Turbidity and TSS showed higher values at almost all stations during rainy season (Fig. 8A-B-F-G), however, DO showed the opposite trend (Fig. 4.6C). In turn, EC and TDS displayed higher values at all stations of upper Bertam and most of its tributaries during rainy season while higher values of those at lower Bertam and one of its tributaries were observed during dry season (Fig. 8D-E). A strong positive relationship of EC and TDS with nutrients variables is the indicative of such variations within the Catchment area (Table 4.3). The NO_3-N showed higher values in almost all of the stations in rainy season, except the stations of lower Bertam where the values showed higher in dry season (Fig. 4.6I). The present agricultural practices under close farming (rain shelter) on steep, gentle slopes and valley floor in the 'Lower Bertam Valley' decreased the NO_3-N concentration in the runoff during rainy season (Aminuddin et al., 2005). 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 (Fig. 4.6H, 4.6J) due to different source pollutants and dilution factor (Ogowueleka et al., 2015). Most of the stations showed higher PO_4-P and TP values during the rainy season due to the influence of the agricultural activities (Fig. 4.6K-L) (Mouri et al., 2011). Moreover, erosion due to land use alteration across the catchment could cause more phosphorus release to the water bodies (Eisakhani et al., 2009, Kilanzo et al., 2014). Seasonally, the concentrations of BOD showed higher values at most of the stations during rainy season while that of COD showed in dry season because of dilution and decomposition of organic matter in rainy season (Fig. 4.6M-8N). Similar findings were observed by Mouri et al. (2011) in the rural-urban Catchment of the Shigenobu River basin, Japan.

4.1.6 Water quality index and River water classification

The indicator parameters namely DO, BOD, COD, SS, ammoniacal nitrogen and pH for water quality index were summarized for each station seasonally (Table 4.4). Based on the parameters and their sub-indices value, the DOE-WQI was calculated and the results of their corresponding water classes are shown in Table 4.5. All the calculated values were ranged from 57 to 95 indicating clean to polluted water quality status of the Rivers within the catchment area. Both the seasons, most of the stations except UB1 and TB5 showed slightly polluted WQ status. Sungai Jasar exhibited polluted status all round the year.

4.1.7 Conclusion

The water quality parameters were assessed and interpreted to evaluate the spatial and temporal variations as well as elucidated with reference to anthropogenic activities within the Bertam Catchment. The spatio-temporal characterization of water quality was mainly influenced by EC, TDS, Turbidity, TSS, BOD, COD and nutrient parameters. In the Catchment, the water quality at mountainous forest area was found unpolluted, whereas, it is significantly deteriorated at other areas. Untreated domestic and municipal wastewater discharge from towns and villages as well as water resources recovery facility significantly influenced the water quality at stations around urban areas. Agricultural runoff from eroded land also remarkably affected the water quality around the agriculturally impacted zones within the catchment. Higher soil erosion and sediment transport as a result of poor agricultural practices at slopes areas as well as land clearing for development activities was also an important reason behind the deterioration of water quality in the Catchment. The tributaries played an important role in spatio-temporal changes of water quality in the main course of Bertam River. Agriculture farming practices influenced in variation of water quality in Lower Bertam mainly in rainy season. It is therefore important to implement compatible policies and programs for improvement in domestic waste water recovery methods, poor agriculture practices and in proper land use management for sustaining the water quality from further deterioration. The results of this study provide acritical information to the policy makers as well as authorities for water resource conservation in mountainous Bertam Catchment.

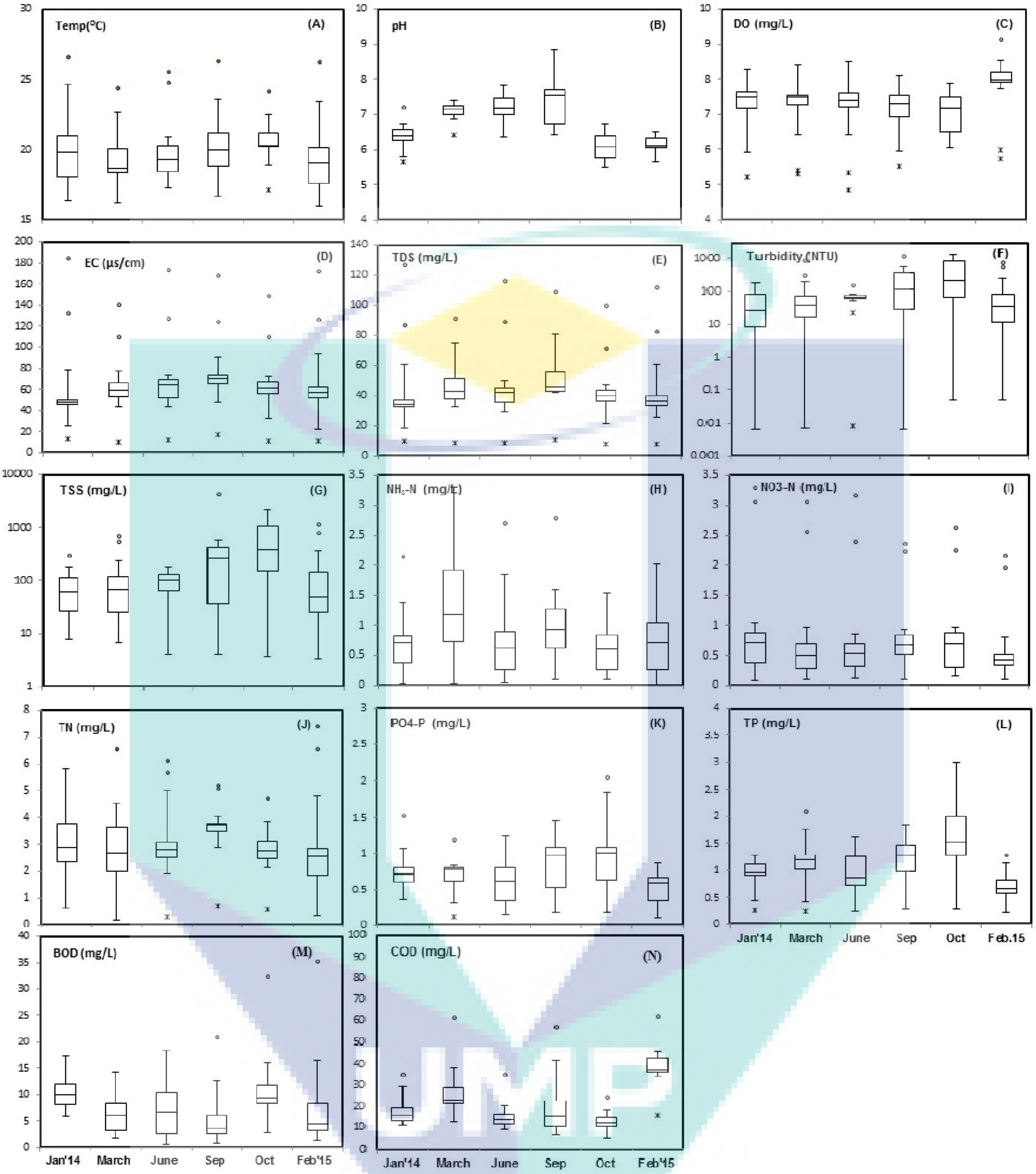


Fig 4.5: The temporal variations of physico-chemical parameters in Bertam Catchment area (o and x denote outliers).

