THE COMPOUND SPECIFIC STABLE ISOTOPE (CSSI) VALUES IN TIMAH TASOH SOIL EROSION STUDY

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ABSTRACT

Erosion studies in some areas of the irrigation system found in Peninsular Malaysia by local researchers are so limited as compared to studies conducted by researchers around the world. There are several factors that can be taken into account, among others, the lack of provisions and the methods used cannot cope with a large number of irrigation systems in the country. Additionally, most studies conducted include conventional methods that only determine soil erosion rates without being able to identify sources of soil erosion in the catchment area. Hence, this research paper is to identify the sources of soil erosion contributed by the diversity of agricultural activities or land use differences into the catchment area at the study site using Compound-Specific Stable Isotopes (CSSI) method. The research has been conducted for three years from September 2015 to August 2018 and various factors have been taken into consideration that is located at Timah Tasoh, Perlis, North of Peninsular Malaysia. Based on the results of the analysis, the largest sediment contributions were coming from Mixed Crops and rubber plantations, each contributing 46.5% and 25% respectively. These two major contributors are from the Sub-Catchment River Pelarit (Lower) and Sub-Catchment River Jarum. Meanwhile, The Chuchuh river sub-catchment contributes low sedimentation by sediments taken from land-use areas covered by primary and secondary forest. In conclusion, this method is useful to be applied in determining the sources of soil erosion from erosion-prone areas in catchment areas throughout the country as well as several other methods in the near future.

Key words: Erosion studies, Irrigation, Compound-Specific Stable Isotopes, Timah Tasoh catchment, Contribution

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INTRODUCTION

Soil erosion is a process of elimination or sculpture on the surface of the earth involving by erosion agents such as rainwater in abundant quantities, flowing water that after heavy rain, tornado winds or sandstorms, waves, glaciers and others. With these causal factors, soil erosion has become a major problem in every country in the world today. Some of these causative factors; land erosion has become a major problem in every country in the world today. Meanwhile, erosion is a natural process and with human activity increases the rate of erosion by 10-40 times globally. The clearing of land particularly through the opening of jungle land under climate-vegetation ecosystems in Malaysia leads to marked changes in the hydrological balance. It has been estimated that during storms, runoff from catchments with plantation crops (oil palm and rubber) during a period of 13 months was twice that of a similar area under jungle, while the low flows were halved (Daniel & Kulasingam, 1974). Tang et al (1979) showed that in an extensive study area in Kelantan, sediment yield under undisturbed forest conditions was 100 m^3/km^2/year. This increased to $300m^3/km^2$/year when 30-40% of the catchment was under logging and dramatically rose to 2500 m^3/km^2/year when the entire catchment was mechanically logged. Pimental et al, (1995 mentioned the arable land continues to be lost for 10 million ha per year with the annual removal of 75 billion t of soil from wind and water erosion processing. Soil erosion is a natural processing which is occurred after landscapes is used from the land use or the acceleration from human activities such as agricultural on the agricultural land. About 21% of the soil degradation in southern China and Southeast Asia is caused by water erosion (IFPRI, 1991). Erosion has several disadvantages associated with the productivity of land as well as several off-site problems such as siltation, drainage disruption, gullying of roads, eutrophication, loss of wildlife habitats, damage to public health, plus increased water treatment costs. Of the 75 x 109 tons of soil eroded worldwide each year, about two-thirds come from agricultural land. This loss costs the world about $400 billion per year, including losses due to nutrient loss, water loss and off-site impacts (Pimentel et al., 1995).

