academicJournals

Vol. 5(6), pp. 303-309, June 2013
DOI 10.5897/IJWREE2012.0368
ISSN 2141-6613 © 2013 Academic Journals
http://www.academicjournals.org/IJWREE

International Journal of Water Resources and Environmental Engineering

Full Length Research Paper

Hydrological assessment and suspended sediment loading of the Chini Lake catchment, Pahang, Malaysia

Sujaul I. M.[1], Ismail B. S.[1]*, Muhammad Barzani G.[1], Sahibin A. R.[1] and Mohd Ekhwan T.[2]

[1]School of Environment and Natural Resource Sciences, Faculty of Science and Technology, Universiti Kebangsaan Malaysia, 43600 UKM Bangi, Selangor, Malaysia.
[2]School of Social Development and Environmental Studies, Faculty of Social Science and Humanities, Universiti Kebangsaan Malaysia, 43600 UKM Bangi, Selangor, Malaysia.

Accepted 26 April, 2013

Hydrological evaluation and sediment loading of the Chini Lake catchment was investigated. Sediment loads and water discharge from seven selected feeder rivers were measured over a period of one year (January to December 2006). Suspended sediment concentration was measured by the standard method. The annual rainfall from 1984 to 2006 at the Chini Lake catchment ranged from 1487.70 mm (1997) to 3071.40 mm (1994), with the annual rainfall for 2006 being 2544.50 mm. Stream flow rate during the sampling periods was relatively slow, ranging from 0.001 to 1.31 m^3s^{-1} (or an average of 0.21 m^3s^{-1}). The highest and lowest stream flow discharges were recorded from the Gumum River and Cenahan River subcatchment. The amount of sediment load ranged from 0.49 to 166.02 $kg/km^2/day$ (or an average of 30.57 $kg/km^2/day$) in the study area. The highest sediment load was recorded in the wet season and the lowest in the dry season. Human activities have significantly affected the hydrological functions and deposition of sediment and thus influenced the variation in sediment loading.

Key words: Hydrological characteristics, feeder river, stream flow, sediment loading, Chini Lake.

INTRODUCTION

Precipitation is the main cause of variability in the water balance over space and time. Changes in precipitation have very important implications on hydrology and water resources. Hydrological variability over time in a catchment is influenced by variations in precipitation over diurnal, temperature, seasonal, soil covering and, annual and decadal time scales (Viesmann and Lewis, 2003). Sediment is recognized as a significant water pollutant. In addition, sediment transports chemicals, which compounds its effect on water quality. Nutrients and suspended sediment loads into rivers are increased by timber harvesting, changes in land use and river channelization (Slaymaker, 1982; Nakamura et al., 1997; 2004). The sediment yield is highly dependent on soil erosion and sediment transport stages. Large volumes of nutrient and suspended sediment inputs have caused degradation of aquatic habitats due to declining water quality (Nakamura et al., 2004; Takamura et al., 2003).

The hydrology of a lake is responsible for the stability of its ecosystem. The water level of the Chini Lake depends on the feeder rivers discharge that comes from the surrounding area. The Chini Lake formation is believed to be similar to that of the Bera Lake (Furtado and Mori, 1982). The average altitude of the lake area is 76 m below sea level. The main water sources contributing to the main lake body comprise: firstly, the natural tributaries of the Chini River which are the Paya Merapuk River to the southwest, the Melai River to the south, the Jemberau and Kura kura Rivers to the southeast, the Cenahan and Gumum Rivers to the north east and the Datang River to the north; secondly the backflow from the Pahang River that occurs during the flood season. Based

*Corresponding author. E-mail: ismail@ukm.my. Tel: +603 89215864.

on the topographical map, most of the lowland within the study area has been converted into agricultural land including rubber and oil palm plantations and mixed crops. Logging activities are still going on in the study area. Most of the sediment problems in and around the Chini Lake are associated with anthropogenic effects such as forestry, agriculture and mining activities. The main objective of the study was to evaluate the hydrological factors and identify the stream flow and discharge pattern of the feeder rivers for the dry and wet seasons, as well as assess the sediment loading into the lake.