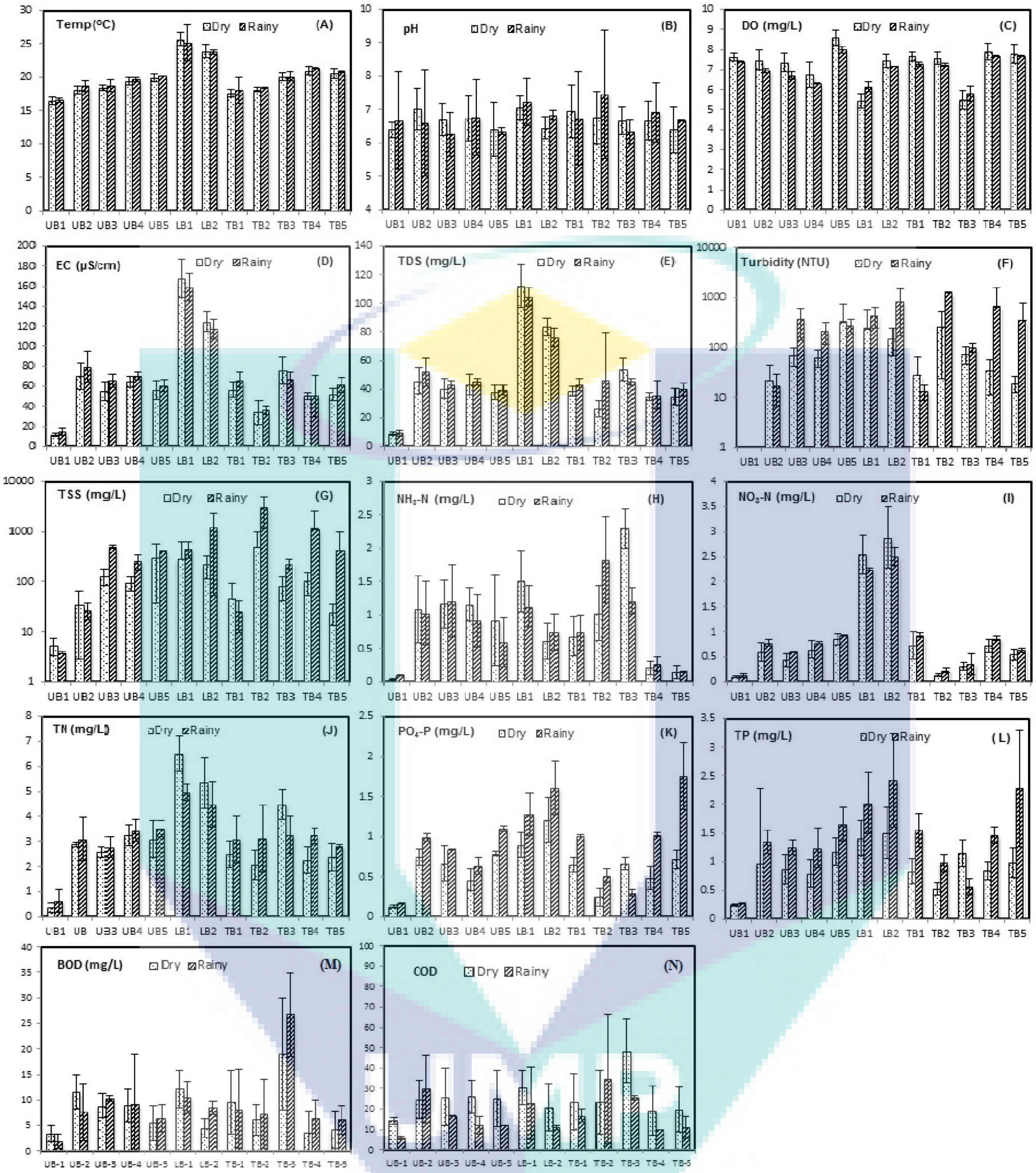


Fig 4.6: Average values (mean±S.E) of physicochemical parameters and nutrient variables during dry and rainy seasons in different stations of Bertam Catchment.

Table 4.4: Summary of indicator parameters for WQI

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	9.90	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	26.73	25.33	1.57	224.67
	SD	0.41	0.47	10.90	15.69	0.29	41.10	0.36	0.37	8.18	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
Overall	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
	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 4.5: Water Quality Index (WQI) at different stations was calculated with the sub-indices values of selective parameters during dry and rainy season.

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

4.2. Assessment of land type changes

4.2.1 Introduction

Land is a basic natural resource that provides habitat and sustenance, as well as facilitates economic development. People undertake different arrangements, activities and inputs in a certain type of land to produce a change or maintain it, generally characterized as landuse. 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, soil erosion and sedimentation, surface runoff and sediment yield, water flow and water quality and subsequently climate changes. (Zhang et al., 2010; Zhou et al., 2012; Amin et al., 2014; Kibena et al., 2014)

An accurate and up-to-date understanding of land usage activity and changes is necessary for the review of environmental changes and consequence assessment. Hence, the spatio-temporal distribution of usage and activity and its changing trend mainly dictates the sustainable management.

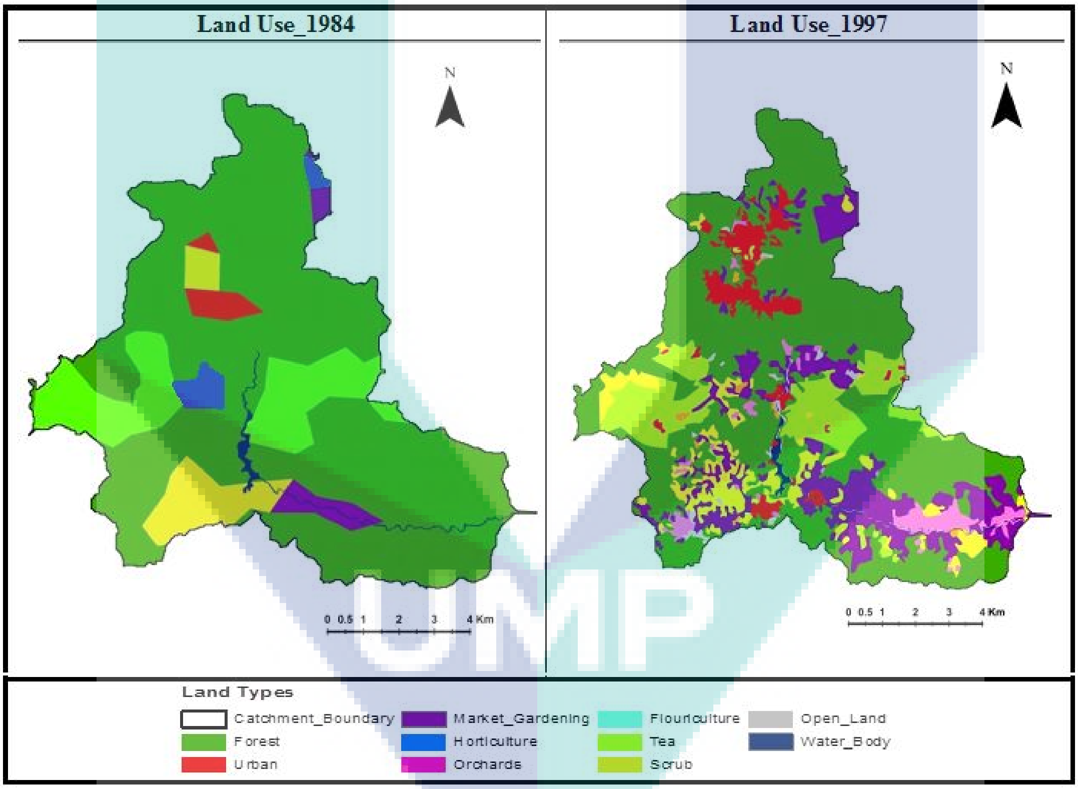
In this study, land usage changes were calculated and interpreted to understand the potential impact of these changes on the Bertam River Catchment, Cameron Highlands, Malaysia.

4.2.2 Pattern change of land area

The overall land types were categorized into 10 types based on the usage, economical significance and practices. These are - forest, urban, market gardening, orchard, horticulture, floriculture, tea, scrub, 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 data presented in Table 5.1 represents the coverage of each landuse category in 1984, 1997, 2004 and 2010 including the area, percentage area and change in between the four time periods for the Bertam river catchment area. The spatio-temporal distributions of these land categories during the study periods are also shown in Figure 5.1.