Moreover, in several regions across the globe, climate change is impacting the precipitation regime (Christensen et al., 2007), resulting in increased drought periods and high-intensity rainfall events (IPCC, 2013, 2014). As a result of climate variability and global warming, world average soil loss is predicted to further increase significantly (Li & Fang, 2016; Yang, Kanae, Oki, Koike, & Musiake, 2003). Soil erosion decreases soil productivity through soil, nutrient, and organic matter losses; deterioration of overall soil health; decrease of fertility, production potential, and biological activity; breakdown of soil structure; increase of soil erodibility; and reduction of soil water holding capacity. Poor soil quality further accelerates soil erosion, in particular on steep farmland, where this process is intensified by overgrazing and improper agricultural practices (McHugh et al., 2004; Tiwari, Sigata, Bajracharya, & Borresen, 2009; Valentin et al., 2008). The intensification of upland erosion also increases sediment delivery downstream, causing further problems such as off-site erosion effects among which the most important is the siltation in water reservoirs and pollution of water sources and coastal sea waters resulting in the dying of coral reefs (eg , Smith & Wilcock, 2015). Meanwhile, today isotope applications are widely used in soil erosion assessment, extending from quantitative approaches using radiogenic isotopes (e.g. ^{137}Cs, ^{210}Pbex, $^{239\ +\ 240}$Pu). Whereas qualitative assessment (d13C, δ15N) and sediment source attribution by using a special compound stable isotope analysis (CSIA) consist of compounds such as fatty acids and n-alkanes. However, the radiogenic approach of these FRNs has been used for more than five decades, aimed at determining the direct impact of a single site or source of soil erosion, and meanwhile, CSIA assesses the impact and measurement of sedimentary source attribution beyond the source of soil erosion or location after a flood. .

In addition, excessive soil erosion, especially after heavy rainfall has brought many problems such as reduction of agricultural productivity due to soil degradation, waterways, ecological collapse due to loss of soil nutrients and also increased use of fertilizers in areas agriculture. Excess erosion leads to problems such as desertification, reduction of agricultural productivity, waterways deposition and ecological collapse resulting from the loss of nutrients on the top layer of soil. The main causes for 84% of soil degradation are coming from two main contributors, water and soil erosion which that to make excessive erosion one of the significant environmental problems facing the world today. Erosion by water can be divided into 4 categories; splashes, strains or small lakes, mass movement and river erosion. Water erosion begins with raindrops exposed to the soil over a long period of time and this will allow the soil pollution process to occur, damaging the granulation and sparks acting as a transport agent in some circumstances. This is due to an energy factor or force generated by so many raindrops that the exposed granules of the spark are exposed but may also be fragmented. This kind of erosion is further reinforced in a steady stream of raindrops over a long period of time and continues on the surface of the soil.

Thus, information on the source of sediment from this study can be obtained by studies involving the number or relative number of stable isotopes ^{13}C and different signatures of δ^{13}C in C3 and / or C4 plants (e.g., Laceby, Olley, Pietsch, Sheldon, & Bunn, 2015; Schindler Wildhaber, Liechti, & Alewell, 2012). And also, the additional information can be obtained using compound specific stable isotope (CSSI) techniques in soil erosion studies and their causes. This technique is based on the fact that plants label soil by organic biomarkers, which are absorbed by soil mineral particles and subsequently dispersed to surrounding areas through soil movement, in a manner similar to FRNs. However, depending on the plant species, these biomarkers have different stable isotope markers and this makes them suitable for differentiating the distribution of soil source sources from different land uses (Gibbs, 2008; Reiffarth, Petticrew, Owens, & Lobb, 2016; Upadhayay et al., 2017). For agricultural investigations, CSSI techniques are based on the determination of 13C natural abundant signature of biomarkers such as fatty acids (FA). Therefore, samples of soil collected after heavy rain at the site of the study were brought directly to the Radiochemistry and Environment Group (RAS), Nuclear Malaysia for pre-treatment preparation before undergoing for Compound-Specific Stable Isotopes (CSSI) analysis. The organic composition of CSSI has been analyzed using gas chromatography-mass spectrometry (GC–MS) and inductively coupled plasma-mass spectrometry (ICP-MS). These two instruments are the most appropriate to investigate the fatty acid values in environmental samples in decayed plant leaves or roots that brings together with the mud or sediment after the flood events. Meanwhile, the main objective for this research paper is to identify the sources of soil erosion contributed by the diversity of agricultural activities from different land use into the catchment area at the study site using Compound-Specific Stable Isotopes (CSSI) application.