MATERIALS AND METHODS

Study area

The Chini Lake (Tasik Chini) is located in the southeastern region of Pahang, Malaysia (Figure 1). It is located approximately 100 km from Kuantan, the capital of Pahang. The lake system lies between 3°22´30˝ to 3°28´00˝N and 102° 52´40˝ to 102°58´10˝E and comprises 12 open water bodies (that are referred to as "laut" by the local people) and is linked to the Pahang River by the Chini River. A few communities of the indigenous Jakun tribe live around the lake. The Chini Lake is the second largest natural fresh-water lake in Peninsula Malaysia, encompassing 202 ha of open water, as well as 700 ha of Riparian Peat and Lowland Dipterocarp forest (Wetlands International Asia Pacific, 1998). The Chini Lake is surrounded by various vegetated low hills and undulating land which constitute the watershed of the region. There are three hilly areas surrounding the lake: (1) Bt. Ketaya (209 m) located southeast; (2) Bt. Tebakang (210 m) in the north and (3) Bt. Chini (641 m) located southwest. The Chini Lake catchment is representative of the upstream site of the Pahang River. The study area has humid tropical climate with two monsoon periods, characterized by the following bimodal pattern. The southwest and northeast monsoons bring an annual rainfall of 1488 to 3071 mm. The mean annual rainfall for the past 20 years is 2,500 mm and the temperature range is from 21 to 32°C. Potential evapotranspiration (PE) is between 500 to 1000 mm. The open water area has expanded since 1994, as a result of increased water retention after the construction of a barrage downstream Chini River. The lake drains northwest into the Pahang River via the Chini River, which meanders for 4.8 km before reaching the Pahang River.

Sampling and stream flow measurement

Seven sampling stations were selected for the study based on the seven feeder rivers that flowed into the Chini Lake. These seven stations were established on each feeder river of the lake: the Datang River (Station 1), the Cenahan River (Station 2), the Gumum River (Station 3), the Kura kura River (Station 4), the Melai River (Station 5), the Paya Merapuk River (Station 6) and the Jemberau River (Station 7). The catchment characteristics such as area, velocity, and flow discharge were evaluated for each feeder river. The area of the catchment was measured from the topographical map of the Chini Lake (scale 1: 25,000). The river morphology such as width, depth and flow were measured at each sampling station. The stream flow and river width were measured using a Flow Meter (model FP101) and the Rangefinder (Bushnell Model 20-0001) was used to measure the distance. At each site, water samples were taken from the mid-channel approximately 10 cm below the surface with care being taken not to disturb the bed sediment. Water samples from the main feeder rivers were collected for measurement of the total sediments. The sediment yield was determined based on calculation of the total suspended solids (TSS) which includes inorganic (sand, silt and clay) and organic materials, and total dissolved solids (TDS) in the water samples. The standard laboratory methods (APHA, 1998) were used. The total rainfall during the study period was obtained from the nearby weather station at Chini Dua, while the rainfall data prior to 2006 was obtained from the Meteorological Department at Petaling Jaya, Selangor, Malaysia.

Suspended sediment load measurement

In the current study, suspended sediment load was calculated by the turbidity threshold sampling (TTS) method. The USDA Forest Service Redwood Sciences Laboratory in Arcata, California developed this methodology to improve the accuracy and efficiency of suspended sediment load estimations (Lewis and Ead, 2001). The discharge-weighted suspended sediment load (Qs) in kilograms (kg) per area (km^2) per day ($kg/km^2/day$) for the river cross-section was obtained by multiplying the concentration, C, in kilograms per liter (kgl^{-1}) with the discharge, Q, in liters per day ($lday^{-1}$), followed by division of the drainage area A (km^2). The discharge, drainage area and concentration values are given in Table 2. The equation used is as follows:

$$Qs = (C*Q)/A$$

RESULTS AND DISCUSSION

Subcatchment areas of the Chini Lake

On the basis of morphometrical characteristics, the Chini Lake catchment consists of thirteen subcatchments (Figure 2). The names and areas of the subcatchments are detailed in Table 1. The Gumum River subcatchment is the largest subcatchment (1306.24 ha, or 21.49% of the total study area), the Paya Merapuk River subcatchment is the second largest (20.90% of total catchment area) and the Datang River subcatchment the third largest (7.92% of the study area).

Rainfall

Hydrological analysis was carried out to evaluate the water level characteristics of the water body as well as the drainage systems (Gray, 1970; Ceballas and Schnabel, 1998). The annual rainfall from 1984 to 2006 at the Chini Lake Catchment ranged from 1487.70 mm (1997) to 3071.40 mm (1994) (Figure 3). The average rainfall was 2344.30 or 195.36 mm $month^{-1}$. The number of rainy days in the study area ranged annually from 130 to 197 with an average of 175 or 15 days/month. The highest number of rainy days per year was obtained in 1993 and 1994 (197 and 190 days respectively), while 2005 had the lowest number of rainy days (130 days) (Figure 4). The number of rainy days during 2006 was 134 days. The highest number of rainy days per month (16 days) was recorded during the wet season in 2006 (December), while January and March 2006 recorded the

