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SCALE EFFECTS ON DISCHARGE AND SEDIMENT TRANSPORT RATES OF TAIWAN WITHIN 1994 AND 2014

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ABSTRACT: *In Taiwan, severe damages occurred due to large and sudden variations in discharge resulting from variable rainfall during typhoons occurring in tropical climatic zoon and combining erosion, sediment transport and deposition, resulting in significant changes in riverbeds and river-basin. Systematic measurements of sediment transport rates and water discharge were conducted in Taiwan. By using the records of daily rainfall of floods, daily mean discharge, and sediment content for connecting the magnitude of sediment transport from Hydrological Year Book of Taiwan R.O.C., the rating curves between annual mean discharge and the corresponding sediment transport rate were built with the concepts of sediment yield for the whole Taiwan, 7 different regions and the given 19 rivers respectively with the regressive coefficients, R square, are acceptable. The influence on the results, such as rainfall, floods, typhoon, water contain of soil, hill-slope, etc., were also discussed here.*

KEYWORDS: Rating Curves; Rainfall; Flood; Discharge; Sediment Content; Erosion; Sediment Transport Rate; Typhoon; Regressive Coefficients; R square; 95% Confidence Interval;

INTRODUCTION

Quantitative estimates of sediment flux and the global cycling of sediments from hillslopes to rivers, estuaries, deltas, continental shelves, and deep-sea basins have a long research tradition. Extremely large and commensurately rare sediment transport events have so far eluded a systematic analysis. Quantifying rates of sediment flux across Earth's surface is a key requirement to understanding one of the planet's primary modes of redistributing crustal mass in response to global plate tectonics. The mobility of sediments helps shape landscapes at much shorter timescales than those tectonic rock uplift and subsidence

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operate on. Taiwan (Figure 1) is an island with total area of 36,000 km^2. Approximate 70% of the island is covered by mountains (Figure 2) that mainly lying on along the central region running north to south and thus forming a ridge for the east- and west-bound rivers, and the rest 30% is the plains below the elevation of 100 m. There are altogether 151 rivers in Taiwan, but only nine of them each possess a basin area exceeding 1,000 km^2(Figure 3). As regards to riverbed slopes, those of the upstream reaches of most rivers exceed 1/100, and of the downstream are between 1/200 to 1/500, among them only five rivers with slope below 1/1,000. The sediment yield per unit area of the rivers in Taiwan is about 64 times of the world average and the sediment concentration is about 16 times of the world average.

Figure 1. Taiwan Administrative Map

Overlying both subtropical and tropical oceanic zones and situated in the Asian monsoon region, Taiwan features warm climate, the annual average temperature in the plain areas is as high as 22°C; even the lowest temperatures in a year stay above 10°C.The rainfall in Taiwan is approximately 2,500 mm annually, which is about 2.6 times that of the world average. Owing to the dense population on this island, however, the average precipitation share per capita amounts to only 3,913 m3 per year, which is less than one eighth of the world average. Hence, it is appropriate to say that Taiwan is among the regions where the potential for water-resource is categorized as low. Statistics further show that there have been huge differences of rainfall distributions among seasons in Taiwan (Figure 4), with the highest annual total rainfall of 3,250 mm, and the lowest, 1,600 mm. The annual evaporation by regional amount is approximately 1,250 mm in the northeast, 1,600 mm in the west, 2,000 mm in the south, and 1,700 mm in the east, and the highest evaporation rate occurs in July.

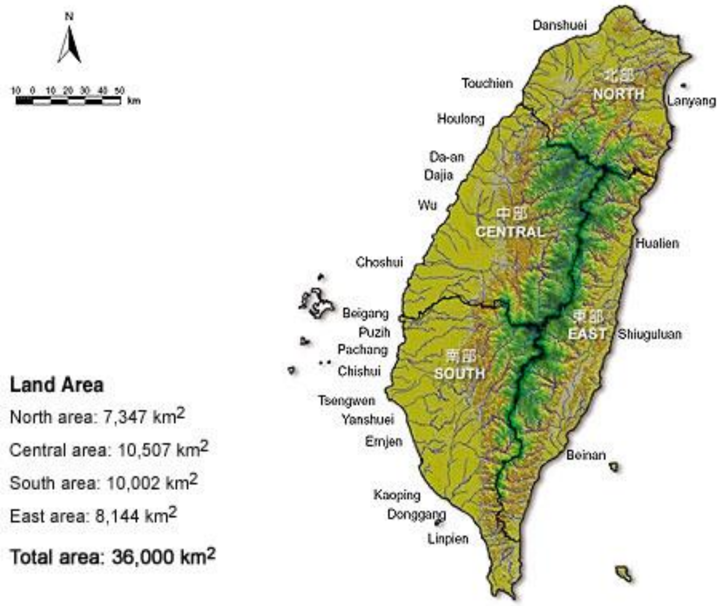

Figure 2. Topography and Some Main Rivers in Taiwan

The mobility of sediments helps shape landscapes at much shorter timescales than those tectonic rock uplift and subsidence operate on. In the Earth system, sediments act as conveyors and nuclei of biogeochemical constituents such as nutrients, contaminants, and pathogens. Recent reviews have addressed the rates and relevance of fluvial sediment flux in a variety of settings and scales, including promises and pitfalls of quantifying the underlying controls.

LITERATURE REVIEW

Rivers result from run-off of water from the continents. River water itself has primarily originated from precipitation, some of which is lost through evaporation, groundwater recharge, etc. On a global scale continental run-off, which includes dominantly river run-off and a small amount of direct groundwater discharge to the oceans, can be thought of as being equal to the excess of oceanic evaporation over precipitation. Hence, in order to have river run-off on a continental scale, there must be net precipitation on land. Geographical

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differences in rainfall distribution arise primarily due to relief, with the windward sides of mountains receiving large amounts of rain and the leeward sides very little. Two distinct methods are used to estimate the mass of river sediments entering the oceans; one estimates the mass being carried ocean ward by rivers, while the other method estimates denudation of the continents. Stream sediment transport is classified into bed load transport and suspended load transport on the basis of the two different motion patterns. Bed load transport depends mainly on the hydraulic characteristics of the streams, consists mainly of coarse material, and originates from stream bed erosion. Suspended load originates from

Figure 3. Main Rivers in Taiwan

soil erosion products inflows into the streams from the surrounding basins and stream bed erosion, and depends on both hydraulic and rainfall characteristics (e.g. rainfall depth, intensity). This can be explained as follows: rainfall and runoff cause soil detachment and hence erosion products can reach the streams and are then transported in the streams as suspended materials. Turbidity currents at the Taiwan shelf are mainly caused by two different mechanisms, namely, hyper-debris river discharge and excrescent accumulation of fine sediment, resulting in submarine landslides. The first mechanism which emerges at river estuaries during typhoon events when river sediment concentration exceeds a certain value has been considered in many works (Dadson et al., 2005; Milliman and Kao, 2005; Milliman et al., 2007). However, much less attention was paid to the second mechanism which also can be induced by elevated sediment load during and shortly after typhoon events. It has a significantly longer preconditioning period and is characterized by distributed potential sources of turbidity flows (Carter et al., 2014).A common method to

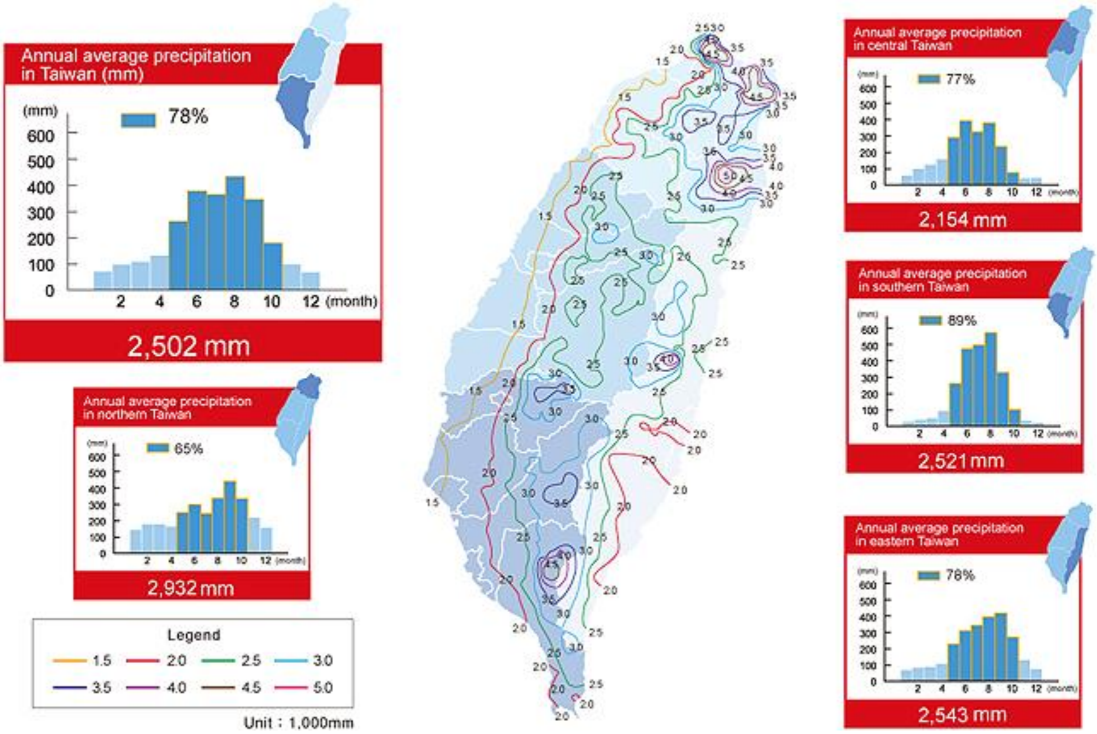

Figure 4. Isohyet Chart of Rainfall of Taiwan

represent the dependence (linear or nonlinear) between two measured variables lies on the regression analysis. The dependence between two variables could be depicted graphically using a curve, whereas the degree of the linear dependence is usually expressed by the correlation coefficient. Numerous regression relationships between suspended load concentration or suspended load transport rates and stream discharge, for different regions in the world, can be found in the literature (Walling, 1977; Griffiths, 1982; Córdova and González, 1997; Asselman, 2000; Achite and Ouillon, 2007; Sadeghi et al., 2008). Bed load is usually estimated as the percentage of suspended load at the outlet of a basin. Bed load transport rates can be computed at a river cross section by semi-empirical bed load formulas (Meyer-Peter and Müller, 1949; Einstein, 1950) or transient flow in such waterways. While regression analysis is a very useful tool to predict sediment transport

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rates at a river cross section as a function of stream discharge, the interaction between stream water and river bed, e.g. river bed erosion and deposition, is not considered in detail. This study aims to identify the relationship between sediment transport rates (bed load transport, suspended load transport) and stream discharge using measured data from Hydrological Year Book of Taiwan R.O.C.

METHODOLOGY AND COMPUTATION PROCEDURE

The suspended sediment transport rates are function of flow hydraulics, bed composition, and upstream sediment supply. A well-known empirical relationship between water discharge, $\boldsymbol{Q_w}$(m^3/sec in day) and instantaneous suspended-sediment concentration, **C** (in ppm. or mg/l or 10^{-6} Ton/M^3) is:

$$\boldsymbol{C = aQ_w^b} \quad \text{with } \boldsymbol{a} \text{ and } \boldsymbol{b} \text{ as empirical constants,} \tag{1}$$

The suspended load of a known station, or instantaneous suspended-sediment rate (discharge), $\boldsymbol{Q_s}$ (in metric Ton/day, Kilo Ton/day or Million Ton/year), with **k** as a conversion factor (0.0864 with the above units), is:

$$\boldsymbol{Q_s = kCQ_w} \tag{2}$$

Based on measurements of **C**, and using equations (1) and (2), one obtains a calculated suspended load rate, $\boldsymbol{Q_s^{calc}}$:

$$\boldsymbol{Q_s^{calc} = AQ_w^B} \quad \text{with } \mathbf{A}=\boldsymbol{ka} \quad \text{and } \mathbf{B}=\boldsymbol{b}+1 \tag{3}$$

Using these equations, we calculate the parameters, $\boldsymbol{a}$ and $\boldsymbol{b}$, or **A** and **B**, based on a regression analysis of the available couples of data $\boldsymbol{Q_w}$ and **C** collected simultaneously. This approach provides better statistical constraints, because recorded values of $\boldsymbol{Q_w}$ are numerous and regularly spaced, which is not the case for recorded values of $\boldsymbol{Q_s}$.

Systematic measurements of water discharge and suspended load transport rates were conducted in the most downstream hydrological gauge station of each river over the 1994-2014 period. Measurements of suspended load transport rates were carried out at the same time as the discharge measurements. Water samples should be taken from each subsection, and the concentration of suspended load for each subsection should be determined in a chemical laboratory. The concentration of suspended load for the whole cross section is determined from the accumulation of the multiplying concentration with discharge for each subsection and dividing the total sectional discharge. Water samples were taken only from

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the middle of the cross sections, and the concentration of suspended load was determined only for the middle of a cross section. Simple nonlinear regression relationships are developed.

The coefficient of determination R^2: square of the Pearson product-moment correlation coefficient in the case of a linear regression) was used to indicate how well the regression line approximates the measured data points. The variables of the regression analysis, the types of the regression curves, the values of the coefficients of determination and the number of sets of measured data for suspended load transport rates and stream discharge in the computational process of the regression analysis, were also controlled by the F-test for the adaptability of the regression model to the measured data (suspended load transport rate or bed load transport rate). Moreover, the lower and upper bounds of the coefficients of the polynomials at a 95% confidence interval were determined.