MATERIAL AND METHODOLOGY

Soil sampling and preparation of samples

Therefore, high-resolution sediment sampling using appropriate equipment in the event of heavy rainfall and this CSSI analysis method has been able to explain the temporal pattern of sediment mobilization under different crop regimes and the specific contribution made by each plant to the load downstream. Analyze all soil samples taken and taken to the laboratory for processing purposes is a soil material from a variety of cover crops in agricultural catchments. Thus, the use of these mixed soils has shown that the CSSI signature of carbon reactive fatty acids particles labels agricultural land with different crop signatures. Moreover, allowing sediment erosion from each cover to be traced downstream after heavy rainfall individually during the study period. Furthermore, the samplings of core soils were carried out in Timah Tasoh reservoir (6º33'U - 6º35'U & 100º13'T - 100º15'T) is located approximately 13 km north of Kangar town near the Thailand border. The catchment has a mean surface area of 13.33 km^2 and a storage capacity of about 40 million m^3 (Figure 1). The catchment receives inputs from two main rivers, the Tasoh River and Pelarit River, which have a combined area of 191 km^2 and supply approximately 97 million m^3 of water into the catchment annually. The Tasoh River consists of two inputs, the Jarum River and the Chuchuh River. The area surrounding the reservoir and its upstream catchments includes mainly agriculture such as sugar, rubber, paddy and timber plantations, the urban area such as Padang Besar town and quarry near Kaki Bukit. The catchment is shallow with the maximum depth of 10 m and submergence aquatic plant can be seen along the shoreline and shallow area. At present, the main purpose of the catchment is to supply water for domestic and industrial use as well as for irrigation as wide as 2372 hectares of paddy land for double cropping and to prevent flood occurrences in the rainy season. All core soil samples were taken in the study area and mix the sample in the bucket using a metal scraper hand corer (Figure 2). It is critical that the sample is well mixed to be representative of the site. The combined 8-10 cores samples in a bucket were brought to Radiochemistry and Environment Group Laboratory (RAS) for further treatment. Each core was dried in the oven at 45- 60 º C to achieve constant dry weight. Dried samples were then fine grinded and sieved at 2 mm before the samples reading for ^{13}C analysis.