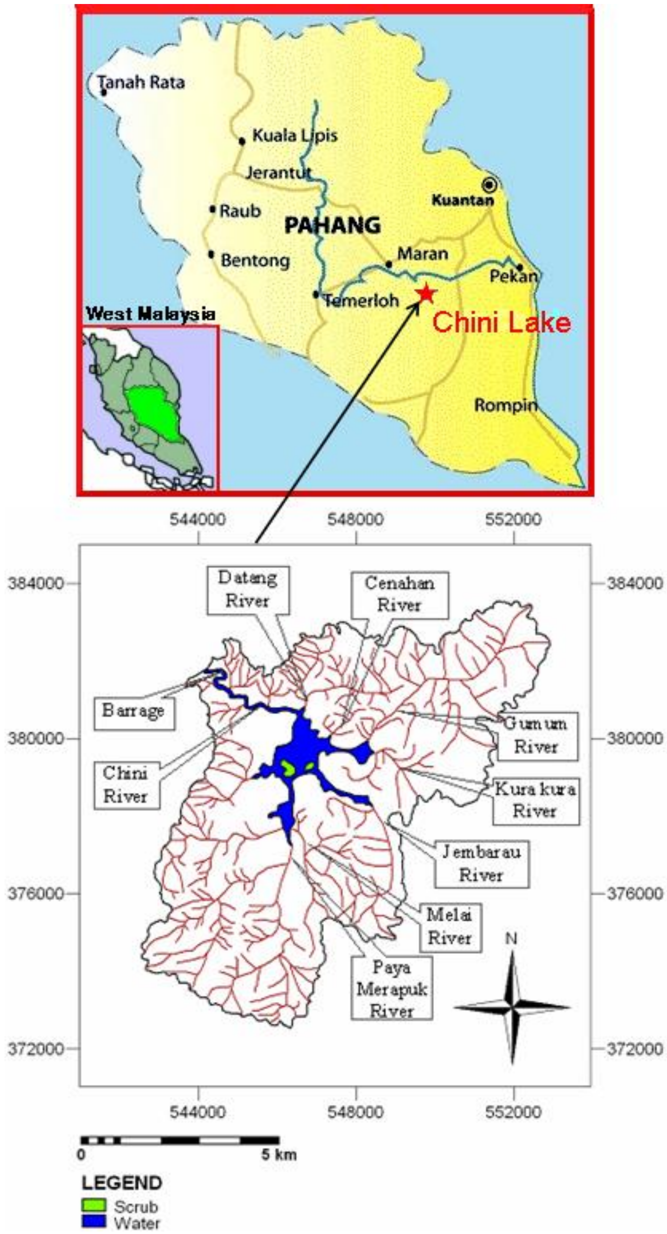

Figure 1. Study area and feeder rivers of the Chini Lake catchment.

lowest number of rainy days (7 days) (Figure 6). The highest rainfall recorded was 440.20 mm in December 2006 and the lowest, 76.50 mm in March 2006 (Figure 5). The annual rainfall for 2006 was 2544.50 mm.

Stream flow of the feeder rivers

Stream flow discharge from the seven feeder rivers to the Chini Lake was relatively low, ranging from 0.001 to 1.31 m^3s^{-1} or an average of 0.21 m^3s^{-1}. Daily discharge ranged seven feeder rivers are shown in Figure 7. The stream from 86.40 to 113,184 m^3, averaging 18,144 m^3/daily.