COMPUTATION RESULTS OF DISCHARGE AND SEDIMENT TRANSPORT

In this section, the computation results of annual discharge and sediment transport rates are presented based on the scale effects, Whole Taiwan Island, 7 regions with Northern part of Taiwan (Taipei City; New Taipei City originally called Taipei County; Taoyuan City previously named Taoyuan County; Hsinchu City and County; and Miaoli County), Central part of Taiwan (original Taichung City and County, now named Taichung City; Changhwa County; Nantou County), Southern part of Taiwan (Yunlin County; Chiayi City and County; Taiwan City combined the original city and county), Gao-Ping Region (Kaohsiung City and County with new named Kaohsiung City; Pingtung County), Taitung Region (Taitung County); Hualien Region (Hualien County), and Yilan Region (Yilan County), respectively, and the 19 main rivers (see Figure 3) for each corresponding region: 5 rivers (Tributary of Tamsui: Dahan and Hsindian, Fengshan, Touqian, and Houlong) for North Taiwan, 3 rivers (Da-an, Wu, and Zhuoshui) for Central Taiwan, 5 rivers (Puzi, Bazhang, Zishui, Yanshui, and Erren) for South Taiwan, 1 river (Gao-Ping) for Gao-Ping, 1 river (Peinan) for Taitung Region. 3 rivers (Siouguluan, Hualien, and Heping) for Hualien Region, and 1 river (Lanyuan) for Yilan Region. And the computing and regressing results are expressed into two groups: the whole year and the flood seasons (from May to October).

Computation Results of Discharge

Based on the stream discharge measured data of 19 main rivers from Hydrological Year Book of Taiwan R.O.C. within 1994 and 2014, the hydrological characteristic of flood

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season discharge ratio, discharge of flood season divided by the one of whole year, is calculated and showed as the followings:

A. Whole Taiwan Island: Range from 0.548 to 0.891 with mean 0.742;
B. Northern part of Taiwan: Range from 0.489 to 0.837 with mean 0.650;
C. Central part of Taiwan: Range from 0.669 to 0.957 with mean 0.802;
D. Southern part of Taiwan: Range from 0.606 to 0.948 with mean 0.820;
E. Gao-Ping Region: Range from 0.734 to 0.955 with mean 0.869;
F. Taitung Region: Range from 0.429 to 0.955 with mean 0.754;
G. Hualien Region: Range from 0.532 to 0.797 with mean 0.679;
H. Yilan Region: Range from 0.498 to 0.853 with mean 0.618;

By combining the results of Southern part of Taiwan and Gao-Ping Region, the mean is 0.845; and the mean with the combinations of Taitung Region, Hualien Region, and Yilan Region is 0.684. By comparing these hydrological characteristic of flood season discharge ratio with those of hydrological characteristic of flood season rainfall ratio in Figure 4, we could find the results show a little bit difference except the ones of Eastern part of Taiwan. The larger the magnitude of the ratio for both of the rainfall and discharge, the higher the water shortage risk is.

Computing the Relationship Rating Curves of Sediment Transport Rate to Discharge

The rating curves for the relationship between Annual Sediment Transport Rate and Annual Discharge are calculated based on the sediment concentrations of 19 main rivers from Hydrological Year Book of Taiwan R.O.C. within 1994 and 2014, and the equations, from Eq. (1) to Eq. (3). The results are divided into two groups, whole year and flood season, in order to clearly search for the significance by the influence of flood.

A. <u>The Results of Whole Taiwan Island</u>

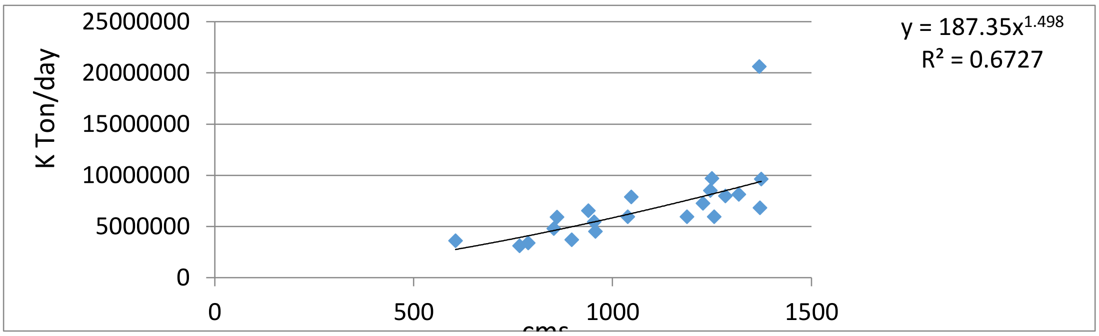

Figure 5. Whole Year Relationship in Taiwan Island

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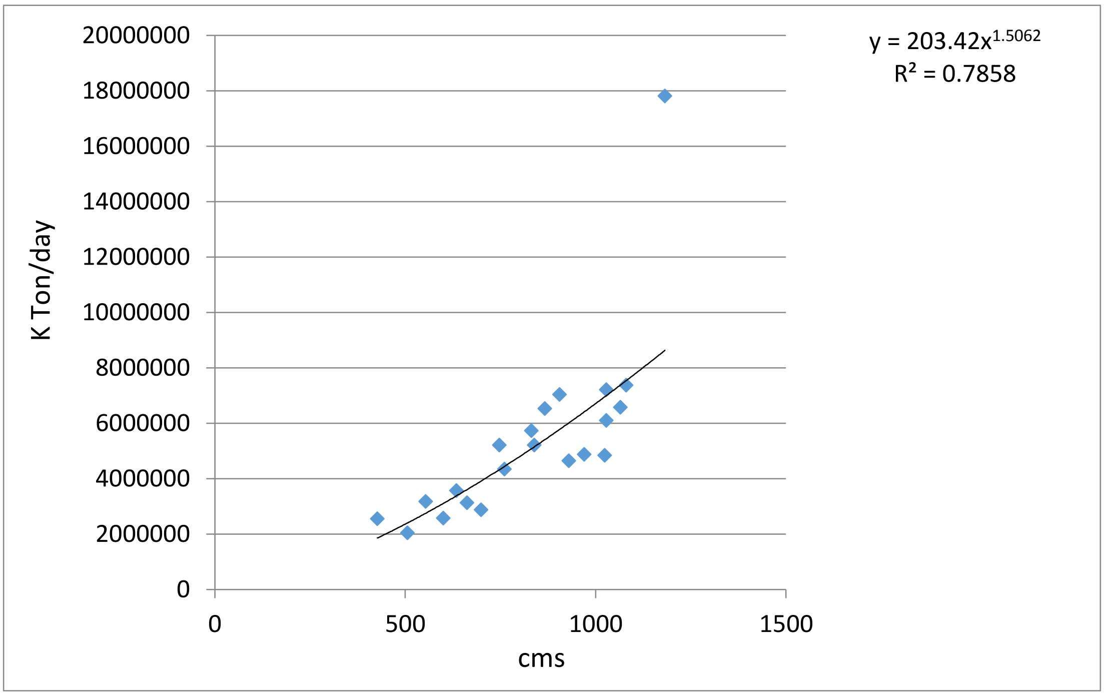

Figure 6. Flood Season Relationship in Taiwan Island

B. The Results of the Northern part of Taiwan

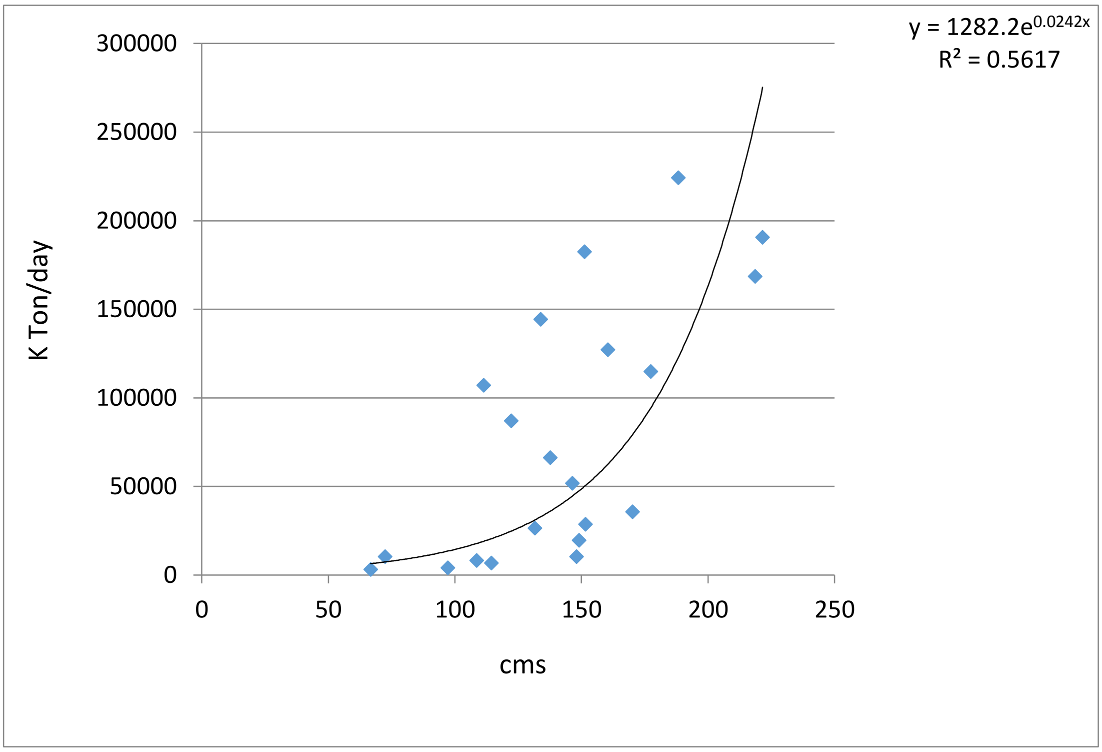

Figure 7. Whole Year Relationship in the Northern part of Taiwan

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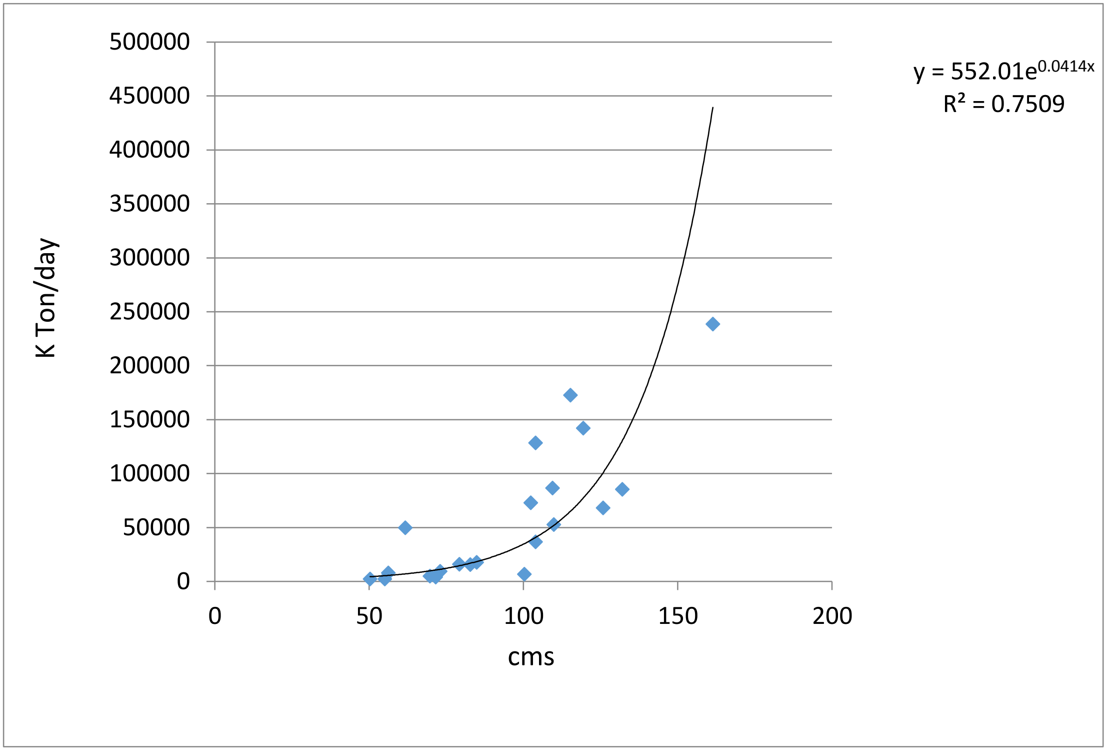