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



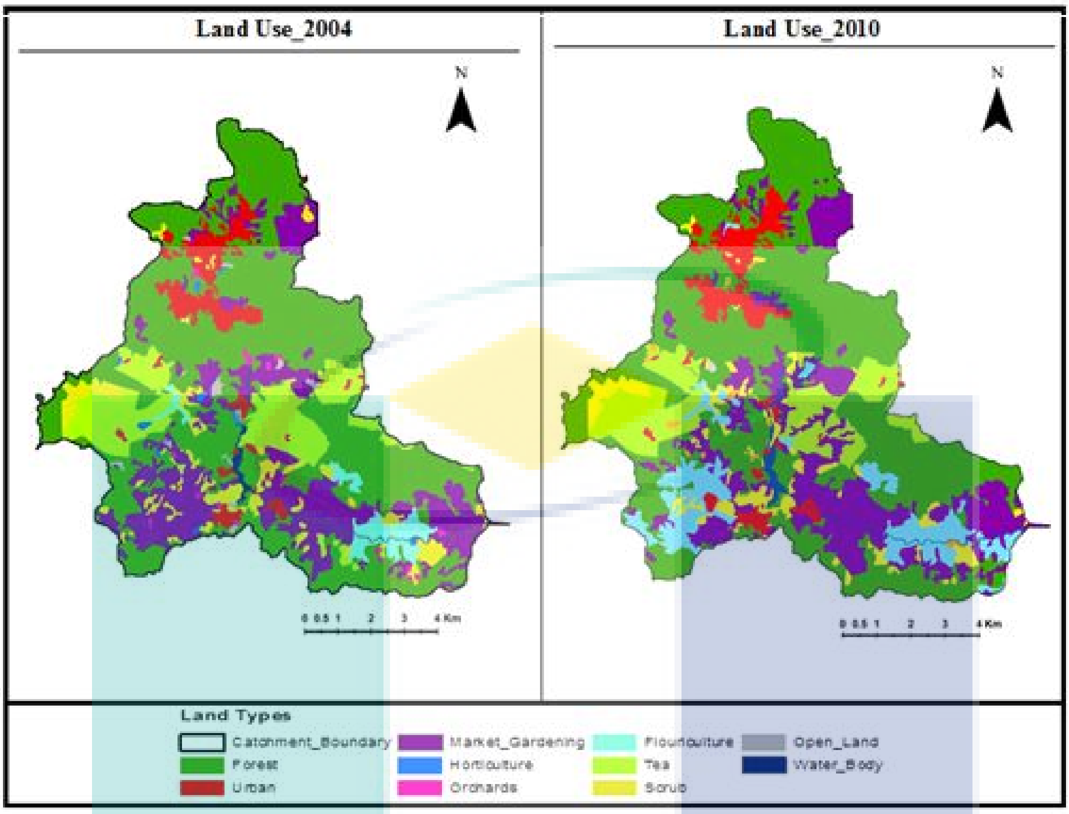


Fig 5.1 Land use maps of study area (Bertam Catchment) in 1984, 1997, 2004 and 2010

During the year 1984 forest had the majority of coverage followed by tea, scrub, market gardening, urban, horticulture and water body (Table 5.1, Fig 5.2). The land use scenario became different in 1997 with a major increment of market gardening and urban area as well as a reduction of forest and horticulture area. Orchard introduced as a new landuse type during 1997. With these changes, a new order of abundance was observed in landuse types as forest exceeded market gardening, followed by tea, scrub, urban, orchard, water body, open land and horticulture, respectively. It was clearly evident that the growth of market gardening area by 13.12 % from 1984 to 1997 bears a positive relationship with the decreasing tendency of forest area (Fig 5.3).

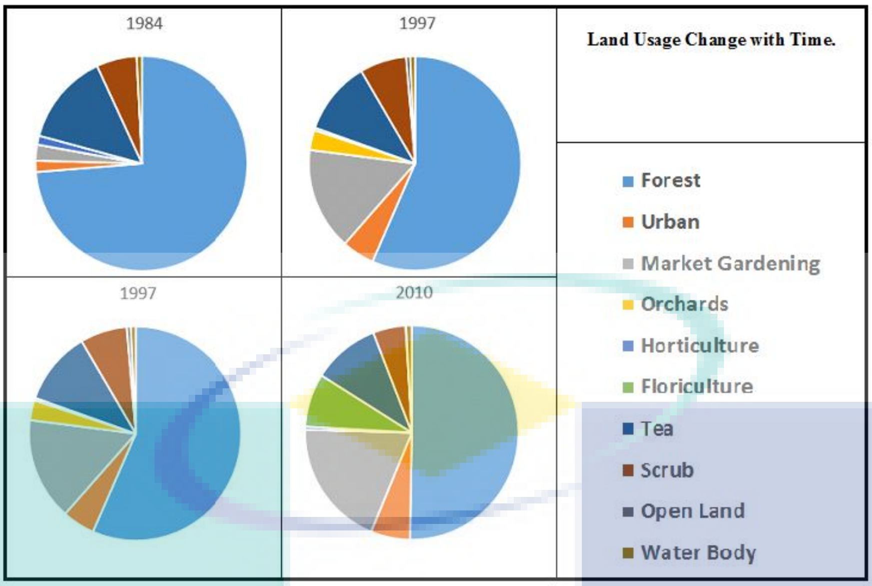


Fig 5.2: Land usage practice change along time within the catchment area

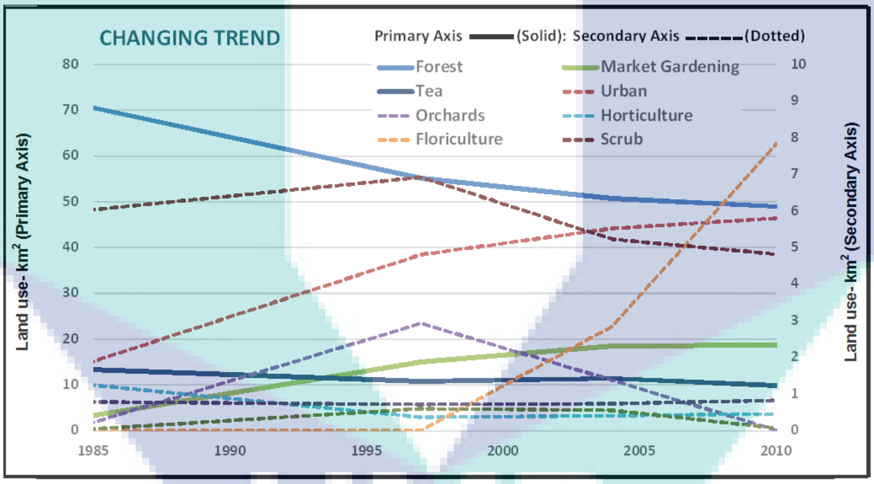


Fig 5.3 The changing trend of Land usage within the catchment area.

With a newly introduced floriculture area and a reduction of scrub land (1.73 %) further modified the land use by 2004. The changing trend of market gardening and the forest followed the same changing pattern. Orchard that was introduced as a new land type during 1997 was decreased by 1.59% in 2004.

A major and significant land use change was the expansion of floricultural area and the reduction of orchard area by 2010. In a span of 6 years from 2004 to 2010, the usage area of floriculture and orchards increased 5.11% and decreased 1.41%, resulting in a total area of 8.04% and 0.01%, respectively. A decreasing trend in 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>market gardening>tea>floriculture>urban>scrub >water body> horticulture> open land> orchard.

The distribution of different land-use types in successive year of 1984, 1997, 2004 and 2010 has shown that the percent 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. (Fig 5.5)

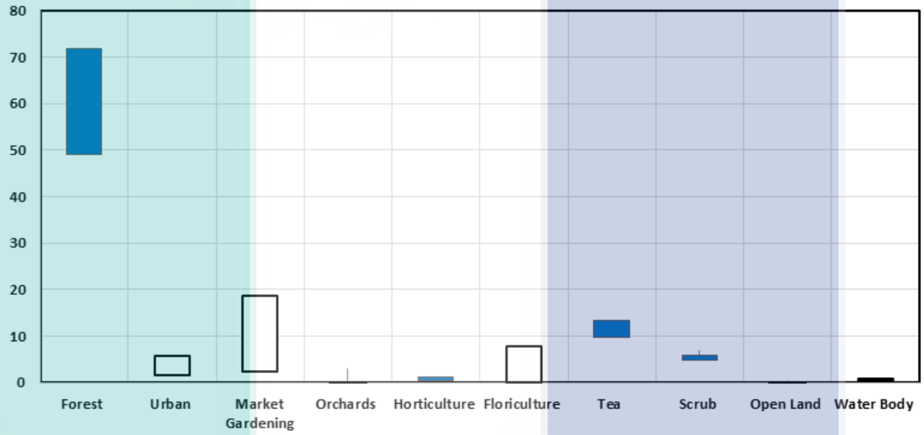


Fig 5.5: Change differences of the different categories of land types withing the catchment area.