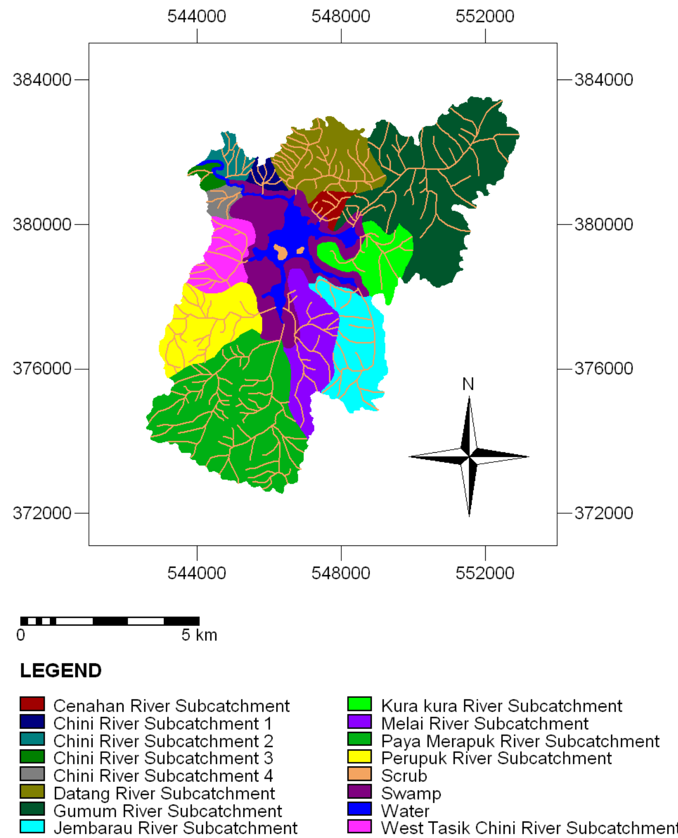

Figure 2. Subcatchment areas of the Chini Lake (DOA, 2006)

Table 1. Area (ha) of subcatchments in Chini Lake catchment area.

River subcatchment (ha)	Area (ha)	Area (%)
Perupuk River subcatchment	450.40	7.41
Paya Merapuk River subcatchment	1270.28	20.90
Melai River subcatchment	395.72	6.51
Jembarau River subcatchment	455.72	7.49
Kura kura River subcatchment	292.12	4.81
Gumum River subcatchment	1306.24	21.49
Cenahan River subcatchment	69.24	1.14
Datang River subcatchment	481.36	7.92
Chini River subcatchment 1	59.08	0.97
Chini River subcatchment 2	92.76	1.53
Chini River subcatchment 3	43.84	0.72
Chini River subcatchment 4	65.08	1.07
West Tasik Chini River subcatchment	247.08	4.06

The seasonal (dry and wet) discharge variability of the flow rate of the Gumum River was higher (1.31 m^3s^{-1}) and the Cenahan River lower (0.01 m^3s^{-1}). The Paya Merapuk River was considered the second highest (1.26 m^3s^{-1}). The stream flow of these rivers depended mainly on the rainfall pattern. The fastest stream flow rate was observed during the wet season, especially in September,

Table 2. Suspended sediment load of the selected feeder rivers of the Chini Lake catchment.

Feeder river	Drainage area (km^2)	Water discharge (m^3s^{-1})	Sediment load ($ton/km^2/year$)
Melai	3.96	0.19	9.10
Paya Merapuk	12.7	0.4	7.58
Chenahan	0.69	0.04	14.91
Jemberau	4.55	0.1	5.77
Kura kura	2.92	0.07	6.53
Gumum	13.06	0.42	16.45
Datang	4.81	0.22	17.74

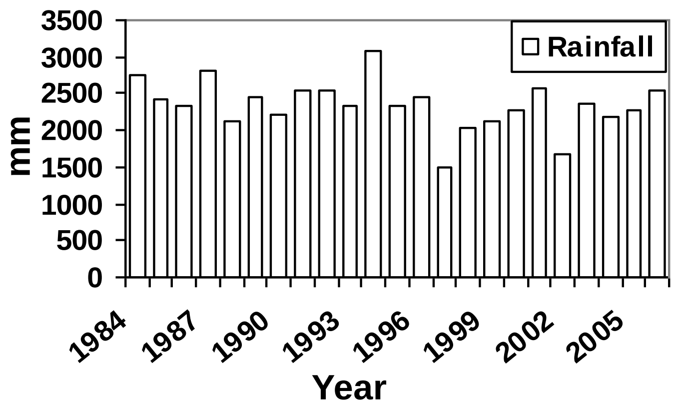

Figure 3. Distribution of rainfall from 1984 to 2006.

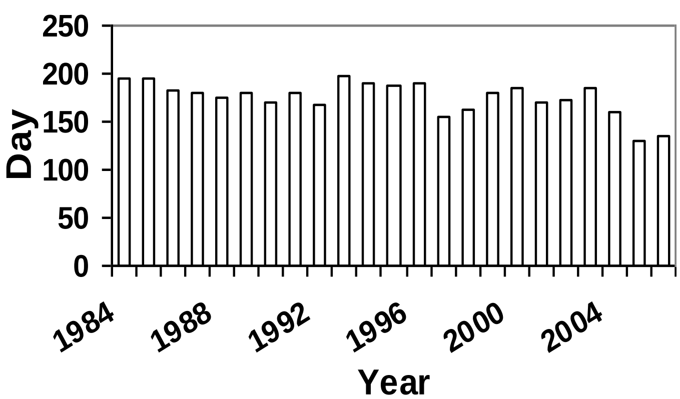

Figure 4. Distribution of the number of rainy days from 1984 to 2006.