Figure 8. Flood Season Relationship in the Northern part of Taiwan

C. *The Results of the Central part of Taiwan*

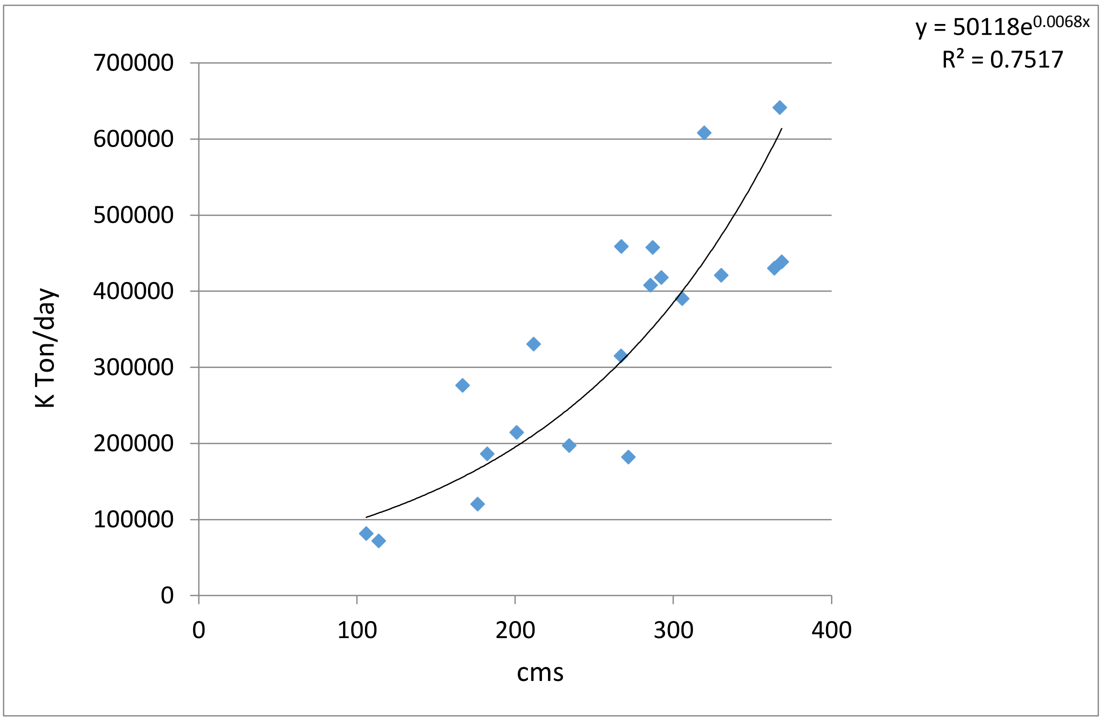

Figure 9. Whole Year Relationship in the Central part of Taiwan

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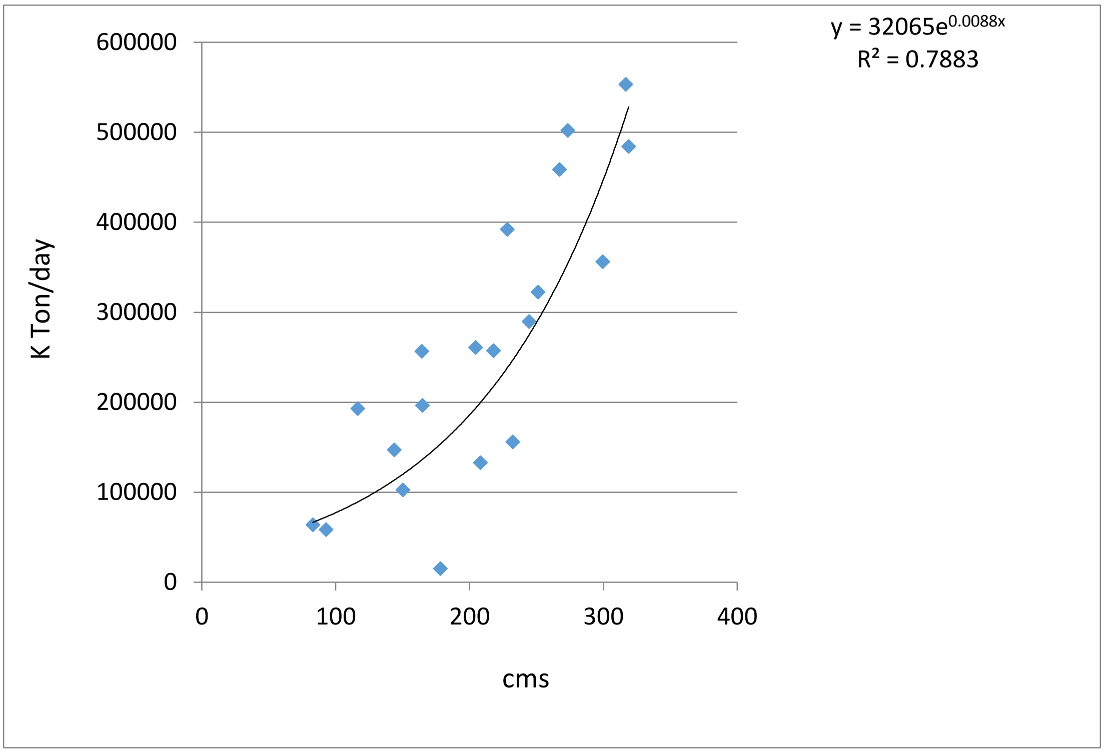

Figure 10. Flood Season Relationship in the Central part of Taiwan

D. The Results of the Southern part of Taiwan

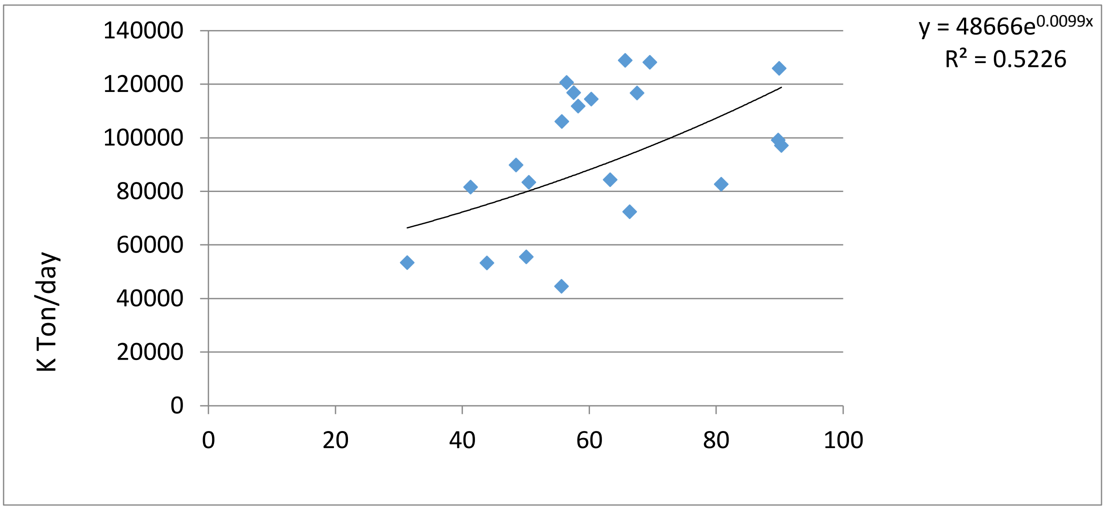

Figure 11. Whole Year Relationship in the Southern part of Taiwan

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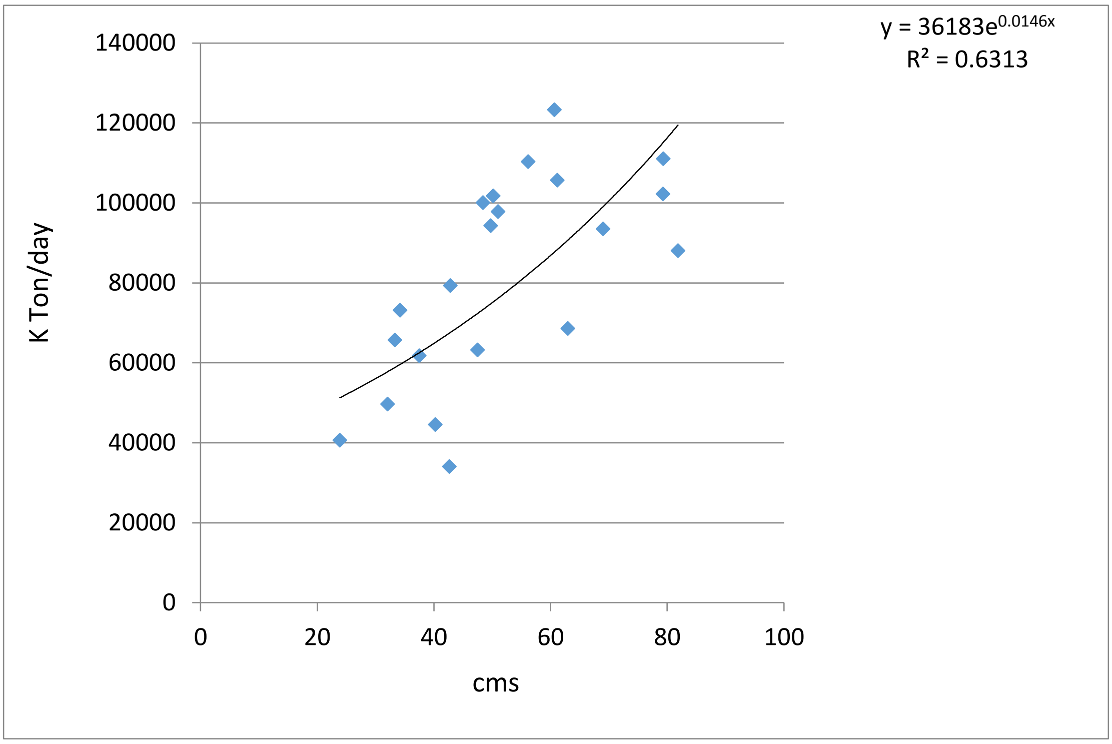

Figure 12. Flood Season Relationship in the Southern part of Taiwan

E. *The Results of the Gao-Ping Region of Taiwan (Gao-Ping River)*

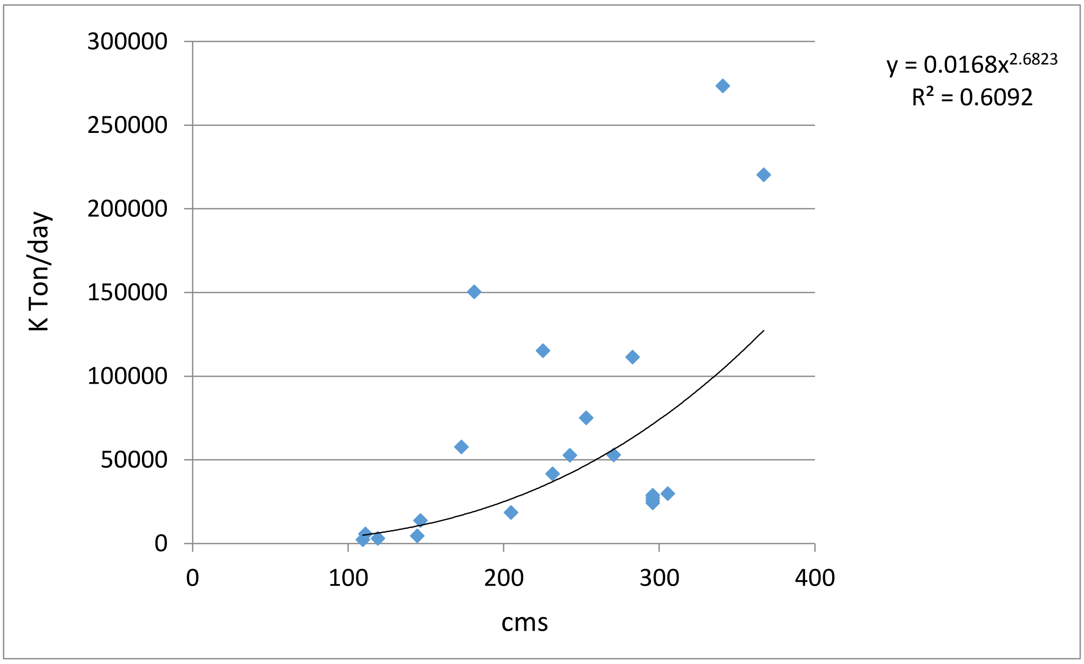

Figure 13. Whole Year Relationship in the Gao-Ping Region of Taiwan (Gao-Ping River)

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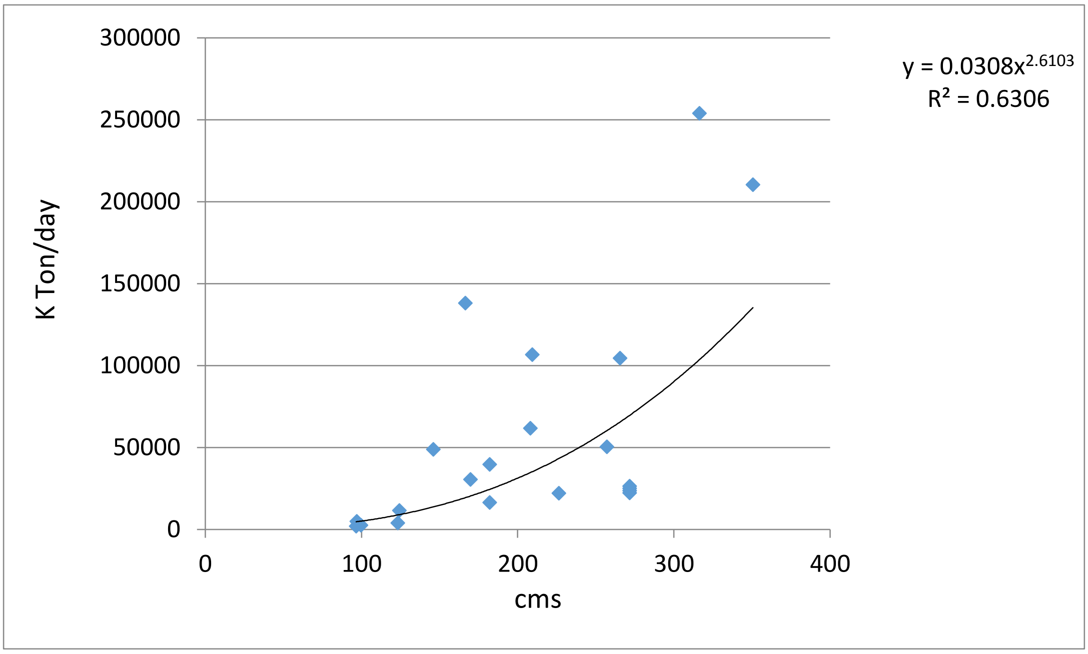