4.2.3 Distribution of land type area

The changes in elevation over distance as well as the surficial features of the catchment area were shown in Fig 5.6. The data presented in Table 5.2 represents the slope classes, percentage, landuse types distribution according to slope classes. Within the catchment, it was estimated that 23.70% of the area has slopes in between 10^0-20^0 and 17.76% in between 20^0-30^0 (Table 5.2). Slopes that are in between 20^0-30^0 are classified as dangerous by Department of Environment, Malaysia. 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 5.2, Fig 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, noticeable rate of increment was observed in slope classes of 20^0-30^0 and 10^0-20^0 (Figure 8).

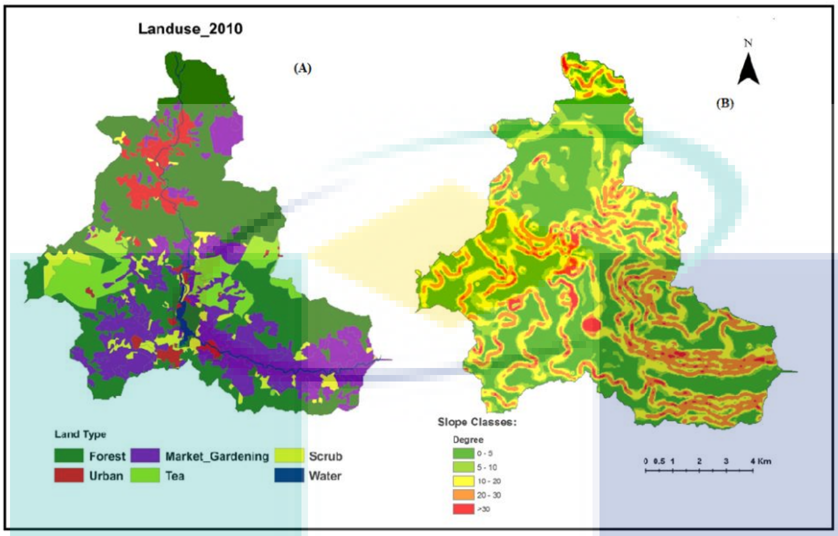


Fig 5.6: Slope classification and shaded relief maps of the Bertam catchment area.

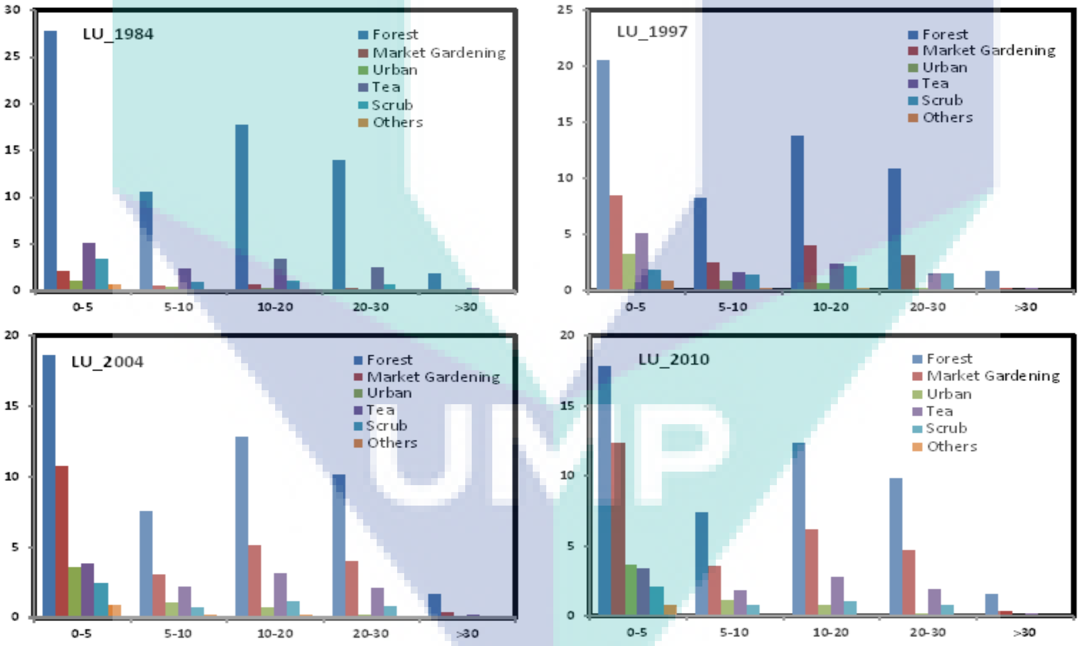
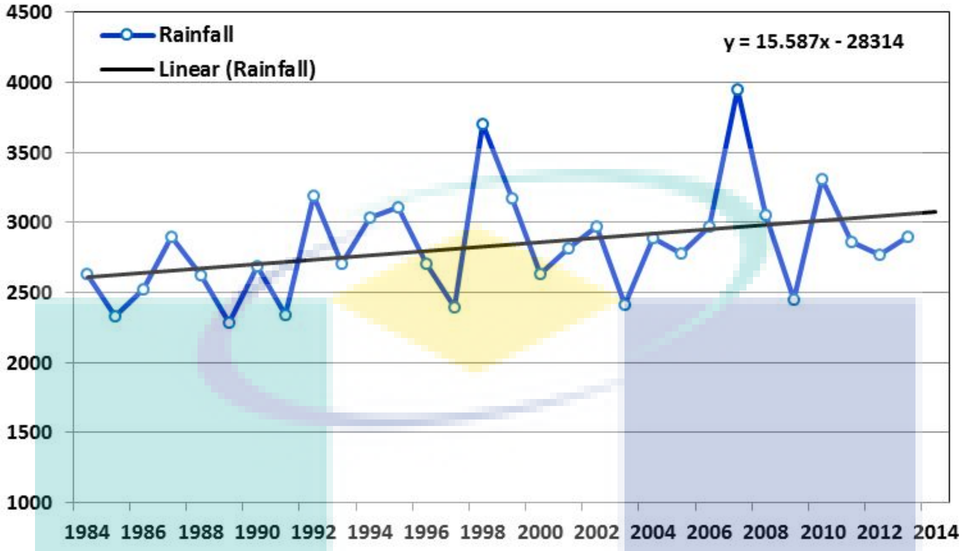


Fig 5.7 Land use types distribution by slope classes in study area (Bertam Catchment) over time.

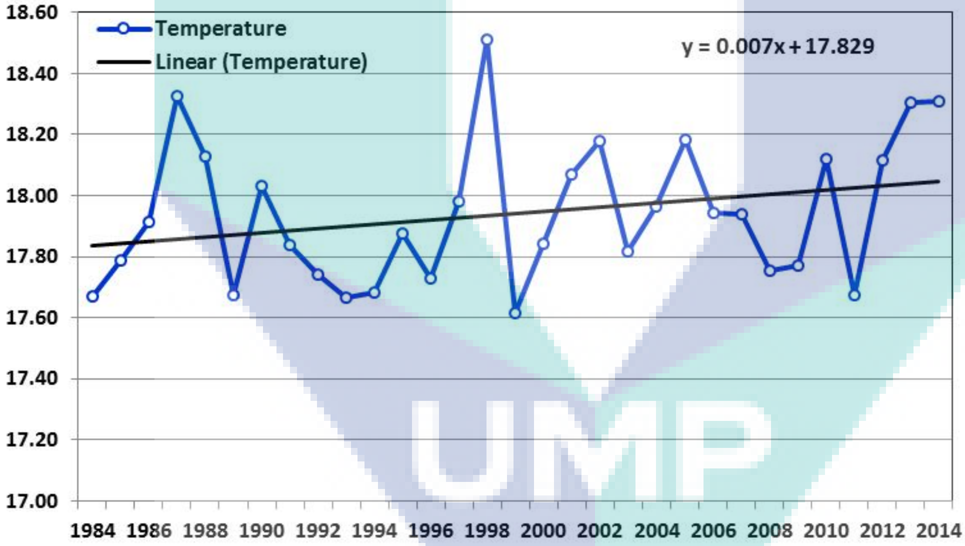
Table 5.2: Change types distribution according to slope classes within Bertam river catchment area