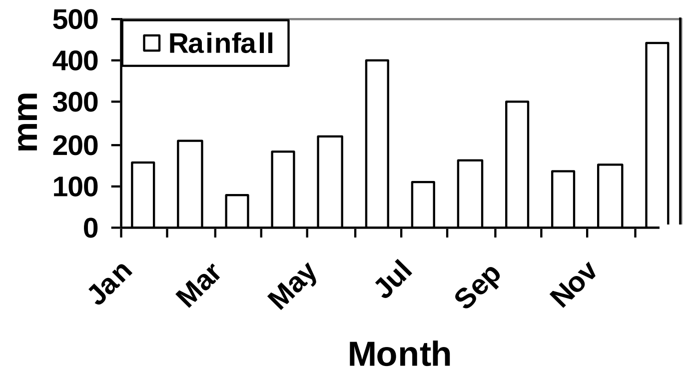

Figure 5. Distribution of rainfall from January to December 2006.

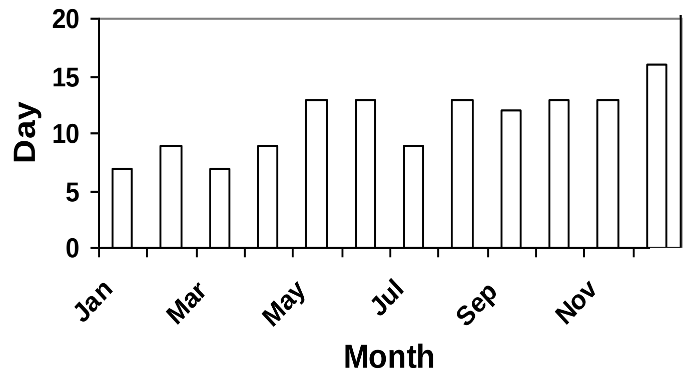

Figure 6. Distribution of the number of rainy days from January to December 2006.

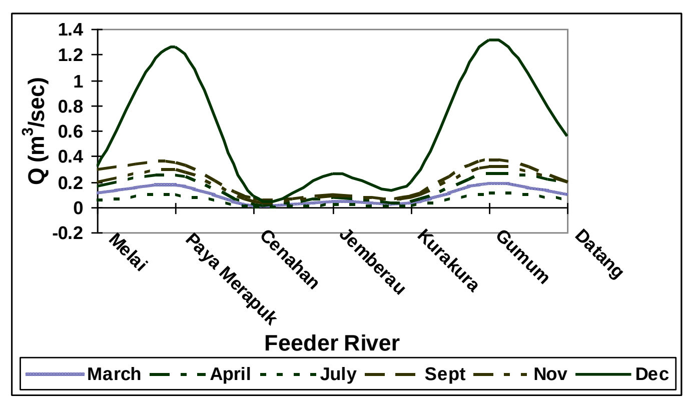

Figure 7. Stream flow distribution of the seven feeder rivers of the Chini Lake catchment.

November and December 2006, while in the dry season, especially during March, April and July 2006 a lower stream flow rate was recorded. Stream flow discharge from the seven subcatchments to the Chini Lake was relatively slow. The highest stream flow discharge was recorded from the Gumum River subcatchment as it was the largest subcatchment (1,306.24 ha) of the Chini Lake.

Lower stream flow rate was recorded at the Cenahan River subcatchment (69.24 ha) as it was a small subcatchment. The results of this study highlight that intense precipitation through the Chini Lake catchment controlled the discharge rate of the seven feeder rivers. The maximum discharge was recorded in the study area due to the monsoonal storm intensity especially from September to December. Discharges of all feeder rivers were low during the month of July due to the low intensity of rainfall.