Figure 1: Main rivers and its tributaries at Timah Tasoh reservoir catchment

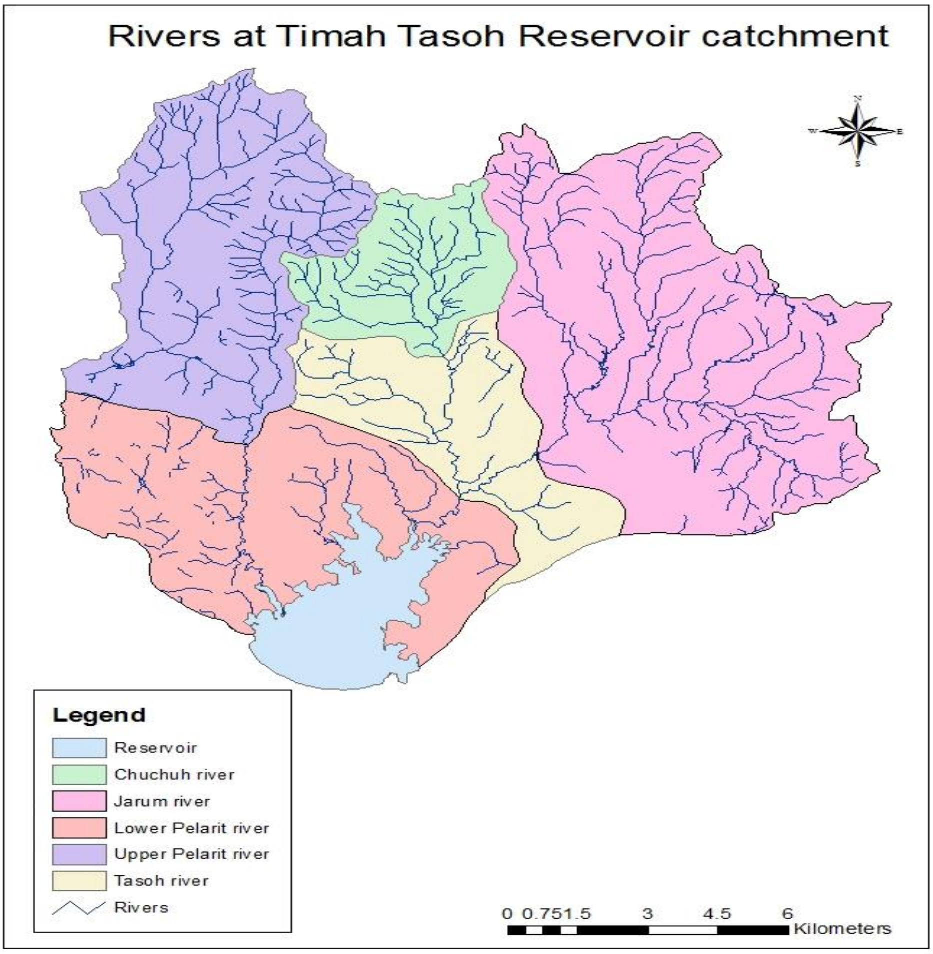


Figure 2: Hand corer for CSSI sampling

Measuring percent organic carbon (%C)

This information is required for the estimation the amount of sample to be weighed for the determination of bulk $\delta^{13}C$ and used for the extraction of fatty acids.

1. Weight a small aluminium pie dish (about 5 cm in diameter) and record the weight.
2. Place an aliquot of about 5 g of dry sample in the pie dish and record the weight.
3. Heat the pie dish and sample at 450ºC for 3 hours in a muffle furnace
4. Allow to cool, then reweigh and record the weight.
5. Calculate the total organic matter (TOM) as the loss of weight on ignition at 450ºC.
6. Estimate the total organic carbon (TOC) content as TOM x 0.47.
7. Express the result as a percentage in the dry sample = % C.

Preparation for bulk $\delta^{13}C$ Analysis

Before starting this preparation, remove inorganic carbonate. Then, transfer about. 5 g aliquot of sample into a 50 ml plastic screw cap centrifuge tube. Some chemical had been used such as 10 % HCL to the sample in the centrifuge tube, stir with a plastic spatula to mix the sample with the acid. Add another 2 ml of 10 % HCl and Centrifuge at 3000 rpm for 10-20 min. Dispatch tube to analytical laboratory, to measure bulk $\delta^{13}C$ (for CSSI) and %C (for percent soil conversion). Include the estimate of %C in the sample for the analyst.

Preparation for $\delta^{13}C$ Analysis of fatty acids

The solvent used in this procedure must be very high purity dichloromethane (DCM). Either HPLC grade or double distilled and the Accelerated Solvent Extractor (ASE) cells must be cleaned. For Shaker (takes 24 hours) or ultrasonic (takes 6-8 hours) extraction, the sample is soaked in 100 ml DCM, in a glass 250 ml Erlenmeyer flask with a ground-glass stopper. These samples must be filtered to remove the soil. Reduce the solvent to dryness in a 100 ml, round-bottom flask using a Buchi Evaporator, and retain the solvent for recycling through the distillation system.

Derivative the fatty acids to fatty acid methyl esters (FAME)

Take up the dry extract from the 100 ml round-bottom flask in 2 ml of DCM. Using a cleaned Pasteur pipette, transfer the DCM extract into a 10 ml Kimax screw-cap reaction tube. Add 2 ml of 5% BF_3 (boron trifluoride) in methanol to the Kimax tube, screw on the cap, and place in a test tube rack in a fan oven at 70°C for 20 minutes. To each Kimax tube add 2 ml of hexane / DCM (4:1) mixture, screw on the cap and mix on a Vortex mixer for 2 minutes. Reduce the hexane to dryness in an aluminium-heating block at 40°C under a gentle stream of dry nitrogen through a stainless steel needle positioned vertically above the open vial and blowing onto the solvent surface. Dispatch the set of vials to the analytical laboratory to measure $\delta^{13}C$ of the FAMEs. In addition, this approach is useful in identifying the sources of high sediment load and the major contributor to water pollution (Gibbs, 2014; Heng, Sakadevan, Dercon, & Nguyen, 2014). This technique is based on the CSSI, which can provide information on the source or source and thus provide information on the quantitative amount of sediment received.