Figure 14. Flood Season Relationship in the Gao-Ping Region of Taiwan (Gao-Ping River)

F. The Results of the Taitung Region of Taiwan (Pei-nan River)

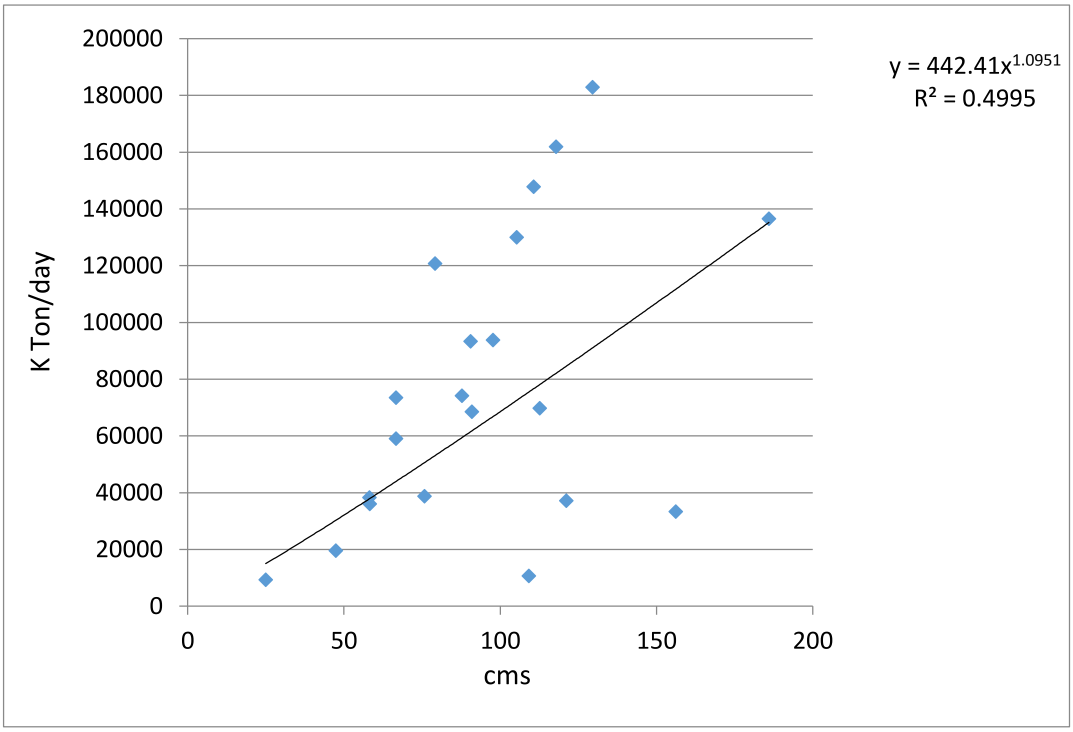

Figure 15. Whole Year Relationship in the Taitung Region of Taiwan (Pei-nan River)

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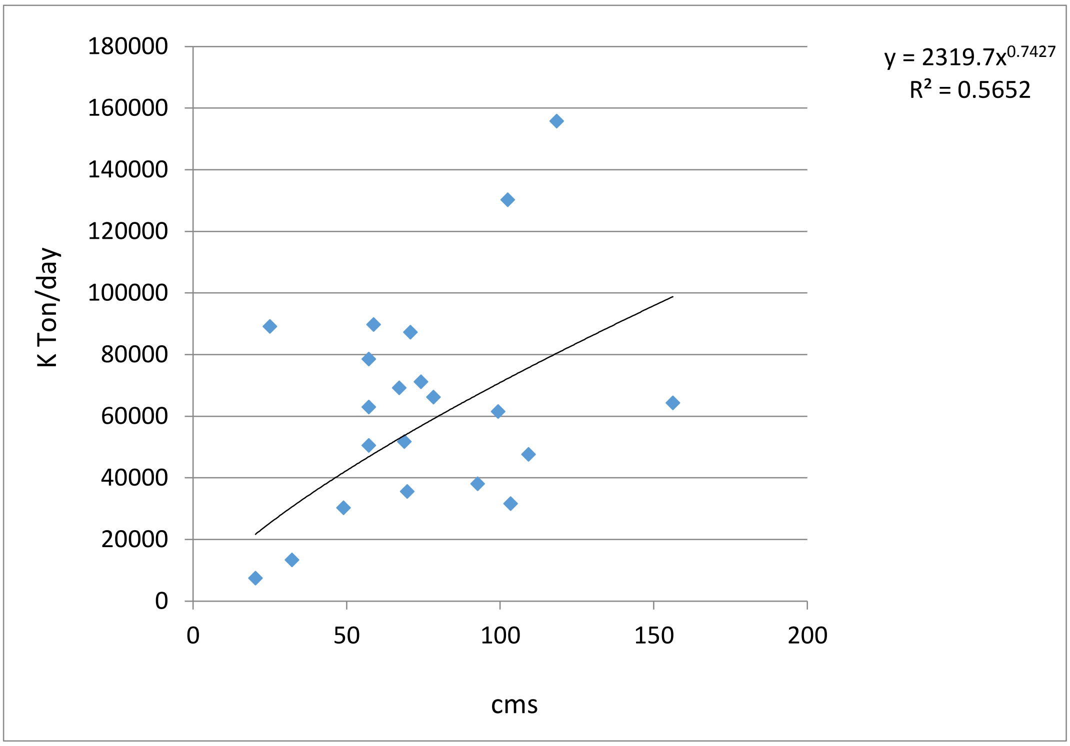

Figure 16. Flood Season Relationship in the Taitung Region of Taiwan (Pei-nan River)

G. The Results of the Hualien Region of Taiwan

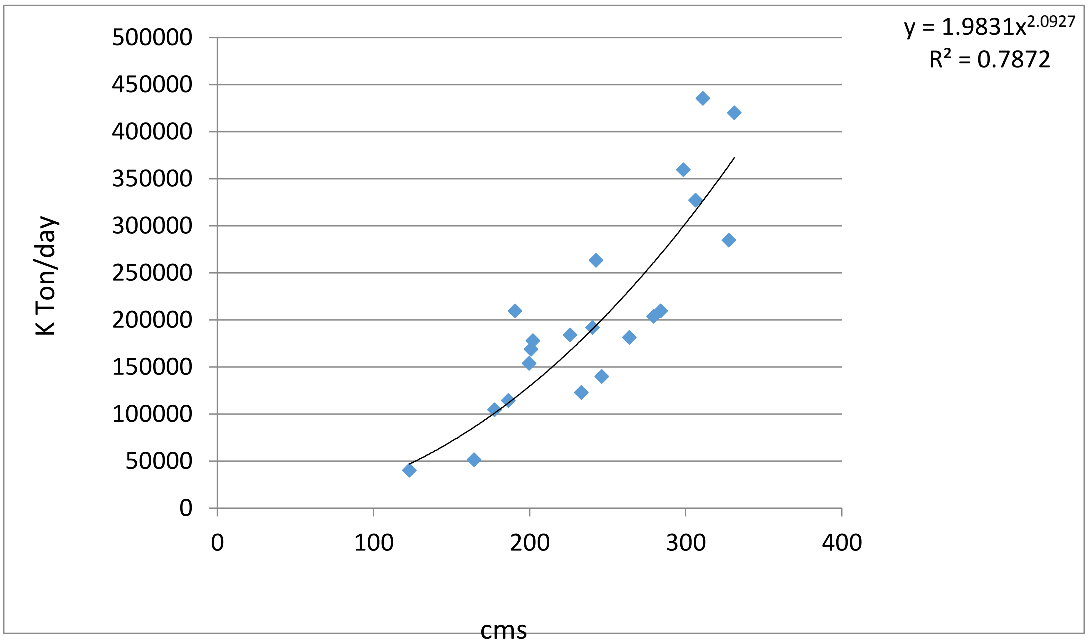

Figure 17. Whole Year Relationship in the Hualien Region of Taiwan

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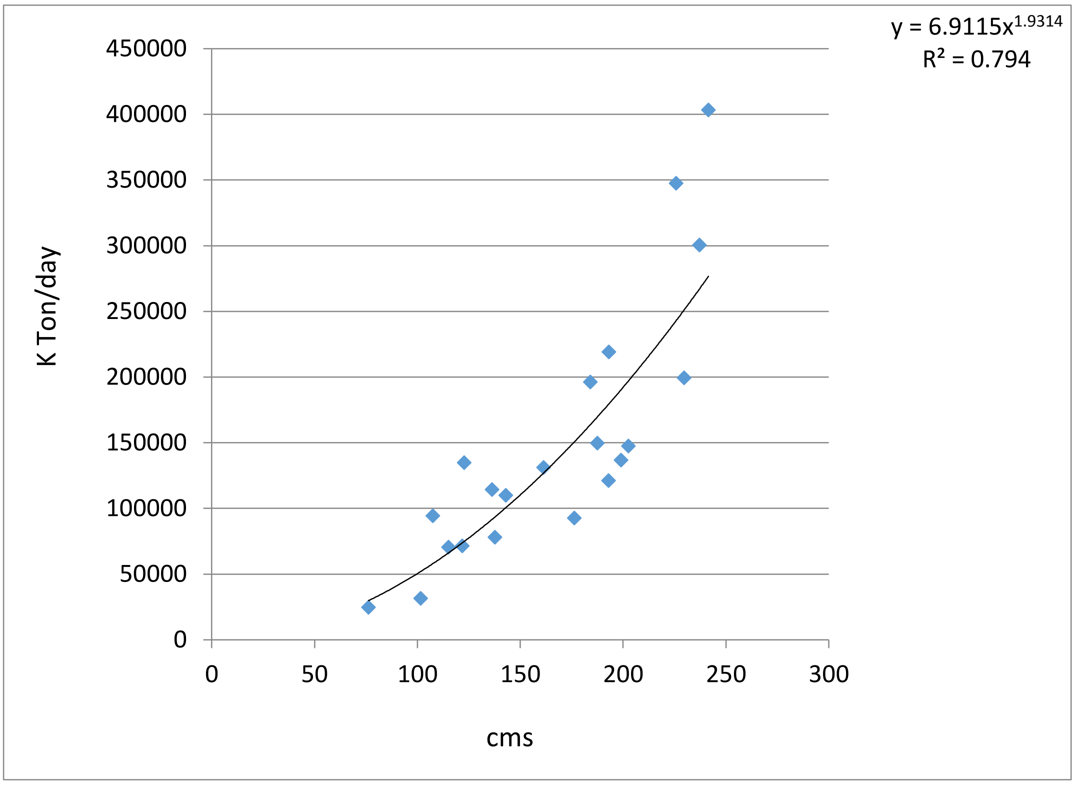

Figure 18. Flood Season Relationship in the Hualien Region of Taiwan

H. The Results of the Yilan Region of Taiwan (Lanyuan River)

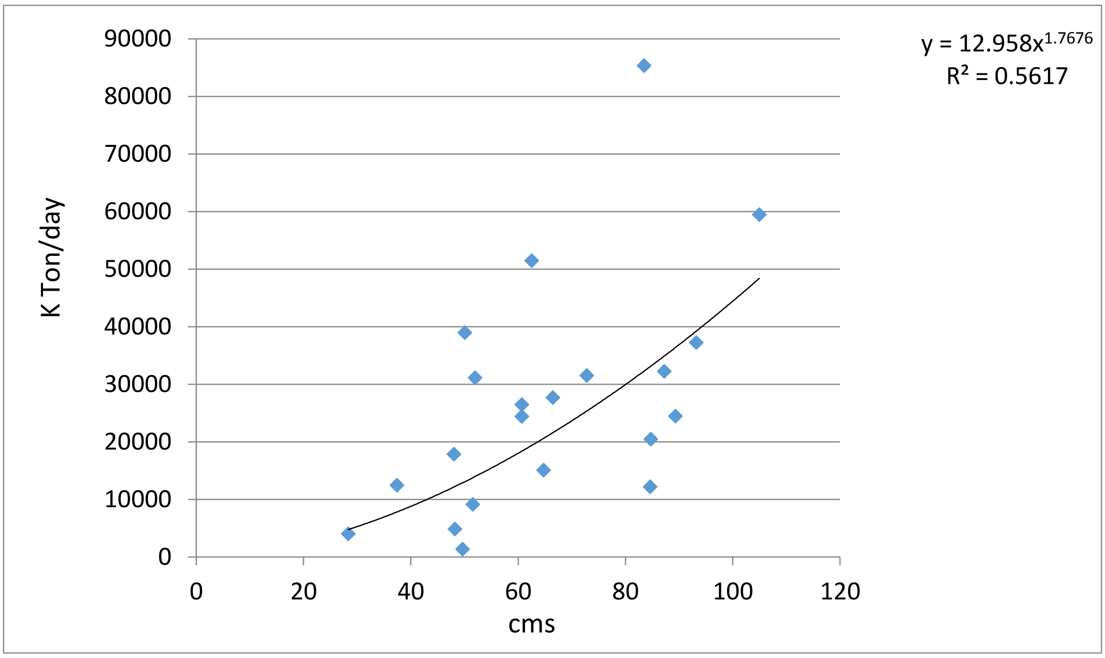

Figure 19. Whole Year Relationship in the Yilan Region of Taiwan (Lanyuan River)

