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

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Doctor of Philosophy

(ENVIRONMENTAL MANAGEMENT)

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SUPERVISOR'S DECLARATION

We hereby declare that we have checked this thesis and in my opinion, this thesis is adequate in terms of scope and quality for the award of the degree of Doctor of Philosophy in Environmental Management

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STUDENT'S DECLARATION

I hereby declare that the work in this thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at Universiti Malaysia Pahang or any other institutions.

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ABSTRAK

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

ABSTRACT

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

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LIST OF SYMBOLS

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

LIST OF ABBREVIATIONS

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

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

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