Analysis of CSIA

The methyl (CH_3) group added to the fatty acid to produce the FAME will have a different isotopic value than the fatty acid, the isotopic signature of the FAME must be corrected for that addition. The correction for the addition of one methyl group is relatively small but must be done for each fatty acid in each sample. This can be done quickly in a spreadsheet using a simple equation:

$$\delta^{13}C_{FA} = \frac{\delta^{13}C_{FAME} - (1 - X)\delta^{13}C_{Methanol}}{X}$$

Where **FA** is the fatty acid and ***X*** is the fractional contribution of the FA to the FAME. This can be calculated from the number of carbons in the FA molecule divided by the number of carbon atoms in the FAME derived from the FA. For example, the FA stearic acid (C18:0) produces the FAME, methyl stearate, which has one added carbon (19 carbon atoms) and thus an ***X*** value of 18/19 or 0.9474.

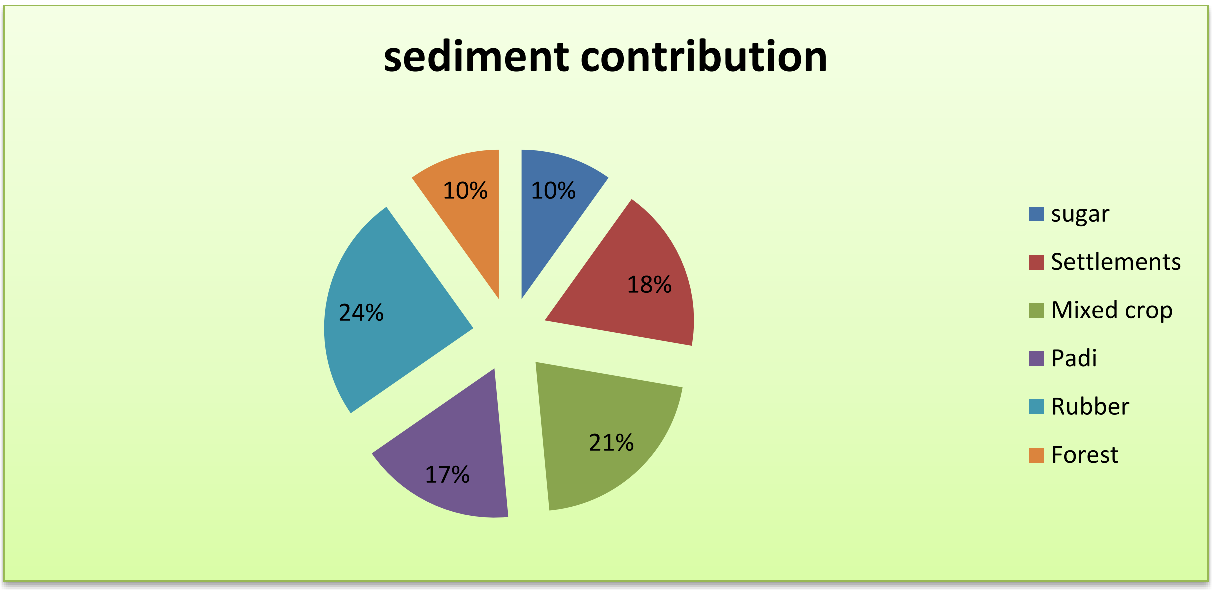
- Correct all FAMEs to produce the CSSI isotopic signatures
- Correlate the CSSI values with the bulk $\delta^{13}C$ and % C from each sample in a spreadsheet.
- Use these data in the Iso-Source modelling.