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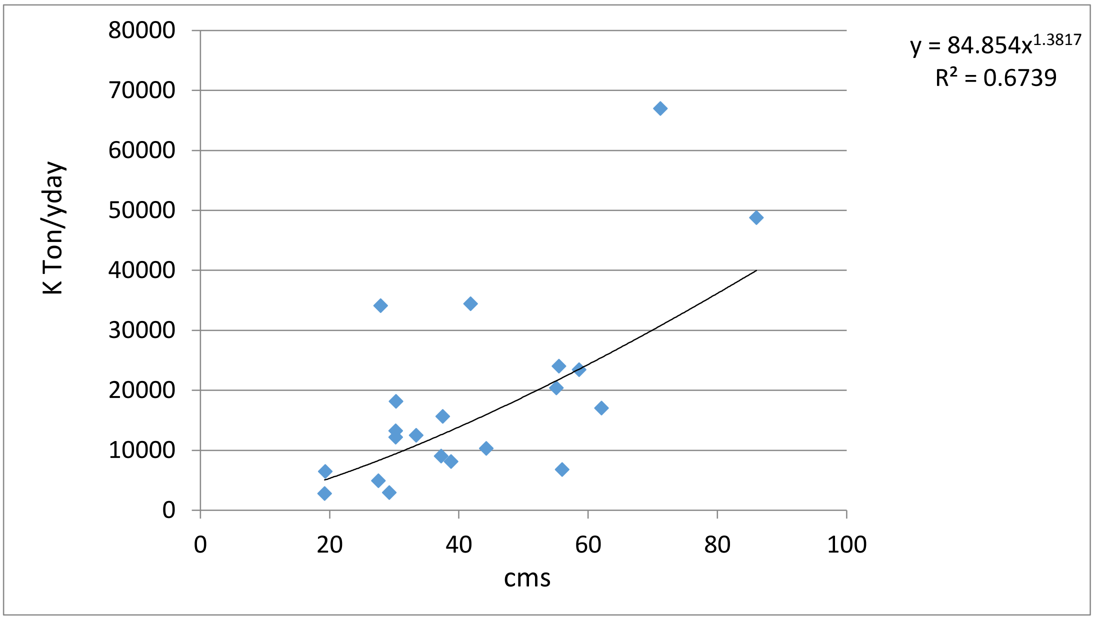

Figure 20. Flood Season Relationship in the Yilan Region of Taiwan (Lanyuan River)

I. ***The Results of the Dahan River***

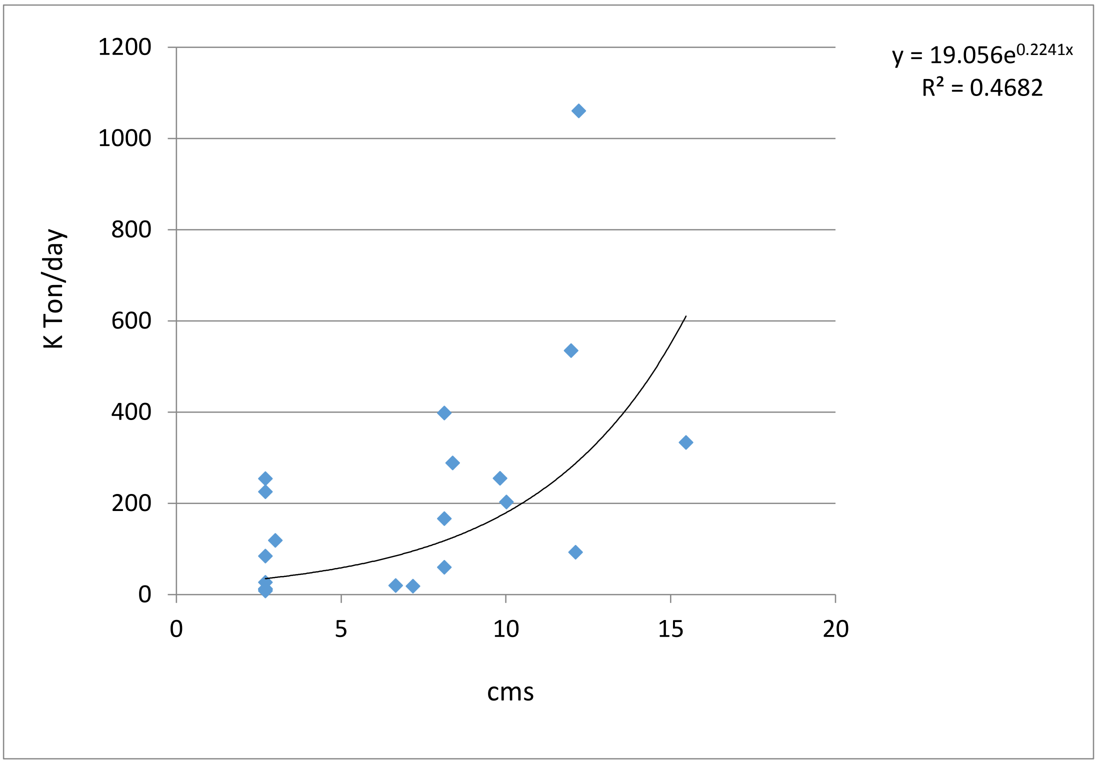

Figure 21. Whole Year Relationship in the Dahan River

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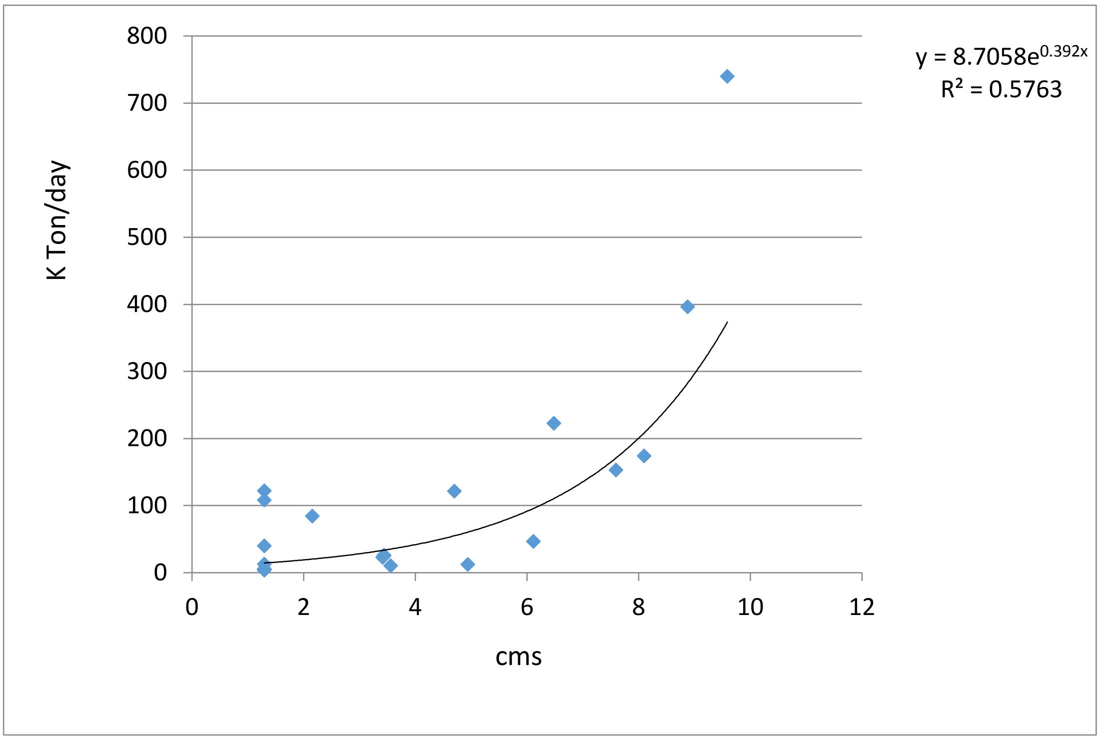

Figure 22. Flood Season Relationship in the Dahan River

J. The Results of the Hsindian River

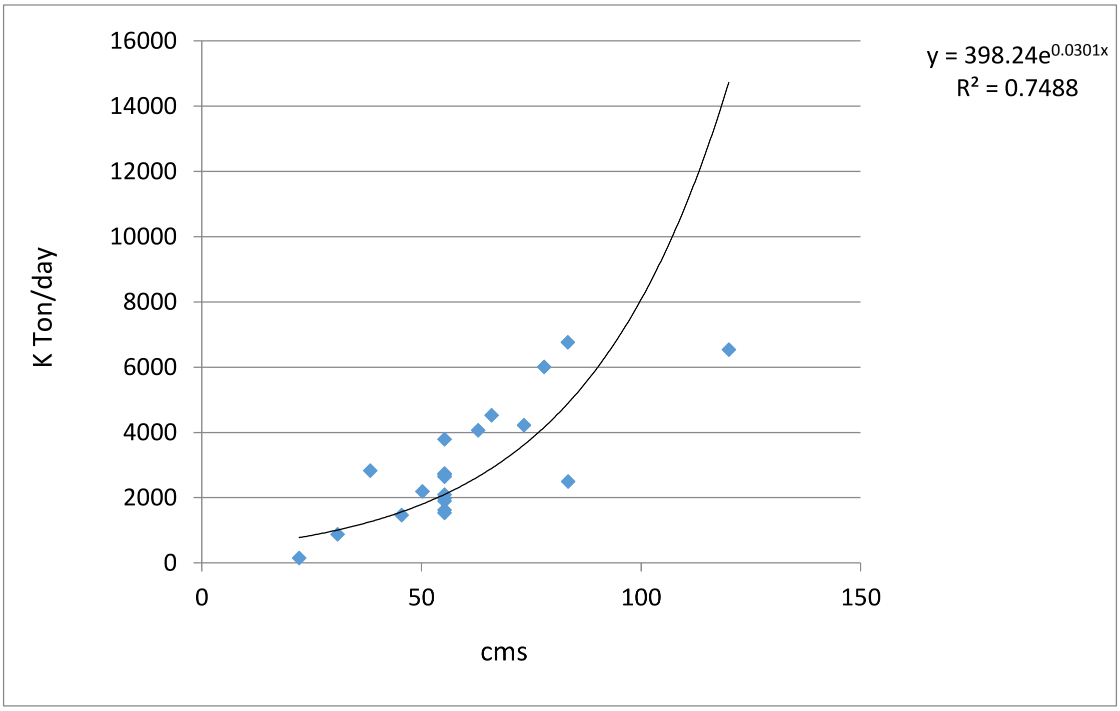

Figure 23. Whole Year Relationship in the Hsindian River

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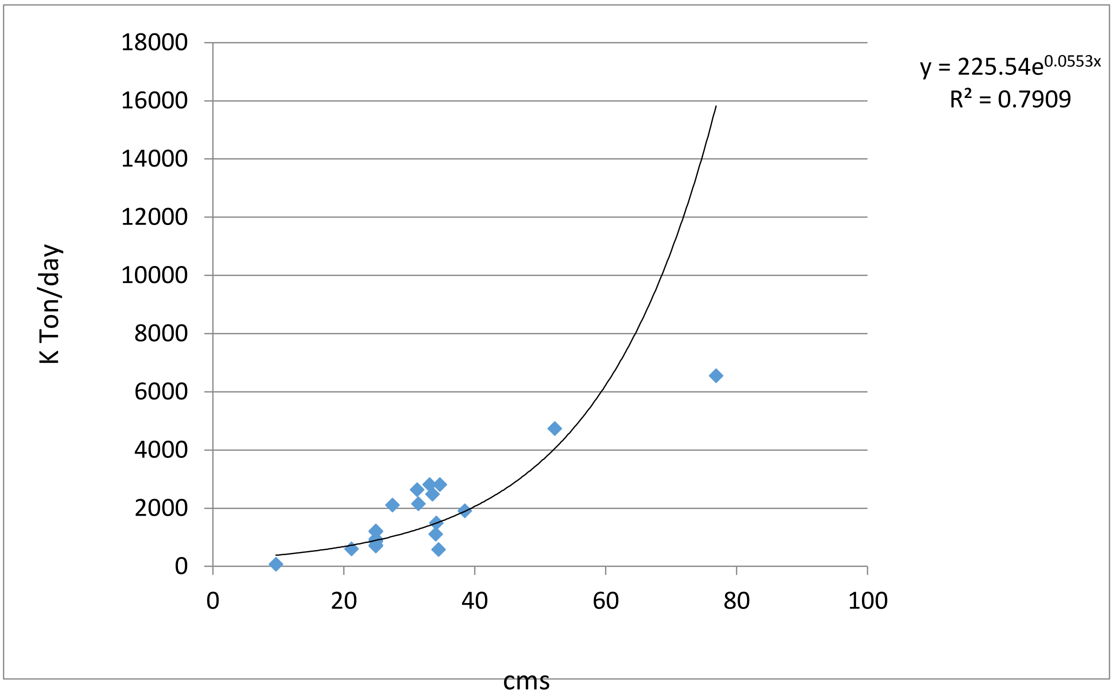

