HYDROLOGICAL AND SUSPENDED SEDIMENT DYNAMICS IN CATCHMENTS OF DIFFERING LAND-USE HISTORY IN THE TROPICS – AN EXPERIMENT IN SABAH (NORTH BORNEO)

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THESIS SUBMITTED AS A FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY (SCIENCE)

FACULTY OF SCIENCE AND NATURAL RESOURCES
UNIVERSITI MALAYSIA SABAH
2017

UNIVERSITI MALAYSIA SABAH

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4th May 2017

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CERTIFICATION

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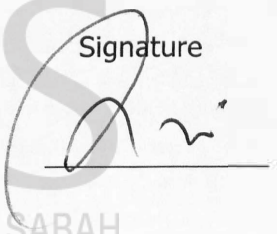

ACKNOWLEDGEMENT

The author would like to thank both supervisors, Professor Dr. Kawi Bidin (Universiti Malaysia Sabah) and Professor Dr. Rory P. D. Walsh (Swansea University) for their endless support, guidance, patience, teaching and involvement in this research project.

The author would also like to thank and acknowledge the Sime Darby Foundation as the main funder of this research as well as other funders and participating institutions namely the Royal Society of London, South East Asia Rainforest Research Partnership (SEARRP), Imperial College London, the Sabah Foundation, Benta Wawasan Sdn. Bhd. and the Sabah Forestry Department. Also, thank you to Datuk Dr. Glen Reynolds MBE (Director of SEARRP) and Dr. Robert M. Ewers (Principal Investigator of the SAFE Project, Imperial College London) for conceptualising and the overall directing of the Stability of Altered Forest Ecosystems (SAFE) Project.

The author would like to specially mention the names of Scientific Coordinators Dr. Edgar C. Turner, Khoo Minsheng, Ryan Gray; Manager Johnny Larenus; as well as excellent Research Assistants Samsudi Mastor and Mohd. Jamal Hanapi.

To his parents Muthu Nainar and Mary Lau; his sister Meera Michele Nainar, the author understands that it has been a painfully long, stealthy nevertheless necessary journey for the completion of this thesis. Thank you for the patience and understanding especially to mother Mary Lau who never once questioned regarding the progress of this soul-crushing work but only offered her silent prayers, because she always trusts her son to finish what he started.

This thesis is now finished but the science will grow. Cheers to Science.

Anand Nainar
4th May 2017

ABSTRACT

Land use change has been the main driver of adverse changes in hydrological and suspended sediment characteristics especially in the tropics. Several notable studies on the hydrological and erosional impacts from logging and agriculture were done in Southeast Asia and Sabah, especially during logging operations around the Danum Valley. However, paired catchment studies are few – especially those investigating a few land use on a scale of increasing disturbance while taking into account the history of the land. This study was conducted for that purpose. Five different catchments from the Kalabakan and Segama area with increasing historical land-use disturbance were selected – primary forest (PF), virgin jungle reserve (VJR), twice-logged forest (LF2), repeatedly-logged forest (LF3) and an oil palm plantation (OP). Streams in each catchment has been instrumented with a depth sensor, turbidity sensor, conductivity sensor, temperature sensor and a tipping bucket rain gauge all connected to a "Campbell CR850" solar powered datalogger that records data every 5 minutes. Values of water depth, turbidity and conductivity were converted to discharge (Q), suspended sediment concentration (SSC) and total dissolved solids respectively. For computation of annual yields, data gap predictions were attempted using relationship curves derived from intra-catchment and inter-catchment regression of stream variables. However, it was found that the regression relationships were unsuitable and hence three-month yields were presented instead. Three-month water yield was found to be highest in the LF3 and lowest in the OP. Mean suspended sediment concentration is highest in the OP and lowest in the LF3. Three-month sediment yield is highest in the OP and lowest in the LF2 (most likely caused by better interception, better hydrological characteristics and sediment exhaustion). At the event scale, subsurface flow was found to be highest in the PF and lowest in the OP. Peak discharge has no significant difference between the catchments. Water yield is highest in the LF3 and lowest in the OP. The baseflow, peak and end SSC at the event scale are highest in the OP and lowest in the PF. Clockwise hysteresis was found to be the dominant type in the PF, LF2 and LF3 (40.00%, 40.00% and 53.33% occurrence respectively) indicating source of sediment within the stream channel. The VJR has anticlockwise hysteresis as the dominant type (46.67% occurrence) whereas the OP has similar counts of clockwise, anticlockwise and anticlockwise figure-eight – VJR has distant sediment source while OP has multiple sources of sediment. The modified Lawler hysteresis index [HImean] that was used to quantify the magnitude of hysteresis shows no significant difference between the different land uses. The classification of hysteresis patterns in the tropics, especially figure-eights and complex hysteresis are mostly generalised. With high intra-event variability, each hysteresis requires a separate analysis to best describe its pattern and to derive a "story" of sediment delivery. Key findings that are directly applicable to management practices: (i) suspended sediment concentration is highest in the oil palm plantation but sediment yield can be greatly minimised with careful selection of areas for oil palm cultivation (lower rainfall and relief); and (ii) there is still a high value in repeatedly logged forest from a water and soil conservation aspect. The common practice of converting repeatedly-logged forest into plantations based on the assumption that there is little ecological function left has to be re-considered.