RESULTS AND DISCUSSION

Based on the results of this analysis conducted on this site, the Specific Stable Isotope (CSSI) sediment tracking approach has provided a first-hand value in the agricultural catchment environment of sustainable geochemical fingerprinting techniques. For agri-environmental investigations, CSSI techniques are based on the soil determination of ^{13}C natural abundance signatures of biomarkers such as the fatty acids (FAs). From the analysis shown in figure 3 and figure 4, the CSSI results provide mixed results from the diversity of different land uses. The analysis of CSSI on sediment accumulated in the sediment trap in the catchment area after the occurrence of mud floods at study area using the IsoSource model. The study was conducted from September 2015 to August 2018 with some of several various factors have been taken into consideration that is located at Timah Tasoh, Perlis, North of Peninsular Malaysia. This can be seen based on the analysis results from figure 3 in which the five variants of land use give a fairly interesting CSSI value to be discussed. The largest sediment contribution to the study site is from rubber and mixed crop contributing more or less than 45% of the total sediment percentage from Sungai Jarum Sub-catchment into the catchment area. This situation is due to the rubber plantation found in this area which is composed of young rubber trees and has small foliage compared to the Lower Pelaric Sub-catchment area.

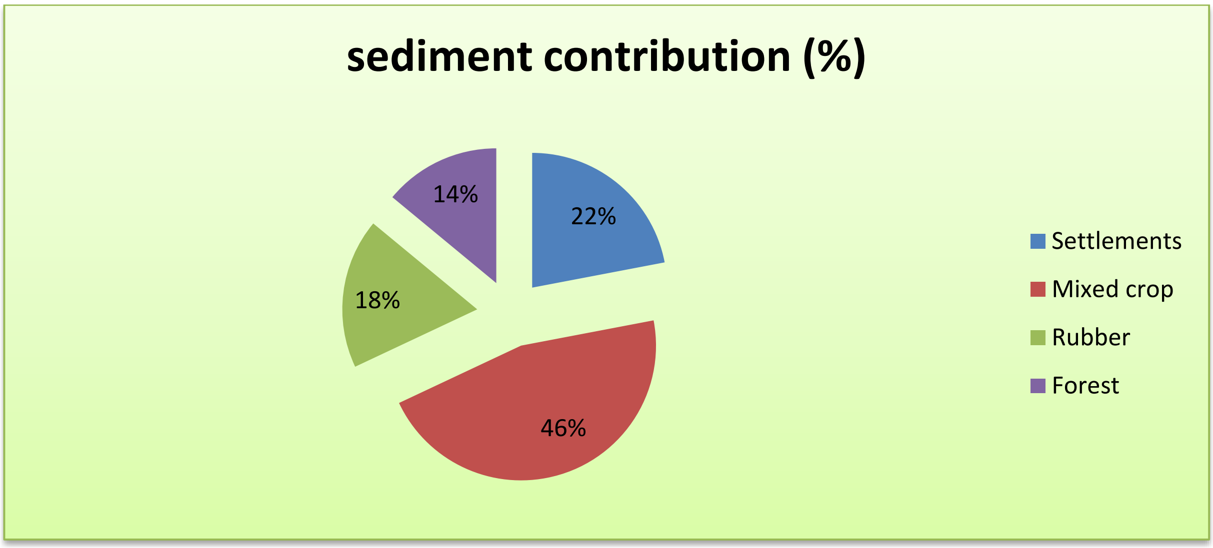
This has resulted in a 24% higher sediment yield or contribution compared with 18% contribution from the Pelarit River (Lower) Sub-catchment. Factors such as the amount of rainfall that fall to the ground are more widespread and accurate are the major factors contributing to the higher sediment contribution than normal days. However, the sediment contribution from the mixed crop here is still low compared to the Pelarit River (Lower) Sub-catchment, only 21% contribution. Therefore, the smallest contribution is coming from sugar and forest land use which each contributed as much as 10% from Sungai Jarum Sub-catchment each separately. Meanwhile, sediment contributions from Sungai Pelarit (Lower) Sub-catchment have also contributed to the movement of sediments such as from Sungai Jarum Sub-catchment. Nevertheless, the main contributor to this sediment comes from four major contributors of Sungai Pelarit (Lower) Sub-catchment to the diversification of land use, namely from settlements, mixed crop, rubber and forest. This is less than the sediment comes from Sungai Jarum Sub-catchment which resulted from the six largest contributors where are settlements, mixed crop, rubber, padi, sugar cane and forest. The mixed crop has become a major contributor, of which 46% of the total sediment that has entered the catchment area is from it. This incident may be due to some of the factors that cannot be avoided. One of these factors is the vegetable crop that does not last long because it is a short crop and this causes the soil in this area to be empty. This condition has made the catalytic factor for the occurrence of soil erosion and the abundance of mud after the heavy rain.