Figure 24. Flood Season Relationship in the Hsindian River

K. The Results of the Fengshan River

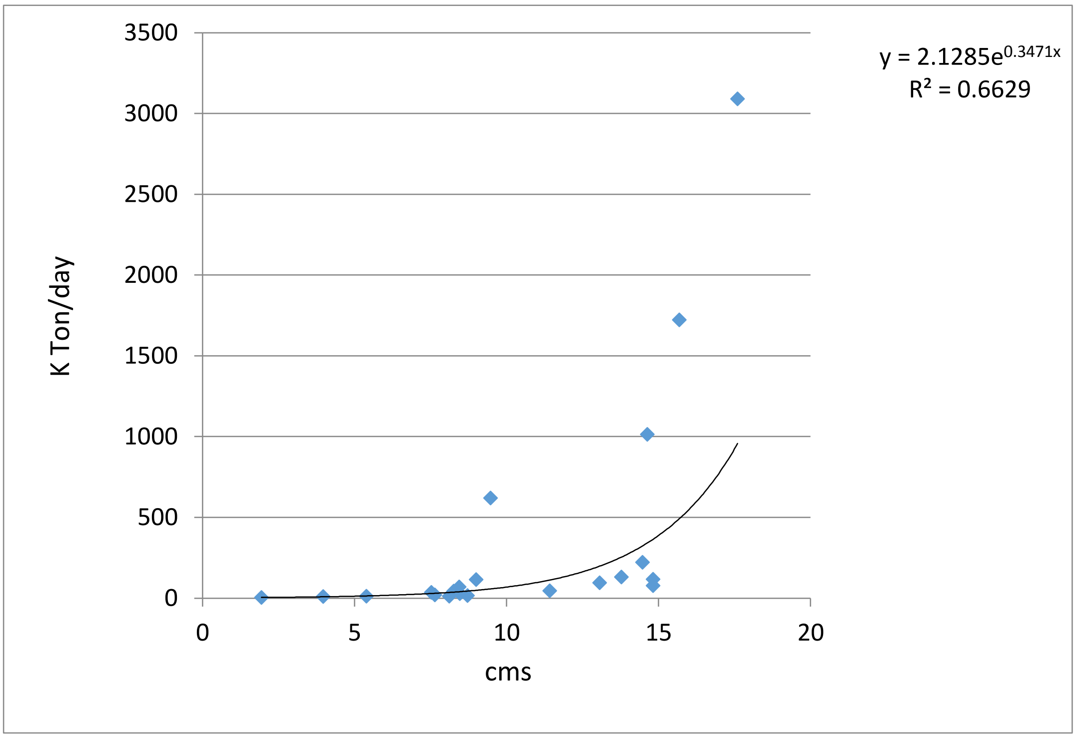

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Figure 25. Whole Year Relationship in the Fengshan River

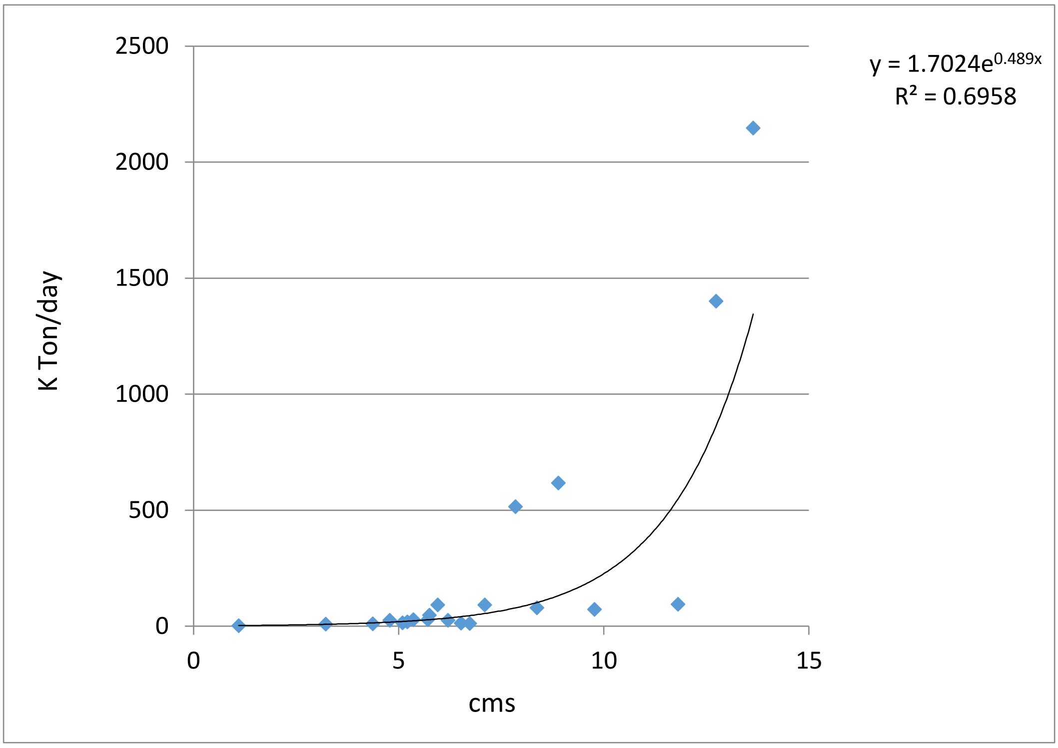

Figure 26. Flood Season Relationship in the Fengshan River

L. ***The Results of the Touqian River***

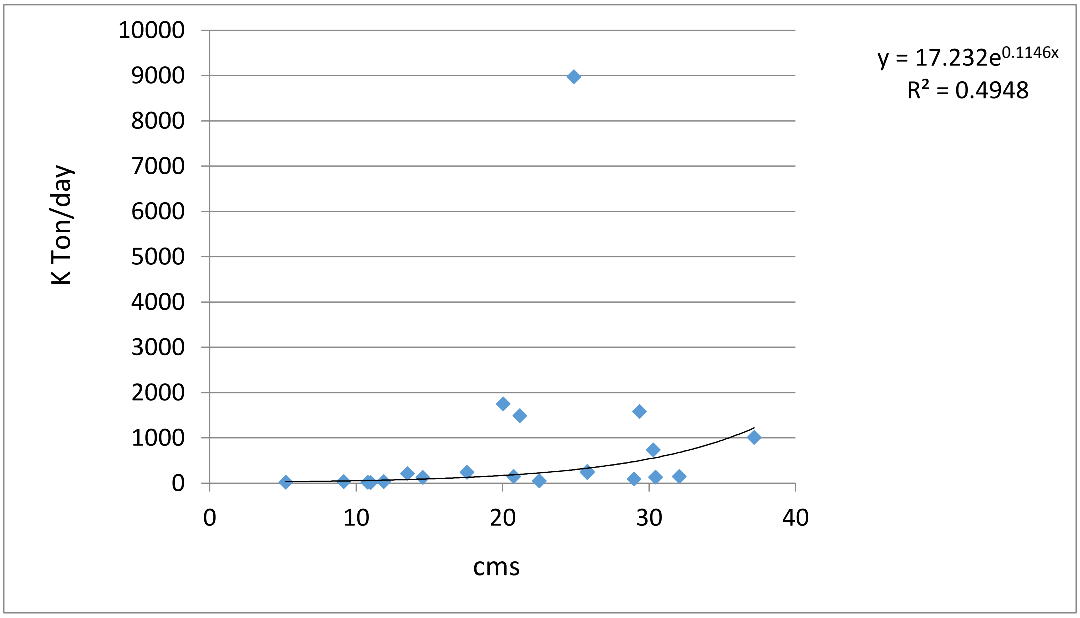

Figure 27. Whole Year Relationship in the Touqian River

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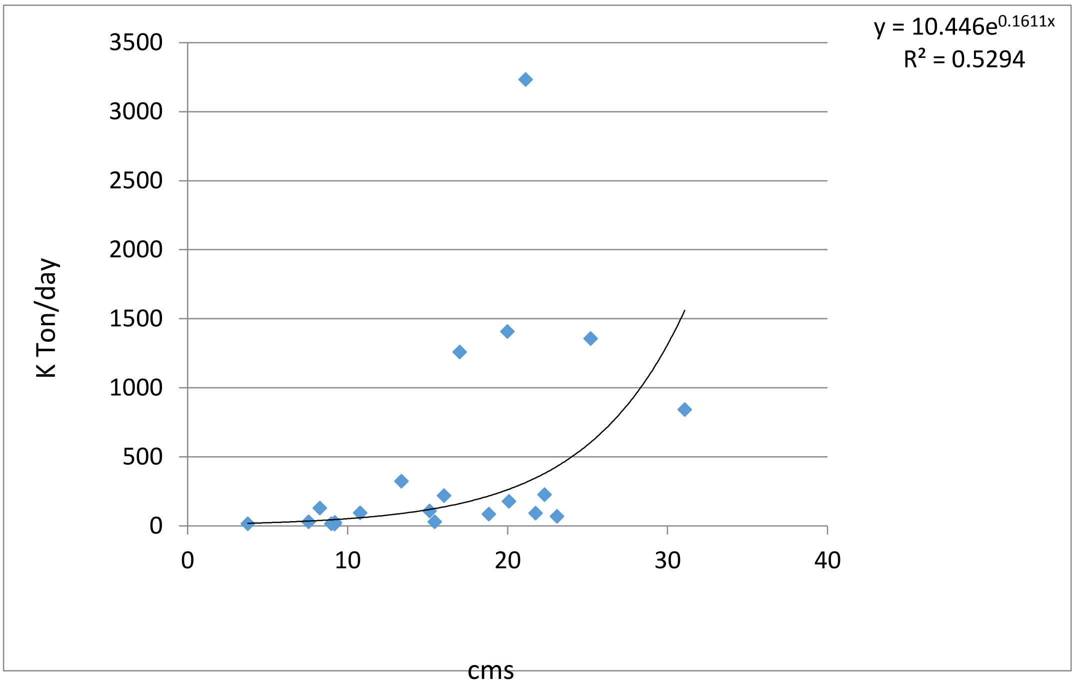

Figure 28. Flood Season Relationship in the Touqian River

M. The Results of the Houlong River

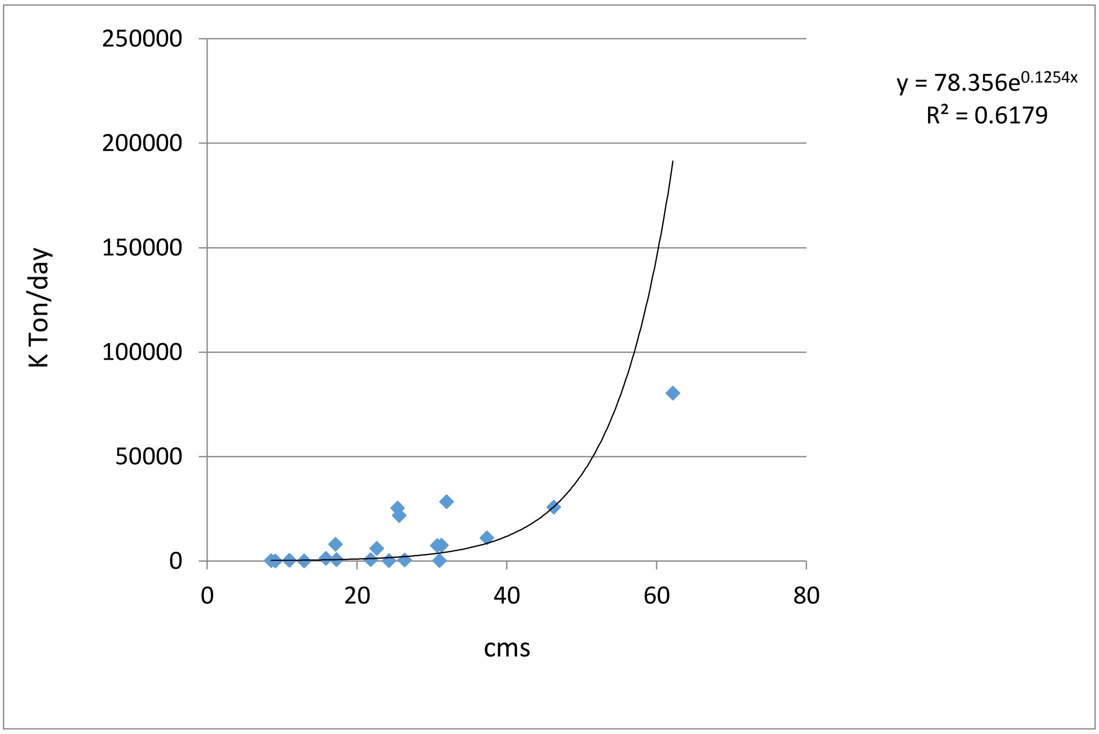

Figure 29. Whole Year Relationship in the Houlong River

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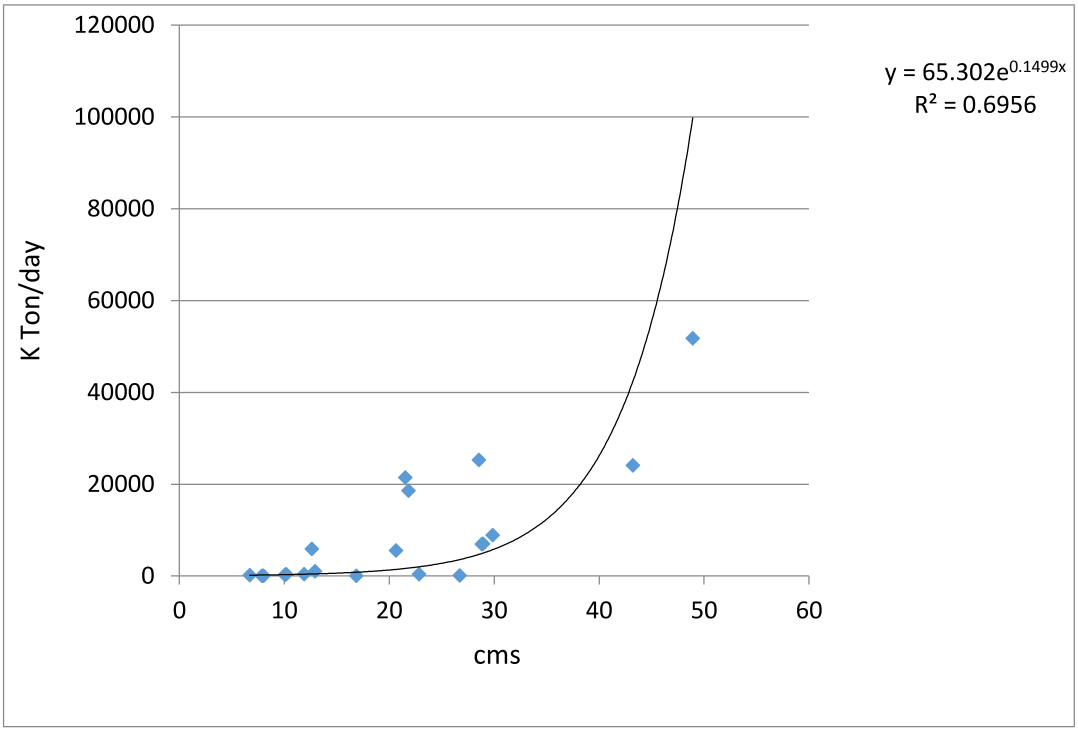