Sediment loading

The sediment concentrations varied from month to month reflecting the influence of the rainfall regime. Sediment loads varied depending on the discharge, sediment concentrations and the study area. The highest sediment concentration (19.16 mgL^{-1}) was observed in December 2006, the lowest (0.11 mgL^{-1}) in the dry month of July 2006 where water flow was also low. The average sediment load for the seven feeder rivers is shown in Table 2. The amount of sediment load was recorded from the seven feeder rivers, and they ranged from 5.98 to 17.05 kg/km^2/day (or, an average of 10.36 kg/km^2/day) in March, 6.42 to 34.10 kg/km^2/day (or, an average of 16.84 kg/km^2/day) in April, 0.49 to 6.18 kg/km^2/day (or, an average of 2.81 kg/km^2/day) in July, 11.10 to 48.57 kg/km^2/day (or, an average of 28.78 kg/km^2/day) in September, 5.53 to 39.22 kg/km^2/day (or, an average of 19.64 kg/km^2/day) in November and 57.53 to 166.02 kg/km^2/day (or, an average 104.96 kg/km^2/day) in December 2006. The details are in Figures 8 to 13. The mean sediment load in the Chini Lake was 30.56 kg/km^2/day (11.16 ton/km^2/year). The calculated sediment loads deposited in the Chini River were: 9.38 kg/km^2/day in March, 13.14 kg/km^2/day in April, 5.28 kg/km^2/day in July, 15.50 kg/km^2/day in September, 13.50 kg/km^2/day in November and 40.96 kg/km^2/day in December 2006 (Figure 14a and 14b). The mean sediment load deposited in the Chini River was 16.29 kg/km^2/day (5.95 ton/km^2/year). The highest sediment load was recorded in December and the lowest in July 2006. The highest load in December 2006 was due to rain and probably related to the high flow and concentration of sediment yield. The results also indicated that the total rainfall during December 2006 directly influenced the flow of the feeder rivers into the Chini Lake catchment. Mohd Ekhwan (2005) while carrying out a study at the Bebar River catchment (in Malaysia) found that sediment yield varied with the rainfall and factors such as channel slope, relief and basin size.

The study showed that the Chini Lake suffered high sediment loading from its feeder rivers. The highest suspended sediment discharge recorded was from the Gumum River subcatchment and it ranged from 6.18 to 166.02 kg/km^2/day (or an average of 45.08 kg/km^2/day).

The Jemberau River subcatchment had the lowest sediment discharge ranging from 1.33 to 57.53 (or an average of 15.80). The Gumum River subcatchment was located within the settlements and agricultural areas. The highest suspended sediment concentration came from this subcatchment due to its land use pattern. The discharge

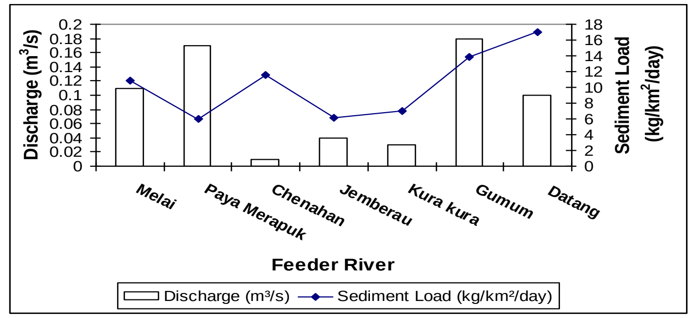

Figure 8. Distribution pattern of sediment loads and discharges of the seven feeder rivers in March 2006.

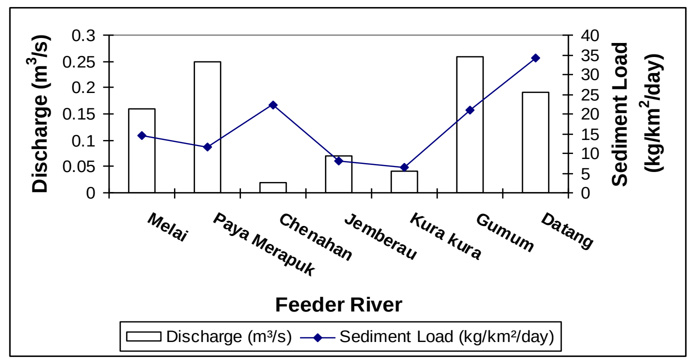

Figure 9. Distribution pattern of sediment loads and discharges of the seven feeder rivers in April 2006.

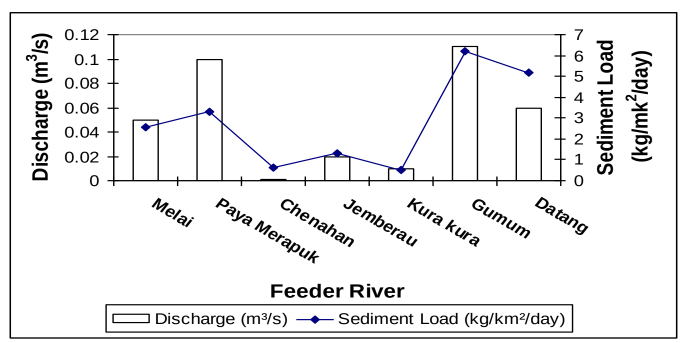

Figure 10. Distribution pattern of sediment loads and discharges of the seven feeder rivers in July 2006.

from the Gumum River subcatchment was higher due to the size of the drainage area of all the feeder rivers. The Gumum River carried the largest amount of sediment into the catchment. The Datang River carried the second largest amount of sediment, discharging more than 41.01 kg/km^2/day into the lake. Logging activities and shifting cultivation were the main land use patterns in the Datang River subcatchment area. The Jemberau River carried a low load of suspended sediment. The Jemberau River subcatchment was located under forested areas thus the