Land Type	Slope Classification				
1984					
	0^0-5^0	$5^0$$10^0$	10^0-20^0	20^0-30^0	>30^0
Forest	27.76	10.52	17.75	13.94	1.83
Urban	0.97	0.35	0.30	0.04	0.04
Market Gardening	2.05	0.56	0.68	0.30	0.06
Tea	5.10	2.36	3.36	2.41	0.24
Scrub	3.45	0.89	0.96	0.60	0.05
Others	0.69	0.06	0.02	0.00	0.00
Area (km^2)	40.02	14.76	23.07	17.29	2.22
Percentage	41.11	15.16	23.70	17.76	2.28
1997					
	0^0-5^0	$5^0$$10^0$	10^0-20^0	20^0-30^0	>30^0
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					
	0^0-5^0	$5^0$$10^0$	10^0-20^0	20^0-30^0	>30^0
Forest	18.63	7.53	12.79	10.15	1.61
Urban	3.57	1.07	0.67	0.19	0.01
Market Gardening	10.75	3.05	5.10	3.95	0.31
Tea	3.80	2.19	3.15	2.12	0.16
Scrub	2.43	0.73	1.14	0.82	0.11
Others	0.84	0.20	0.19	0.06	0.01
Area (km^2)	40.02	14.76	23.07	17.29	2.22
Percentage	41.11	15.16	23.70	17.76	2.28
2010					
	0^0-5^0	$5^0$$10^0$	10^0-20^0	20^0-30^0	>30^0
Forest	17.82	7.37	12.35	9.77	1.57
Urban	3.66	1.16	0.78	0.17	0.03
Market Gardening	12.23	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

4.3 Trends in climatic variables (1984-2014)



The inter-annual variations of the average rainfall from 1984 to 2014 revealed a gradual positive trend in the rainfall with annual increase rate of 15.59 mm.



The annual temperature time-series clearly presented a positive trend over the area with annual increase rate of 0.007 °C.

4.4 Conclusion

Bertam river catchment is rich in natural resources and the core of socio-economic activities of Cameron Highlands, Malaysia. Rapid development pressure has accelerated the remarkable changes over last few years, imposing the area under cumulative risks and brought negative effects on its pristine environment. The present study attempts to understand the potential impact of landuse changes and their distributions on environment over the last 26 years within the catchment. Landuse changes and landuse types distribution were carried out using GIS technique to find out such changes. The analytical 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 also observed in the study area. 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.

Rapid changes in agricultural activities (market gardening, floriculture) and urban expansion along with terrain features resulted in a wide range of water quality degradation in the catchment area. The conversion of forest to agriculture activities is the most significant anthropogenic changes that influence on environment. The agricultural activities on terraces, platforms as well as valley floors of different slopes are the main causes of soil erosion and subsequently leading to sedimentation in the existing river systems. Huge sedimentation in the catchment area resulted in water quality deterioration.

REFERENCE:

Abdullah, A. R. (1995). Environmental pollution in Malaysia: trends and prospects. TRAC trends in analytical chemistry, 14(5), 191-198.

Abdullah, W. W., Aminuddin, B. Y., Salama, R. B., Cheah, U. B., Jamaluddin, J., & Osman, G. (2001). Site descriptions and project field activities in the Cameron Highlands. In *ACIAR PROCEEDINGS* (pp. 3-9). ACIAR; 1998.

Adler, R. W. (2013). Agriculture and Water Quality: A Climate-Integrated Perspective. Vt. L. Rev., 37, 847-1153.

Ahearn, D.S., Sheibley, R.W., Dahlgren, R.A., Anderson, M., Johnson, J. and Tate,K.W. (2005). Land use and land cover influence on water quality in the last free-flowing river draining the western Sierra Nevada, California. Journal of Hydrology, 313, 234-247.

Ahmed, G., Miah, M. A., Anawar, H. M., Chowdhury, D. a, & Ahmad, J. U. (2012). Influence of multi-industrial activities on trace metal contamination: an approach towards surface water body in the vicinity of Dhaka Export Processing Zone (DEPZ). Environmental Monitoring and Assessment, 184(7), 4181–90.doi:10.1007/s10661-011-2254-9.

Ai, L.; Shi, Z. H.; 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.

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, 03(11), 1428–1441. doi:10.4236/jep.2012.311161.

Ali, N. S., Mo, K., & Kim, M. (2012). A case study on the relationship between conductivity and dissolved solids to evaluate the potential for reuse of reclaimed industrial wastewater. KSCE Journal of Civil Engineering, 16(5), 708–713. doi:10.1007/s12205-012-1581-x.

Allen, M. J., Brecher, R. W., Copes, R., Hrudey, S. E., & Payment, P. (2008). TURBIDITY AND MICROBIAL RISK IN DRINKING WATER (pp. 1–69). The Minister of Health, Province of British Columbia.

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.

Aminuddin, B. Y., Ghulam, M. H., Abdullah, W. W., Zulkefli, M., Salama, R. B., 2005. Sustainability of Current Agricultural Practices in the Cameron Highlands, Malaysia. Water, Air, & Soil Pollution: Focus, 5(1-2), 89-101.

Aminu, M.; Matori, A. N.; Yusof, K. W.; Malakahmad, A.; Zainol, R. B. (2014) A GIS-based water quality model for sustainable tourism planning of Bertam River in Cameron Highlands, Malaysia. *Environmental Earth Sciences*, *73*(10), 6525-6537.

Aminuddin, B. Y., Ghulam, M. H., Abdullah, W.Y.W., Zulkefli, M., and Salama, R.B. (2005) Sustainability of Current Agricultural Practices in The Cameron Highlands, Malaysia; Water, Air, and Soil Pollution: Focus 5: 89–101.

Amist, M. (2010). Riverine nutrient inputs to lake Kivu. Department of Zoology, Makerere University, Uganda.

Anon (1997) 'Post-conference tour guide to Cameron Highlands', in International Conference on Steepland Agriculture in the Humid Tropics, MARDI and MSSS, 19–21, 25 pp.

Appelo, C., & Postma, D. (2010). Geochemistry, groundwater and pollution (2nd editio.). A. A. Balkema Publishers Leiden/London/New York/ Philadelphia/ Singapore.

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.

Balandin, A. A. (2011). Thermal Properties of Graphene, Carbon Nanotubes and Nanostructured Carbon Materials. Nature Materials, 10(8), 569–581.

Barling, R.D. and Moore, I.D. (1994). Role of buffer strips in management of waterway pollution: a review. Journal of Environmental Management, 18 (4), 543-558.

Basnyat, P., Teeter, L. D., Lockaby, B. G. and Flynn, K. M. (2000).The use of remote sensing and GIS in watershed level analyses of non-point source pollution. Forest Ecology and Management, 128, 65-73.

Bates BC, Kundzewicz ZW, Wu S, Palutikof JP (2008).Climate change and water. Geneva:Technical paper of the Intergovernmental Panel on Climate change. IPCC Secretariat.

Beard, J. (2013). Environmental chemistry in society (2nd Editio., pp. 1–409). CRC Press, Taylor & Francis Group. Retrieved from ://books.google.com/books?hl=en&lr=&id=UMCQ71mN8acC&oi=fnd&pg=PP1&dq=Environmental+Chemistry+in+Society&ots=Cp9pfqUIVZ&sig=ynwTyIA3W8-tPosz6M4QThw6Wxc.

Bouraoui, F., Grizzetti, B., Granlund, K., Rekolainen, S., & Bidoglio, G. (2004). Impact of climate change on the water cycle and nutrient losses in a Finnish catchment. Climatic Change, 66(1-2), 109-126.

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.

Bu, H., Meng, W., Zhang, Y., & Wan, J. (2014).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.

Callender, E. and Rice, K.C. (2000). The urban environmental gradient: anthropogenic influences on the spatial and temporal distributions of lead and zinc in sediments. Environmental Science and Technology, 34, 232-238.

Campbell JL, Rustad LE, Boyer EW, Christopher SF, Driscoll CT, Fernandez IJ, (2009). Consequences of climate change for biogeochemical cycling in forests of northeastern North America. Can J Forest Res;39:264–84.

Carey, R.O., Migliaccio, K.W., Li, Y., Schafferd, B., Kiker, G.A., Brown, M.T., 2011. Land use disturbance indicators and water quality variability in the Biscayne Bay Watershed, Florida. Ecol. Indic. 11, 1093–1104.