Figure 3: Results of sediment contribution from Sungai Jarum Sub-catchment



Additionally, in this area not only involve vegetable cultivation, but also corn and fruit yielding yields within a short period of time. Hence, the condition of the soil and the constant soil clearing process during the replanting period also contributes to soil erosion occurs. Meanwhile, settlements also contributed high sediments compared to rubber and forest of 22% compared to 18 and 14% each as a result of human activities such as continuing deforestation for development purposes. The reduction of CSSI values in both of these lands is due to the presence of a cover system of the earth's cover and a large-sized forest and large leaf surface area. Both of these factors have been able to provide a high reduction in the number of erosion processes as the amount of rainfall received during heavy rain is slightly above ground level due to both these factors. Based on both these figures, settlements in the area from Sungai Pelarit (Lower) Sub-catchment is high compared to Sungai Jarum Sub-catchment. As a result of population density as well as higher human activity has caused sediment movement from settlements from Sungai Pelarit (Lower) Sub-catchment is higher than Sungai Jarum Sub-catchment as much as 22%. Meanwhile, The Chuhuh river sub-catchment does not provide a significant impact on sediment contribution as most of the land uses are covered by primary and secondary forest compared to other sources.

Figure 4: Results of sediment contribution from Sungai Pelarit (Lower) Sub-catchment



The results of this study are not significantly different from those reported by (Gibbs, 2014) and (Blake, Ficken, Taylor, Russell, & Walling, 2012) on the use of CSSI in soil erosion areas in different agricultural land use areas. Whereas, CSSI techniques show how past land degradation and its relevance to land use history over the centuries can be revealed (Gibbs, 2014). Similarly, the use of CSSI and geochemical combinations has been successfully used to identify the importance of damaged grasslands as hot erosion areas in the UK (Blake, Ficken, Taylor, Russell, & Walling, 2012). In addition, historic land use from four sources is clearly dominated by C3 crops (e.g. grass, peas, rapeseed, spring barley, sugar beet, sunflower, winter wheat); the only C4 crop cultivated being maize.

CONCLUSION

This study has shown that the new CSSI techniques used in this study have the potential to provide significant support to land resource management policies and inform the assessment of sediment risk for the protection of aquatic habitats and water sources in particular at study sites and in Malaysia generally. Therefore, high-resolution sediment sampling using appropriate equipment in the event of heavy rainfall and this CSSI analysis method has been able to explain the temporal pattern of sediment mobilization under different crop regimes and the specific contribution made by each plant to the load downstream. From the findings, the major contributors of sediment into the catchment area at the study site are from two major causes namely, Sungai Jarum Sub-catchment and Sungai Pelarit (Lower) Sub-catchment. Thus, these two major contributing areas, the rubber and mixed crop from the two river sources contributed by 24% and 46% each of the total sediment contributions is compared to other contributors throughout the study period. As conclusion, this method is very useful for studies conducted to determine the true cause or originates of soil erosion during floods. However, this analysis is one of the most recent methods used in land use research in agricultural activities in Peninsular Malaysia. Therefore, a more in-depth study will be conducted at the same study site with the use of FRNs analysis method in the near future to obtain more complete and comprehensive data analysis results.

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