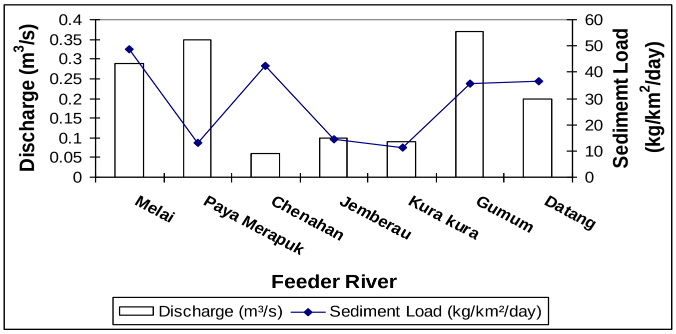

Figure 11. Distribution pattern of sediment loads and discharges of the seven the feeder rivers in September 2006.

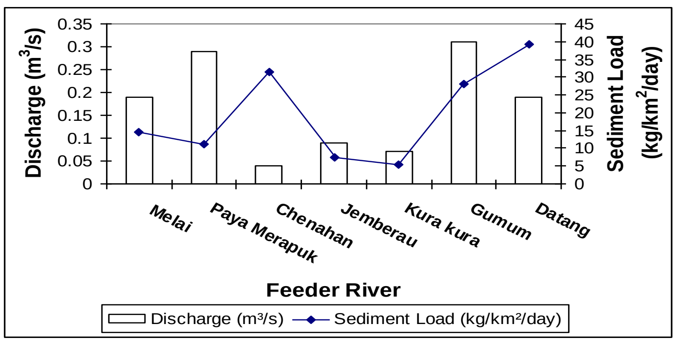

Figure 12. Distribution pattern of sediment loads and discharges of the seven feeder rivers in November 2006.

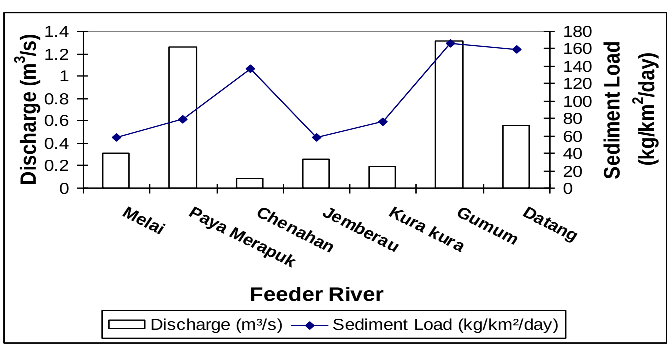

Figure 13. Distribution pattern of sediment loads and discharges of the seven feeder rivers in December 2006.

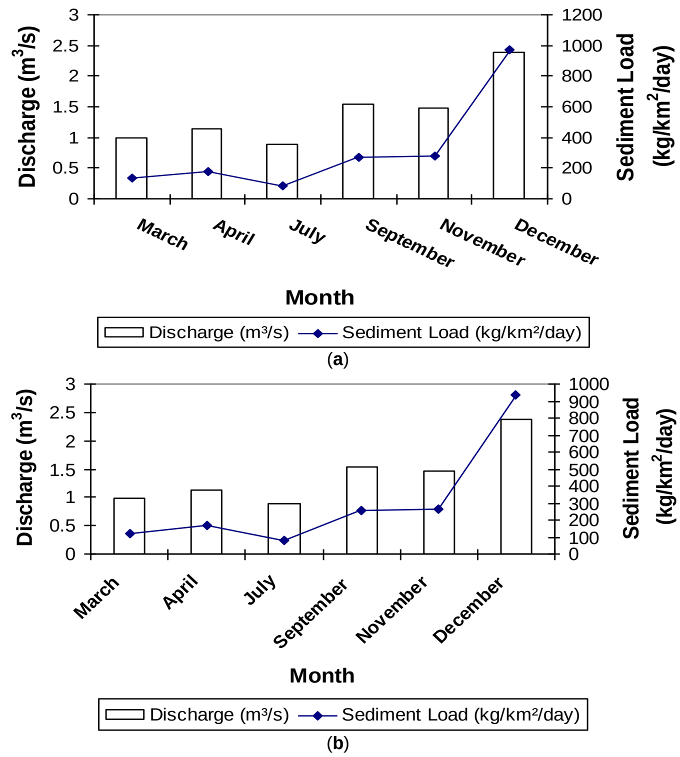

Figure 14. Distribution pattern of sediment loads and discharge variations of the Chini River (a) Up stream and (b) Down stream in 2006.

drainage area and the stream flow was also low. The study indicated that the sediment load varied from month to month reflecting the influence of the rainfall regime. All the feeder rivers had lower sediment loads during the dry season and higher in the wet season. There was a relationship between the water discharge and sediment loads during the study period (Figures 8 to 14). Suspended sediment concentration depended on hydrological behavior during the very event. The hydrological response was influenced by the land type and study area. The study area was also subjected to intense erosion because of the land relief and the monsoon climate. Aha et al. (2008) stated that high concentration of sediment load was dependant on land use, stream channels, vegetation cover, climatic conditions and degree of channelization.