Carpenter, S. R., Caraco, N. F., Correll, D. L., Howarth, R. W., Sharpley, A. N. and Smith, V. H. (1998). Nonpoint pollution of surface waters with phosphorus and nitrogen. Ecological Applications, 8(3), 559-568.

Chan, N. W., (2006) Cameron Highlands Issues and Challenges in Sustainable Development [HC79. E5 C182 2006 f]. School of Humanities, Universiti Sains Malaysia.

Chapman, D. (2002). Water Quality Assessments - A Guide to Use of Biota , Sediments and Water in Environmental Monitoring (Second Edi.). E&FN Spon, an imprint of Chapman & Hall, University Press, Cambridge.

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.

Chen, Q.; Wu, W.; Blanckaert, K.; Ma, J.; Huang, G. (2012) Optimization of water quality monitoring network in a large river by combining measurements, a numerical model and matter-element analyses. *Journal of Environmental Management, 110*, 116-124.

Chen, Q., Wu, W., Blanckaert, K., Ma, J., & Huang, G. (2012). Optimization of water quality monitoring network in a large river by combining measurements, a numerical model and matter-element analyses.Journal of environmental management, 110, 116-124.

Cleophas, F. N., Isidore, F., Han, L. K., & Bidin, K. (2013). Water quality status of Liwagu River , Tambunan , Sabah , Malaysia. JOURNAL OF TROPICAL BIOLOGY AND CONSERVATION, 10, 67–73.

Comber, S., Gardner, M., Georges, K., Blackwood, D., & Gilmour, D. (2013). Domestic source of phosphorus to sewage treatment works. Environmental Technology, 34(10), 1349–1358. doi:10.1080/09593330.2012.747003.

Dabrowski, J. M., & De Klerk, L. P. (2013). An assessment of the impact of different land use activities on water quality in the upper Olifants River catchment. Water SA, 39(2), 231-244.

Dallas, H. (2008). Water temperature and riverine ecosystems : An overview of knowledge and approaches for assessing biotic responses , with special reference to South Africa. Water SA, 34(3), 393–404.

Delpla, I., Jung, A. V., Baures, E., Clement, M., & Thomas, O. (2009). Impacts of climate change on surface water quality in relation to drinking water production. Environment International, 35(8), 1225-1233.

DOE (1994).Classification of Malaysian Rivers. Kuala Lumpur: Department of Environment.

DOE (2010) *Environmental Quality Report (EQR) 2010*: River Water Quality. Department of Environment, Kualampur, Malaysia.

Drewry JJ, Newham LTH, Croke BFW (2009). Suspended sediment, nitrogen and phosphorus concentrations and exports during storm-events to the Tuross estuary, Australia.J Environ Manag ;90:879–87.

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.

Ducharne A, Baubion C, Beaudoin N, Benoit M, Billen G, Brisson N, et al (2007). Long term prospective of the Seine river system: confronting climatic and direct anthropogenicchanges. Sci Total Environ ;375:292–311.

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.

Eisakhani, M.; Pauzi, A.; Karim, O.; Malakahmad, A.; Kutty, S. M.; Isa, M. (2009) GIS-based Non-point Sources of Pollution Simulation in Cameron Highlands, Malaysia.

EQMD.(2005). Water quality report on Bunot lake 1996 – 2005 (pp. 1–26).Environmental Quality Management Division, Rizal Provincial Capitol Compound Pasig City.

Euro-limpacs.(2009). Relationships between organic matter, pH, ANC and Al concentration and speciation (pp. 1–13).Integrated Project to evaluate the Impacts of Global Change on European Freshwater Ecosystems.

Ficklin, D. L., Luo, Y., Luedeling, E., & Zhang, M. (2009). Climate change sensitivity assessment of a highly agricultural watershed using SWAT. Journal of Hydrology, 374(1), 16-29.

Fisher, D.S., Steiner, J.L., Endale, D.M., Stuedemann, J.A., Schomberg, H.H.,Franzluebbers, A.J. and Wilkinson, S.R. (2000). The relationship of land use practices to surface water quality in the Upper Oconee Watershed of Georgia.Forest Ecology and Management, 128: 39-48.

Fortuin, R. (2006) Soil Erosion in Cameron Highlands, an Erosion Rate Study of a Highland Area.Saxion University Deventer.

Fulazzaky, M. A., Seong, T. W., & Masirin, M. I. M. (2010).Assessment of water quality status for the Selangor River in Malaysia. Water, Air, and Soil Pollution, 205(1-4), 63-77.

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., Toriman, M. E., Rahim, S. A., Islam, M. S., Chek, T. C., & Juahir, H. (2006). Hydrology and Water Quality and Land-use Assessment of Tasik Chini's Feeder Rivers, Pahang Malaysia. Geografia, 3(3), 1–16.

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.

GLP, 2005. Science Plan and Implementation Strategy, IGBP Secretariat, Stockholm, Global Land Project (GLP).

Griffith, J.A., 2002. Geographic techniques and recent applications of remote sensing to landscape-water quality studies.Water, Air and Soil Pollution 138, 181e197.

Gyawali, S., Techato, K., Yuangyai, C., & Musikavong, C. (2013). Assessment of relationship between land uses of riparian zone and water quality of river for sustainable development of river basin, A case study of U-Tapao river basin, Thailand. Procedia Environmental Sciences, 17, 291-297.

HACH, (2005) Water Analysis Guide. 1st Edn., ASTM, USA., Philadelphia, pp: 212.
Hill, A.R. (1981). Stream phosphorus exports from watersheds with contrasting land uses in southern Ontario. Water Resources Bulletin, 17, 627-634.

Hopkins, R.L., 2009. Use of landscape pattern metrics and multiscale data in aquatic species distribution models: a case study of a freshwater mussel. Landscape.

Howarth, R. W., & Marino, R. (2006). Nitrogen as the limiting nutrient for eutrophication in coastal marine ecosystems: Evolving views over three decades. Limnology and Oceanography, 51(1_part_2), 364–376. doi:10.4319/lo.2006.51.1_part_2.0364.

Hu, Y.; Cheng, H. (2013) Water pollution during China's industrial transition.*Environmental Development*, *8*, 57-73.

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.

Hubbard, L.; Kolpin, D. W.; Kalkhoff, S. J.; 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), 166-175.

Hutchins, M. (2012). What impact might mitigation of diffuse nitrate pollution have on river water quality in a rural catchment? Journal of Environmental Management, 109(30), 19–26.

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. In Designing Low Carbon Societies in Landscapes pp. 223-238). Springer Japan.

Jackson LJ, Lauridsen TL, Søndergaard M, Jeppesen E (2007). A comparison of shallow Danish and Canadian lakes and implications of climate change. Freshw Biol ;52:1782–92.

Kannel, P. R., Lee, S., Lee, Y.-S., Kanel, S. R., & Khan, S. P. (2007).Application of water quality indices and dissolved oxygen as indicators for river water classification and urban impact assessment. Environmental Monitoring and Assessment, 132(1-3), 93–110. doi:10.1007/s10661-006-9505-1.

Kaste Ø,Wright RF, Barkved LJ, Bjerkeng B, Engen-Skaugen T, Magnusson J, et al. Linked models to assess the impacts of climate change on nitrogen in a Norwegian river basin and fjord system. Sci Total Environ 2006;365:200–22.

Kibena, J., Nhapi, I., & Gumindoga, W. (2013).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.

Kilonzo, F.; Obando, J. (2012) Food production systems and the farmers' adaptive capacity to climate change in the Upper Mara River Basin. *In: 3rd Lake Victoria Basin Scientific conference*, Entebbe, Uganda.

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.

Komatsu E, Fukushima T, Harasawa H (2007).A modeling approach to forecast the effect of long-term climate change on lake water quality. Ecol Model ;209:351–66.

Kumar. N,1997. "A View on Freshwater environment", Ecol. Env & Cons.3, (3-4).

Kumaran, S.; Ainuddin, A. N. (2004) Forests, water and climate of cameron highlands, faculty of forestry. *Universiti Putra Malaysia.*

Kundzewicz, Z. W., Mata, L. J., Arnell, N. W., Döll, P., Kabat, P., Jiménez, B., Shiklomanov, I. A. (2007). Freshwater resources and their management. In Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E.Hanson, (pp. 173–210). Cambridge University Press, Cambridge, UK, 173-210.