Figure 30. Flood Season Relationship in the Houlong River

N. *The Results of the Da-an River*

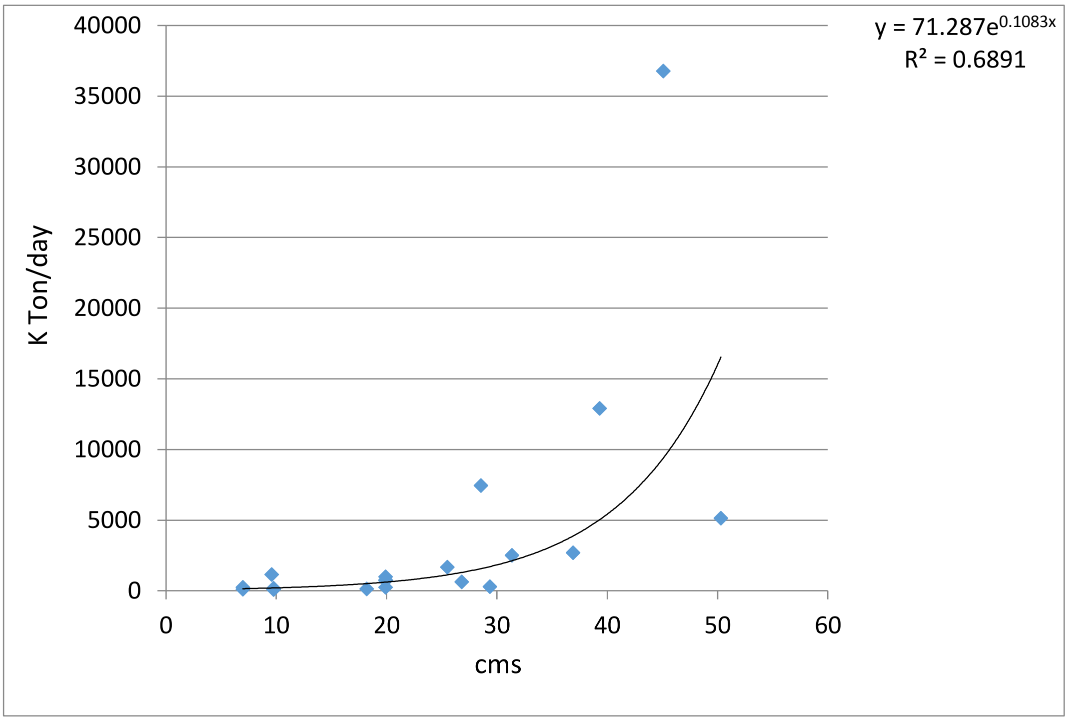

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Figure 31. Whole Year Relationship in the Da-an River

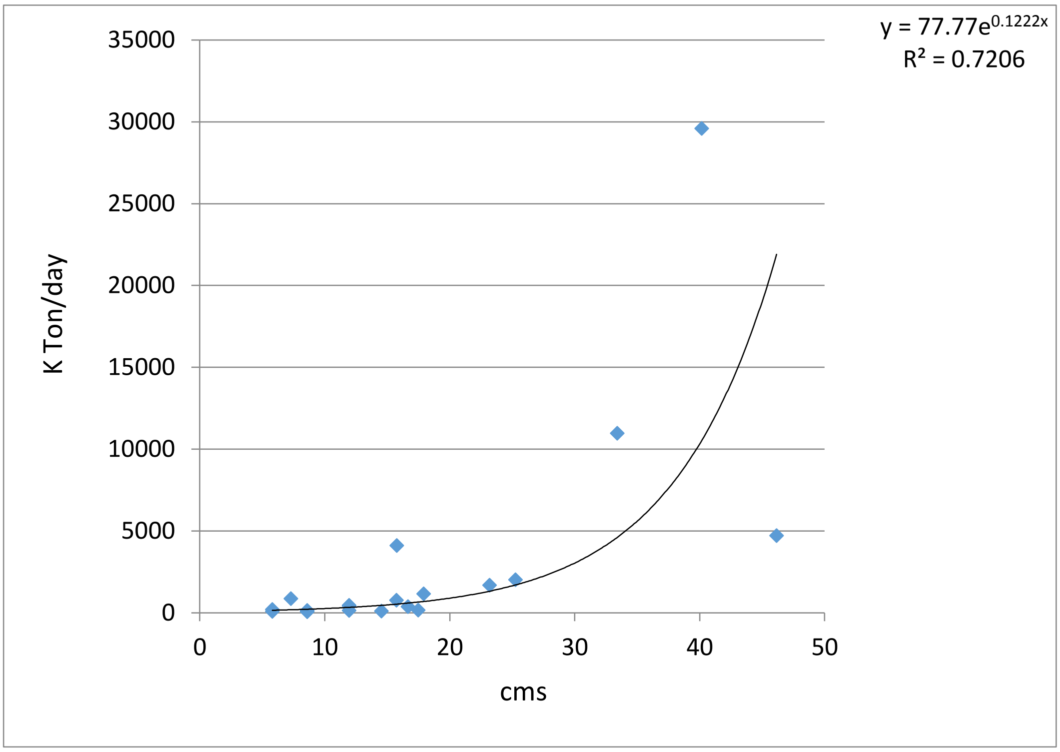

Figure 32. Flood Season Relationship in the Da-an River

O. *The Results of the Wu River*

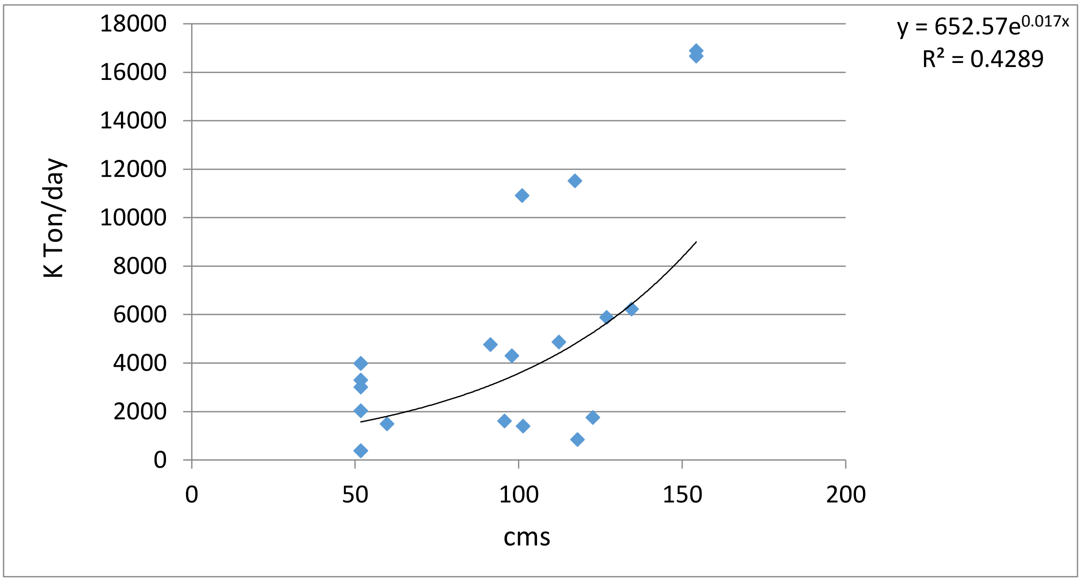

Figure 33. Whole Year Relationship in the Wu River

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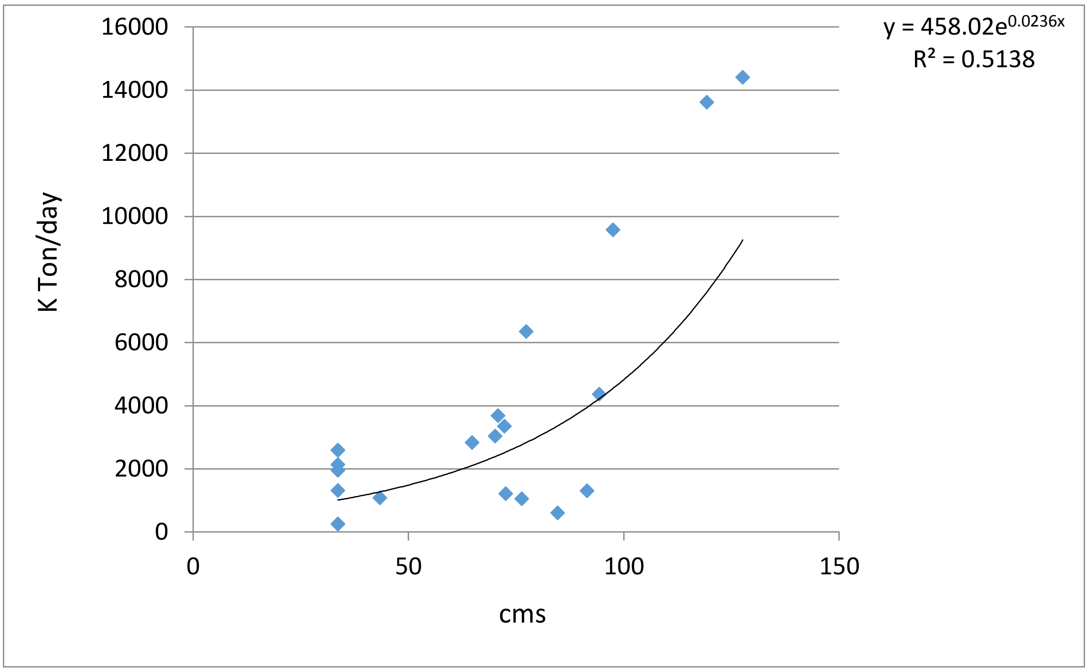