Conclusion

The Chini Lake is a shallow and small natural lake, which is considered a sensitive ecosystem as it responds to changes from its surroundings. In the study the hydrology and sediment dynamics in the Chini Lake catchment were examined in order to clarify the main factors degrading the lake ecosystem. The hydrology and sediment loading into the Chini Lake was dependant on the hydrometeorological conditions. Stream flow discharge from each feeder river into the Chini Lake was directly related to the rainfall pattern. In the dry season the discharge from the feeder rivers was lower than that in the wet season. A series of rain events in the study area favored erosion and mass movement, which also provided sediment sources for the studied catchment. Erosion and sediment yield from this catchment was higher than those from other forested catchment areas in Malaysia because some small scale disturbances were already present in the catchment plus there was the contribution of sediment from anthropogenic activities like progressive deforestation, cultivation and construction activities which led to soil exposure and degradation. Variability in sediment loading necessitates the need for long-term monitoring of sediment yield. As a long-term measure, environmental policies regulating land-use development and management practices should be formulated and implemented.

ACKNOWLEDGEMENT

This study was conducted and supported by the Ministry of Science and Technology, Malaysia through the IRPA grant, code: 09-02-02-0117-EA294, Zamalah Scheme and OUP fund (Code: UKM-OUP-FST-2008) UKM, Malaysia.

REFERENCES

Aha YS, Nakamura F, Mizugaki S (2008). Hydrology, suspended sediment dynamics and nutrient loading in Lake Takkobu, a degrading lake ecosystem in Kushiro Mire, northern Japan. Environ. Monit. Assess. 145:267-281.

APHA (1998). Standard Methods of Water and Waste Water Analysis (Eds.) 20th Edn. American Public Health Association, Washington.

Ceballas A, Schnabel S (1998). Hydrological behavior of a small catchment in the Dehesa land use system. J. Hydrol. 210:146-160.

DOA (2006). Land use map of Tasik Chini, Malaysia. Scale 1: 50,000. Director of National Mapping, Department of Agriculture, Putrajaya.

Furtado JJ, Mori S (1982). Tasik Bera: The Ecology of Freshwater Swamp. Dr. W. Junk Publication, Netherlands.

Gray DM (1970). Handbook on the Principles of Hydrology. National Research Council, Canada.

Lewis J, Eads R (2001).Turbidity threshold sampling for suspended sediment load estimation. In: Proceedings, 7th Federal Interagency Sedimentation Conference. 25-29 March 2001. Reno, Nevada. pp. 110-117.

Mohd ET (2005). Hydrometeorological Condition and Sediment Yield in the Upstream Reach of Sungai Bebar, Pahang, Malaysia. Biodiversity Expedition. Peat swamp forest project, Pahang Forestry Department, Forest Research Institute Malaysia, pp. 41-45.

Nakamura F, Kameyama S, Mizugaki S (2004). Rapid shrinkage of Kushiro Mire, the largest mire in Japan, due to increased sedimentation associated with land-use development in the catchment. Catena 55:213-229.

Nakamura F, Sudo T, Kameyama S, Mieko J (1997). Influences of channelization on discharge of suspended sediment and wetland vegetation in Kushiro Marsh, northern Japan. Geomorphology, 18:279-289.

Slaymaker O (1982). Land use effects on sediment yield and quality. Hydrobiologia, 91:93-109.

Takamura N, Kadono Y, Fukushima M, Nakagawa M, Kim BHO (2003). Effects of aquatic macrophytes on water quality and phytoplankton communities in shallow lakes. Ecol. Res. 18:381-395.

Viessman W, Lewis GL (2003). Introduction to Hydrology (Eds.). 5th Edn. Pearson Education Ltd., Upper Saddle River, USA.

Wetlands International Asia Pacific (1998). The ecological assessment of Tasik Chini Pahang, Peninsular Malaysia: An evaluation of its conservation value and environmental improvement requirements. WIAP, Kuala Lumpur.