Lawson, E. O. (2011). Physico-Chemical Parameters and Heavy Metal Contents of Water from the Mangrove Swamps of Lagos Lagoon , Lagos , Nigeria. Advances in Bilogical Research, 5(1), 8–21.

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.Urban Plan. 92, 80–89.

Leong, C. P., 2006. Global Warming: Has There Been a Change in the Climate of Cameron Highlands? Cameron Highlands Issues and Challenges in Sustainable Development. Universiti Sains Malaysia, 26-34.

Lim, J. S., Chan, Y. K., and Loh, K. F. 1987. Soils in steep land in Peninsular Malaysia. In: Proc. International Conference Steepland Agriculture in Humid Tropics, Kuala Lumpur, 93–129.

Losco, A., Nannan, C., Asare, E., Kylmäaho, J., Gilard, M., & Lampinen, P. (2012). RIVER-BASED ECOSYSTEM SERVICES IN THE CITY: AN ECONOMIC POINT OF VIEW. In HENVI Workshop 2012; Ecosystem services in urban areas (pp. 1–19). Retrieved from http:// www. helsinki.fi/henvi/ teaching/ Reports_12/03_HENVI_Workshop_2012.pd.

Luo, X., Shi, Z., Yin, W., Chen, J., Li, L. and Wu, S. (2010). Effects of Land Use Structure on Nitrogen Export in Hujiashan Watershed of Danjiangkou Reservoir Area, China. Environmental Science, 31(1), 56-62.

MARDITECH Corporation 1998. Strategic directions for the Cameron Highlands vegetables and floriculture industries. Report for The Cameron Highlands Flower and Vegetables Growers Association, 99–106.

Mahananda, H.B, Mahananda, M. R and Mohanty, B.P, 2005 "Studies on the Physio-chemical and Biological Parameters of Fresh water Pond Ecosystem as an Indicator of Water Pollution", Ecol. Env & Cons.11 (3-4), pp537-541.

Malallah, F. M., & Daifullah, A. A. M. (2008).FEASIBILITY OF USING TERTIARY TREATED EFFLUENTS IN IRRIGATION SYSTEMS. In Twelfth International Water Technology Conference, IWTC12 2008 (pp. 1429–1439). Alexandria, Egypt.

Martin, W. E.; Bridgmon, K. D. (2012) Quantitative and statistical research methods: From hypothesis to results (Vol. 42), John Wiley & Sons.

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.

Mian, I. A.; Begum, S.; Riaz, M.; Ridealgh, M.; McClean, C. J.; Cresser, M. S. (2010). Spatial and temporal trends in nitrate concentrations in the River Derwent, North Yorkshire, and its need for NVZ status. *Science of the total environment*, *408*(4), 702-712.

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.

Morse, C.C, Huryn, A.D. and Cronan, C. (2003). Impervious surface area as a predictor of the effects of urbanization on stream insect communities in Maine,USA. Environmental Monitoring and Assessment, 89, 95-127.

Moss, B. (2009). Ecology of fresh waters: man and medium, past to future (3rd Editio.). John Wiley & Sons. Retrieved from http://books.google.com/ books?hl=en&lr=&id=lfZH-xA3BVUC&oi=fnd&pg=PR7&dq=Ecology+of+fresh+waters:+man+and+medium,+past+to+future&ots=mpxXcB48Dc&sig=K3mj7wPkh51ct42rWDJEgmSJObg.

Moss, B. R. (2013). Ecology of Fresh Waters: A View for the Twenty-First Century (4th Editio.). John Wiley & Sons. Retrieved from http://books.google.com/ books?hl=en&lr=&id=uOhSa1X9UcgC&oi=fnd&pg=PA1&dq=Ecology+of+Fresh+ Waters:+A+View+for+the+Twenty-First+Century&ots=zDbUB_miJt&sig= GWyAdJ9fL8Ei7BTVA0anB5kJ2h8.

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.

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.

Murdoch PS, Baron JS, Miller TL. (2000), Potential effects of climate change on surface-water quality in North America. J Am Water Resour As ;36:347–66.

Ngoye, E. and Machiwa, J. (2004). The influence of land-use patterns in the Ruvu river watershed on water quality in the river system. Physics and Chemistry of theEarth,29, 1161-1166.

Nordstokke, D.W.; Zumbo, B.D.; Cairns, S.L.; Saklofske, D.H. (2011) The operating characteristics of the the nonparametric Levene test for equal variances with assessment and evaluation data. Practical Assessment, Research & Evaluation, 1(5).

Norhayati, M. 1981. Indices for water quality in a river.Thesis M.S. Asian Institute of Technology, Bangkok.

Norhayati, M.T., Goh, S.H., Tong, S.L., Wang, C.W. & Abdul Halim, S. 1997. Water quality studies for the classification of Sungai Bernam and Sungai Selangor. Ensearch Malaysia 10: 27-36.

NWRS, 2011 Review of the National Water Resources Study (2000-2050) and Formulation of National Water Resources Policy, Final Report, Volume 12, Pahang. Runhill Consulting Sdn Bhd.

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.

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. Environment International, 36, 212-225.

Paramanathen, S. 1977. Soil genesis on igneous and metamorphic rocks in Malaysia. Thesis, University of Ghent, Belgium.

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.

Praskievicz, S., & Chang, H. (2009).A review of hydrological modelling of basin-scale climate change and urban development impacts. Progress in Physical Geography, 33(5), 650-671.

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.

Prathumratana L, Sthiannopkao S, Kim KW (2008). The relationship of climatic and hydrologicalparameters to surface water quality in the lower Mekong River. Environ Int ;34:860–6.

Pratt, B., Chang, H., 2012. Effects of land cover, topography, and built structure on seasonal water quality at multiple spatial scales. J. Hazard. Mater. 209-210, 45–58.

Razali, N. M.; Wah, Y. B. (2011) Power comparisons of some selected normality tests. In *Regional Conference on Statistical Sciences, Malaysia*.

Rao, P. (2004). Drinking Water. In Textbook of environmental engineering (2nd Editio., pp. 38–91). PHI Learning Pvt. Ltd. Retrieved from ttp://books.google.com/books?hl=en&lr=&id=_8FS2aLoB74C&oi=fnd&pg=PR11&dq=TEXTBOOK+OF+ENVIRONMENTAL+ENGINEERING&ots=kqPEuuELBn&sig=-w5TI0Xnw5aqqmfPRcdQdQz-LMQ.

Rogers, P. (1994). Hydrology and water quality. In Changes in land use and land cover: a global perspective, Meyer, W.B. and Turner, B.L. (eds).

Rose, S. (2002). Comparative major ion geochemistry of Piedmont streams in the Atlanta, Georgia region: Possible effects of urbanization. Environmental Geology, 42, 102-113.

Schock, S., 2000. Projecting Land-Use Change: A Summary of Models for Assessing the Effects of Community Growth and Change on Land-Use Patterns. US Environmental Protection Agency, Washington DC.

Schoonover, J.E. and Lockaby, B.G. (2006). Land cover impacts on stream nutrients and fecal coliform in the lower piedmont of West Georgia. Journal of hydrology, 331, 371-382.

Seeboonruang, U. (2012). A statistical assessment of the impact of land uses on surface water quality indexes.Journal of environmental management, 101, 134-142.

Shapiro, S. S.; Wilk, M. B. (1965) An analysis of variance test for normality (complete samples). *Biometrika*, *52*(3/4), 591-611.

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.

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. doi:10.1016/j.envsoft.2006.02.001.

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.

Soh YC, Roddick F, van Leeuwen J. The future of water in Australia: the potential effects of climate change and ozone depletion on Australian water quality, quantity and treatability. Environmentalist 2008;28:158–65.

Stulina, G., & Eshchanov, O. (2013). Climate change impacts on hydrology and environment in the Pre-Aral region. Quaternary International, 311, 87-96.

TDEC (Tennessee Department of Environment and Conservation). 2009. An Analysis of Spatiotemporal Variations of Water Quality in the Little River and the Harpeth River Watersheds and their Connection with Land-Cover Patterns, ISSE Working Paper 2009-01.