ABSTRAK

CIRI-CIRI HIDROLOGI DAN SEDIMEN TERAMPAI DI KAWASAN TADAHAN AIR DENGAN PENGGUNAAN TANAH YANG BERBEZA DI KAWASAN KHATULISTIWA – EKSPERIMEN DI SABAH (BORNEO UTARA)

Perubahan penggunaan tanah adalah faktor utama kemerosotan ciri-ciri hidrologi dan sedimen terampai terutamanya di kawasan khatulistiwa. Terdapat beberapa penyelidikan mengenai kesan-kesan hidrologi dan hakisan daripada kegiatan pembalakan dan pertanian di Asia Tenggara dan negeri Sabah, terutamanya dari operasi pembalakan di kawasan Lembah Danum. Walau bagaimanapun, bilangan kajian kawasan tadahan berpasangan adalah sedikit – terutamanya kajian yang membandingkan beberapa penggunaan tanah berbeza yang terletak pada skala gangguan tanah yang meningkat. Untuk tujuan itu, kajian ini telah dijalankan. Lima tadahan air di kawasan Kalabakan dan Segama dengan sejarah gangguan tanah yang meningkat telah dipilih – hutan primer (PF), hutan rizab (VJR), hutan yang telah dibalak dau kali (LF2), hutan yang telah dibalak berulang kali (LF3) dan ladang kelapa sawit (OP). Di setiap kawasan tadahan, pengesan kedalaman, pengesan kekeruhan, pengesan kekonduksian, pengesan suhu dan tolok hujan jenis "tipping bucket" dipasang berdekatan sungai dan disambungkan ke alat merekod data jenis "Campbell CR850" yang merekod dan menyimpan data setiap lima minit. Bacaan-bacaan kedalam air, kekeruhan dan kekonduksian ditukar ke luahan sungai, kepekatan sedimen terampai dan kepekatan pepejal terlarut masing-masing. Untuk pengiraan hasil tahunan, percubaan untuk melengkapkan data tercicir menggunakan graf-graf hubungan yang diperolehi dari regresi pembolehubah dalam sungai dan regresi pembolehubah antara sungai telah dilakukan. Walaubagaimanapun, kaedah ini didapati kurang sesuai dan oleh sebab itu, nilai hasil tiga-bulan dilaporkan sebagai alternatif. Nilai hasil luahan air tiga-bulan didapati paling tinggi di PF dan paling rendah di OP. Kepekatan purata sedimen terampai adalah paling tinggi di OP dan paling rendah di LF3. Bagi hasil sedimen tiga-bulan, OP merekodkan nilai tertinggi manakala LF2 merekodkan nilai terendah (kemungkinan besar hasil daripada pemintasan dan ciri-ciri hidrologi yang baik; dan juga kekurangan sedimen). Pada skala kejadian hujan pula, aliran bawah-permukaan mencatatkan nilai tertinggi di PF dan terendah di OP. Puncak luahan sungai tidak mempunyai perbezaan yang besar antara kawasan tadahan air. Hasil luahan air diadapati paling tinggi di LF3 dan paling tendah di OP. Kepekatan permulaan, puncak dan pengakhiran sedimen terampai adalah tertinggi di OP dan terendah di PF. PF, LF2 dan LF3 mempunyai corak histeresis arah jam sebagai histeresis yang utama (kekerapan 40.00%, 40.00% dan 53.33% masing-masing) yang menunjukkan sumber sedimen dari saluran sungai. VJR mempunyai histeresis lawan jam sebagai histeresis utama (kekerapan 46.67%) manakala OP mempunyai kekerapan yang serupa bagi histeresis arah jam, lawan jam dan bentuk-lapan lawan jam – VJR mempunyai sumber sedimen yang jauh dari sungai manakala OP mempunyai beberapa sumber sedimen. Index histeresis Lawler yang diubahsuai [HImean] yang dipakai untuk mengukur magnitud histeresis menunjukkan bahawa tidak ada perbezaan yang besar antara penggunaan tanah yang berbeza. Kaedah semasa pengenalpastian dan klasifikasi bentuk histeresis terutamanya histeresis bentuk-lapan dan histeresis kompleks di kawasan khatulistiwa adalah tidak

mencukupi. Dengan kebolehubahan yang tinggi dalam suatu peristiwa hujan, setiap histeresis memerlukan analisis yang berasingan untuk mengulas bentuknya dan memperoleh penjelasan untuk penghanyutan sedimen. Penemuan utama yang boleh diaplikasikan secara langsung ke dalam kegiatan pengurusan: (i) nilai kepekatan sedimen terampai adalah paling tinggi di ladang kelapa sawit tetapi hasil sedimen boleh dikurangkan dengan pemilihan kawasan penanaman kelapa sawit secara teliti (kawasan dengan hujan dan kecerunan yang rendah); dan (ii) hutan yand telah dibalak berulang kali masih mempunyai nilai yang tinggi dari aspek pemuliharaan air dan tanah. Amalan biasa untuk menukar hutan yang berulang kali dibalak kepada ladang yang berasaskan andaian bahawa hutan yang dibalak tidak mempunyai nilai ekologi perlu dipertimbangkan semula.

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BMP	–	Best management practices
DBH	–	Diameter at breast height
DSY	–	Dissolved Solids Yield
DVCA	–	Danum Valley Conservation Area
DVFC	–	Danum Valley Field Centre
Ei	–	Interception loss
EIA	–	Environmental Impact Assessment
ET	–	Evapotranspiration
Et	–	Transpiration
et al.	–	And others
GDP	–	Gross domestic product
HI_{mean}	–	Average value of hysteresis index at k = 0.25, k = 0.5 and k = 0.75
HI_{mid}	–	Lawler Hysteresis Index
HOF	–	Hortonian Overland Flow
HSA	–	Hydrologically Sensitive Area
LCD	–	Liquid Crystal Display
LF2	–	Twice-Logged Forest
LF3	–	Repeatedly-Logged Forest
MBSC	–	Maliau Basin Studies Centre
NPP	–	Net primary production
OP	–	Oil Palm Plantation
P	–	Precipitation
pa	–	Per annum