Tirado, R., & Allsopp, M. (2012).Phosphorus in agriculture Problems and solutions (pp. 5–36). Greenpeace International, Ottho Heldringstraat 5, 1066 AZ Amsterdam, The Netherlands.

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).

Tran, C.P., Bode, R.W., Smith, A.J. and Kleppel, G.S. (2010). Land-use proximity as a basis for assessing stream water quality in New York State (USA). Ecological Indicators, 10, 727-733.

Tu, J. (2009). Combined impact of climate and land use changes on streamflow and water quality in eastern Massachusetts, USA. Journal of Hydrology, 379(3), 268-283.

Tyler, H. L., Moore, M. T., & Locke, M. a. (2012).Potential for Phosphate Mitigation from Agricultural Runoff by Three Aquatic Macrophytes. Water, Air, and Soil Pollution, 223(7), 4557–4564. doi:10.1007/s11270-012-1217-2.

UNEP. (2010). Clearing the Waters: A focus on water quality solutions (pp. 12–22).

Van der Ent, A; Termeer, C. (2005) Study on river water quality of the Upper Bertam catchment. Saxion University, Institute of Spatial Planning and Environmental Science, Deventer.

Van Vliet MTH, Zwolsman JJG (2008). Impact of summer droughts on the water quality of the Meuse river. J Hydrol;353:1–17.

Vanloon, G.W. and S.J. Duffy, 2005. The Hydrosphere. In: Environmental Chemistry: A Global Perspective. 2nd Edn. Oxford University Press, New York. pp.197 - 211.

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. doi:10.1016/j.catena.2011.11.013.

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.

Xue, C. H.; Yin, H. L.,; Ming, X. I. E. (2015) Development of integrated catchment and water quality model for urban rivers. *Journal of Hydrodynamics, Ser. B*, *27*(4), 593-603.

Wang, X., Bai, S., Lu, X., Li, Q., Zhang, X., & Yu, L. (2008).Ecological risk assessment of eutrophication in Songhua Lake, China. Stochastic Environmental Research and Risk Assessment, 22(4), 477–486. Retrieved from http://link.springer.com/article/10.1007/s00477-007-0147-9

Ward, P. J., van Balen, R. T., Verstraeten, G., Renssen, H., & Vandenberghe, J. (2009).The impact of land use and climate change on late Holocene and future suspended sediment yield of the Meuse catchment. Geomorphology, 103(3), 389-400.

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.

Webb, A., & Haywood, A. (2005). IMPACT OF MITIGATED FORESTRY ACTIVITIES ON TURBIDITY Assessing the effect of improved harvesting practices. Water (Australia), 32(8), 76–81.

WHITEHEAD, P. G., WILBY, R. L., BATTARBEE, R. W., KERNAN, M. & WADE, A. J. 2009. A review of the potential impacts of climate change on surface water quality. Hydrological Sciences Journal-Journal Des Sciences Hydrologiques, 54, 101-123.

Williams CE, Dodds W, Kratz TK, Palmer MA.(2009). Lakes and streams as sentinels of environmental change in terrestrial and atmospheric processes. Front Ecol Environ;6:247–54.

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. (2013). Water Quality Notes : Water Clarity (Turbidity , Suspended Solids , and Color) (pp. 1–8). Department of Soil and Water Science, UF/IFAS Extens. Retrieved from http://edis.ifas.ufl.edu

Worrall F, Burt T (2007). Trends in DOC concentration in Great Britain. J Hydrol ;346: 81–92.

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.

Wu, Y., Yu, Y., Li, X., Hu, H., & Su, Z. (2012).Biomass production of a Scenedesmus sp. under phosphorous-starvation cultivation condition. Bioresource Technology, 112, 193–198. Retrieved from http://www.sciencedirect.com/science/article/pii/S096085241200288X

Yusof, A. M., Thanapalasingham, V., & Wood, A. K. (2007).Assessment of the health of a river ecosystem due to the impact of pollution from industrial discharge using instrumental neutron activation analysis and inductively coupled plasma-mass spectrometry.Journal of radioanalytical and nuclear chemistry, 273(3), 525-531.

Yusuf, M. A. (2001). River water quality and ecosystem health in Langat Basin, Selangor, Malaysia PhD Thesis.“Managing for healthy ecosystems.”University Kebangsaan, Malaysia). Retrieved from http://scholar.google.com/scholar?hl=en&btnG=Search&q=intitle:River+water+quality+and+ecosystem+health+in+Langat+basin,+Selangor,+Malaysia#3

Zarghami, M., Abdi, A., Babaeian, I., Hassanzadeh, Y., & Kanani, R. (2011). Impacts of climate change on runoffs in East Azerbaijan, Iran. Global and Planetary Change, 78(3), 137-146.

Zhang, X., Kang, T., Wang, H., Sun, Y., 2010. Analysis on Spatial Structure of Landuse Change Based on Remote Sensing and Geographical Information System. International Journal of Applied Earth Observation and Geoinformation, 12, S145-S150.

Zhang, X., Cao, W., Guo, Q., & Wu, S. (2010). 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.

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.

Zhu Z, Arp PA, Mazumder A, Meng F, Bourque CPA, Foster NW. (2005). Modeling stream waternutrient concentrations and loadings in response to weather condition and forest harvesting. Ecol Model 2005;185:231–43.

Zwolsman JJG, van Bokhoven AJ (2007). Impact of summer droughts on water quality of the Rhine River—a preview of climate change? Water Sci Technol ;56:44–55

APPENDIX- A

Best fit equations for the estimation of the sub-index values

Sub-index	WQI Calculation	Ranges
SIDO	= 0	For x ≤ 8
	= 100	For x ≥ 92
	= - 0.395 + 0.03 x2 – 0.0002 x3	For 8 < x < 92
SIBOD	= 100.4 – 4.23 x	For x ≤ 5
	= 108 e0.055x – 0.1 x	For x > 5
SICOD	= - 1.33 x + 99.1	For x ≤ 20
	= 103 e0.0157x – 0.04 x	For x > 20
SIAN	= 100.5 – 105 x	For x ≤ 0.3
	= 94 e0.573x – 5 | x – 2 |	For 0.3 < x < 4
	= 0	For x ≥ 4
SISS	= 97.5 e0.00676x +0.05 x	For x ≤ 100
	= 71 e0.0061x – 0.015 x	For 100 < x < 1000
	= 0	For x ≥ 1000
pH (SIPH)	= 17.2 – 17.2 x + 5.02 x2	For x < 5.5
	= - 242 + 95.5 x – 6.67 x2	For 5.5 ≤ x < 7
	= - 181 + 82.4 x – 6.05 x2	For 7 ≤ x < 8.75
	= 536 – 77 x + 2.76 x2	For x ≥ 8.75
WQI	= 0.15 x SIAN + 0.19 x SIBOD + 0.16 x SICOD + 0.22 x SIDO + 0.16 x SISS + 0.12 x SIPH	

APPENDIX – B

PUBLICATIONS

Journal Publications

1. Spatial and Temporal Variation of Water Quality in the Bertam Catchment, Cameron Highlands, Malaysia. *Water Environment Research*. In press (2017)

2. Characterization of Chini lake water quality with Malaysian WQI using multivariate statistical analysis. *Bangladesh Journal of Botany*. In press. (2017)

3. Assessment of Heavy Metal Contents in Surface Sediment of the Tungguk River Surrounding the Industrial Complex of Gebeng City. *Bioresearch Communications*, 3 (1), 362-371. (2017)

4. Status of Contamination and Distribution of Effluents in Tasik Chini, Pahang, Malaysia. *International Journal of Ecology and Environmental Sciences* 42 (3): 201-208. (2016)

5. 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. (2015)

Conference Proceedings

1. The performance of coconut husk and shell for the removal of methyl red from aqueous solution: adsorption equilibrium and kinetic study. *2nd International Conference on Marine, Ocean and Environmental Sciences and Technologies (MAROCENET),* 15 – 17 March, HARRIS Hotel & Conventions Festival CityLink, Bandung, Indonesia, (2016)

2. Status and Contamination Level of Water Quality in Lake Chini, Malaysia. The National Conference for Postgraduate Research (NCON-PGR2016), 24 – 25 September, University Malaysia Pahang, Malaysia. (2016)