Figure 34. Flood Season Relationship in the Wu River

P. The Results of the Zhuoshui River

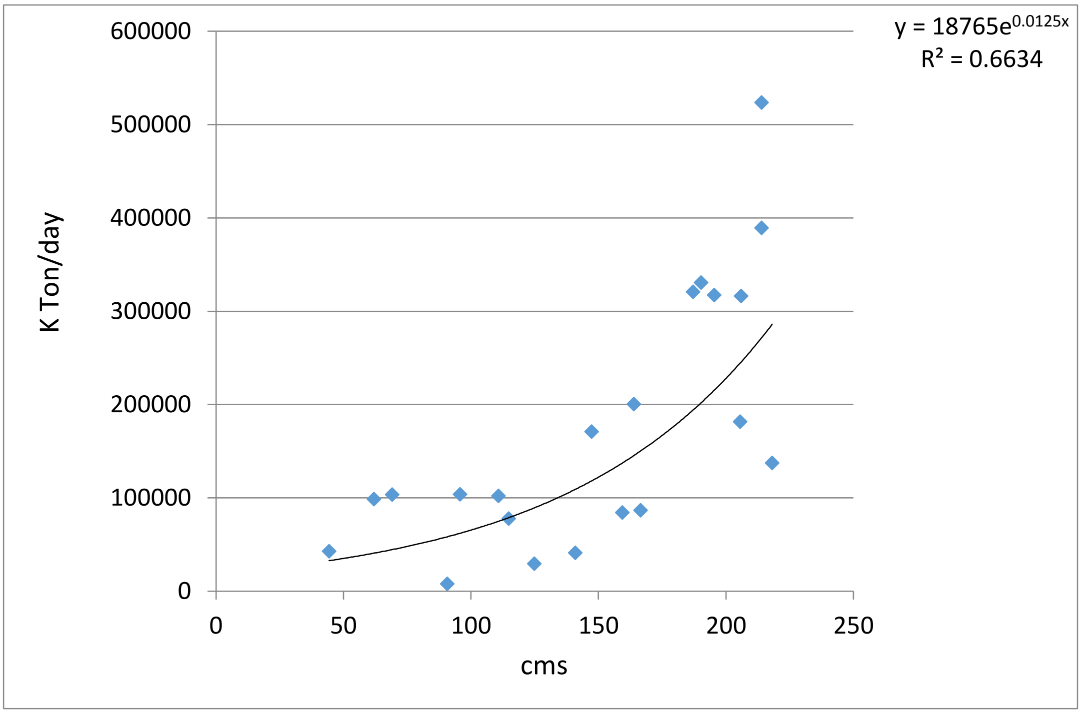

Figure 35. Whole Year Relationship in the Zhuoshui River

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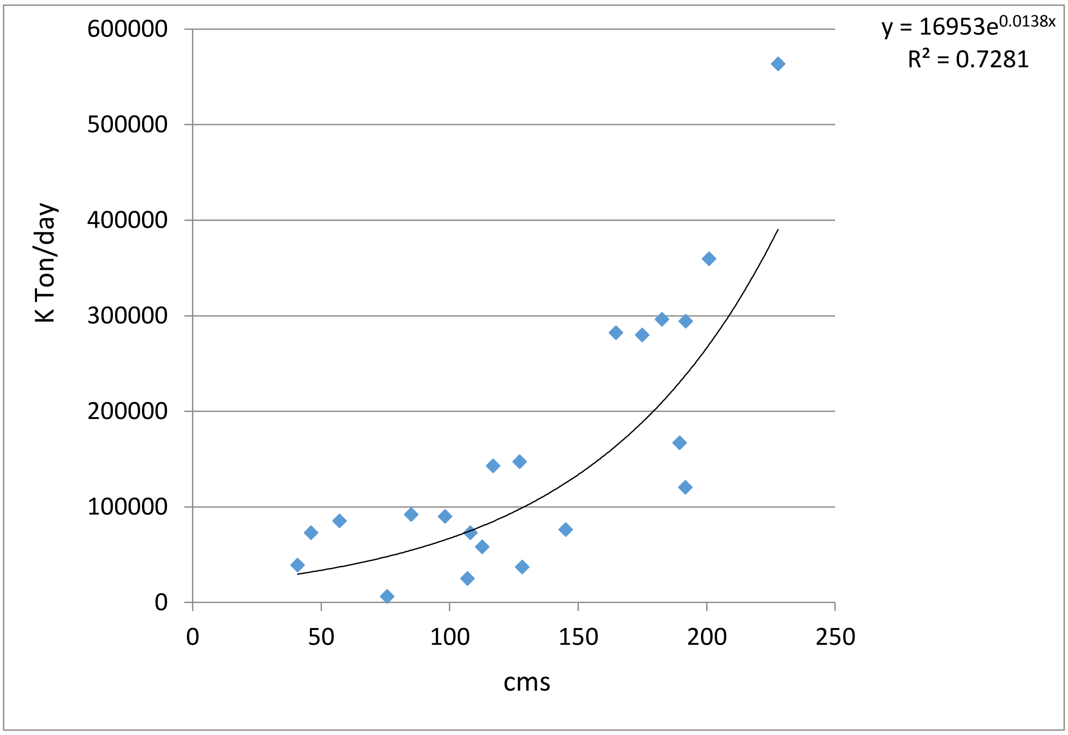

Figure 36. Flood Season Relationship in the Zhuoshui River

Q. The Results of the Puzi River

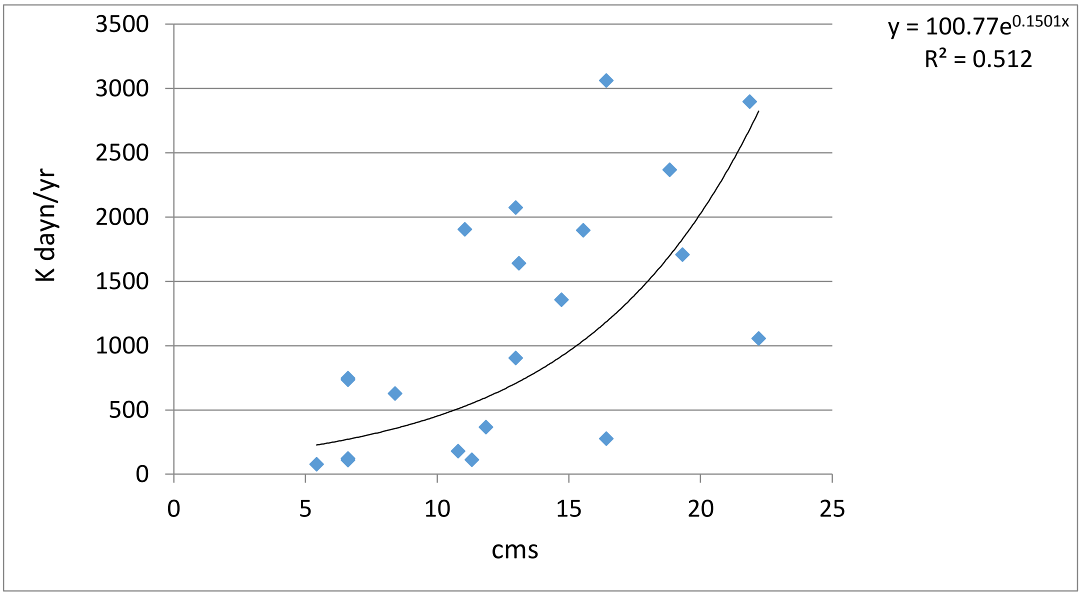

Figure 37. Whole Year Relationship in the Puzi River

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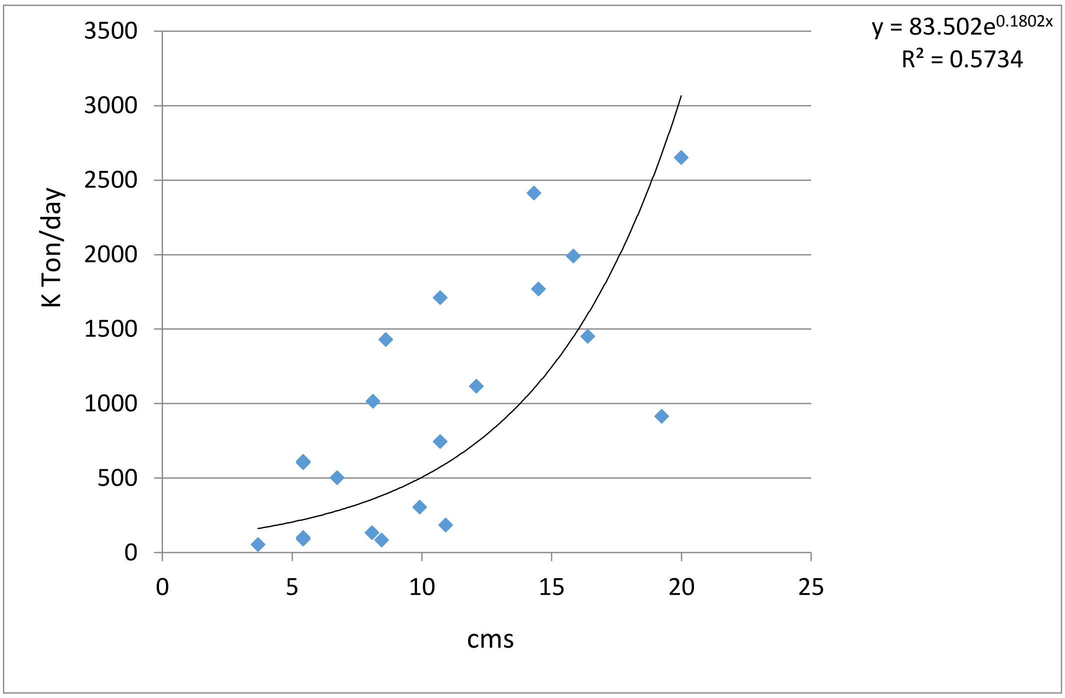

Figure 38. Flood Season Relationship in the Puzi River

R. The Results of the Bazhang River

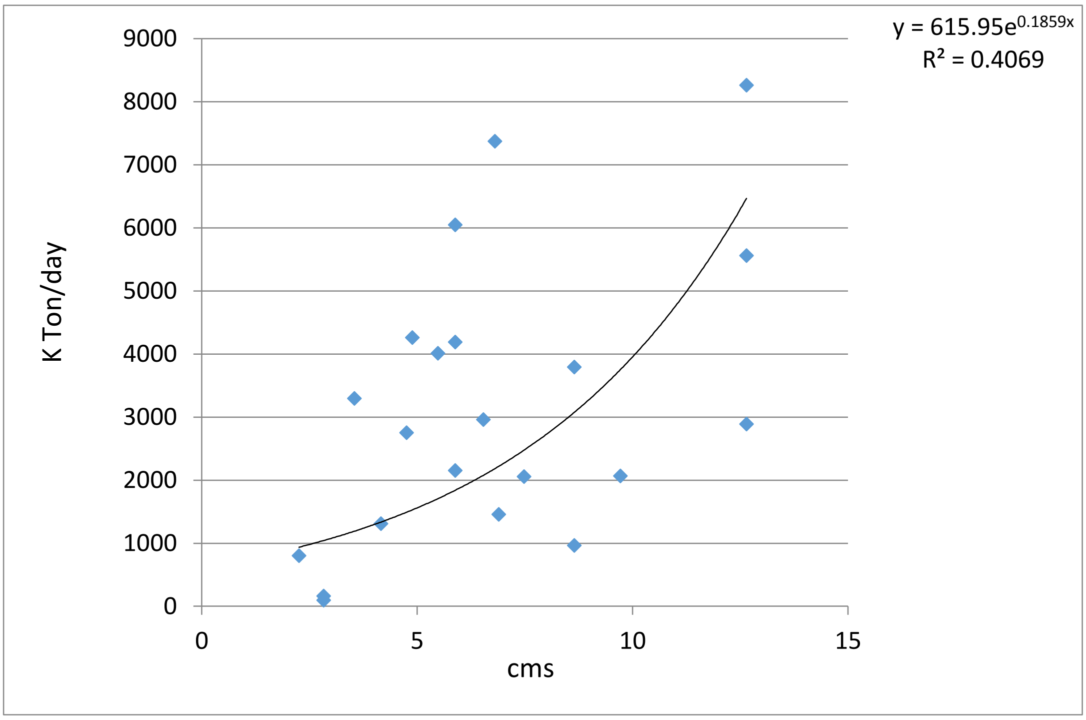

Figure 39. Whole Year Relationship in the Bazhang River

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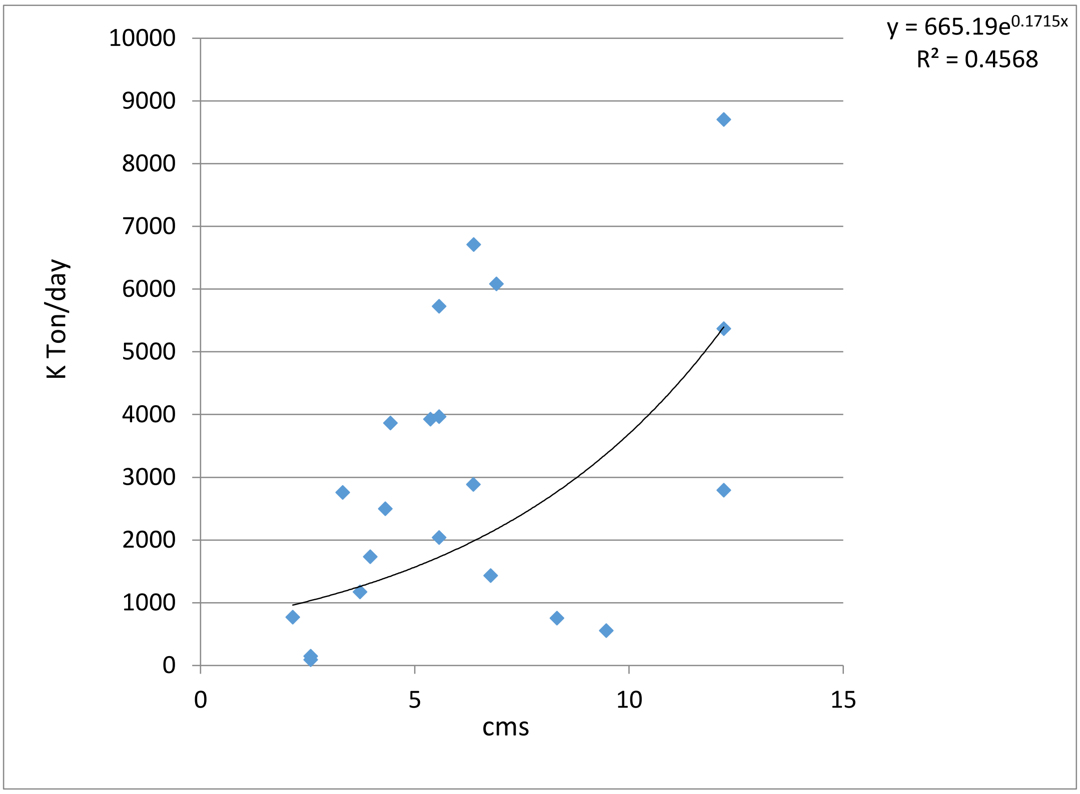

Figure 40. Flood Season Relationship in the Bazhang River

S. *The Results of the Zishui River*

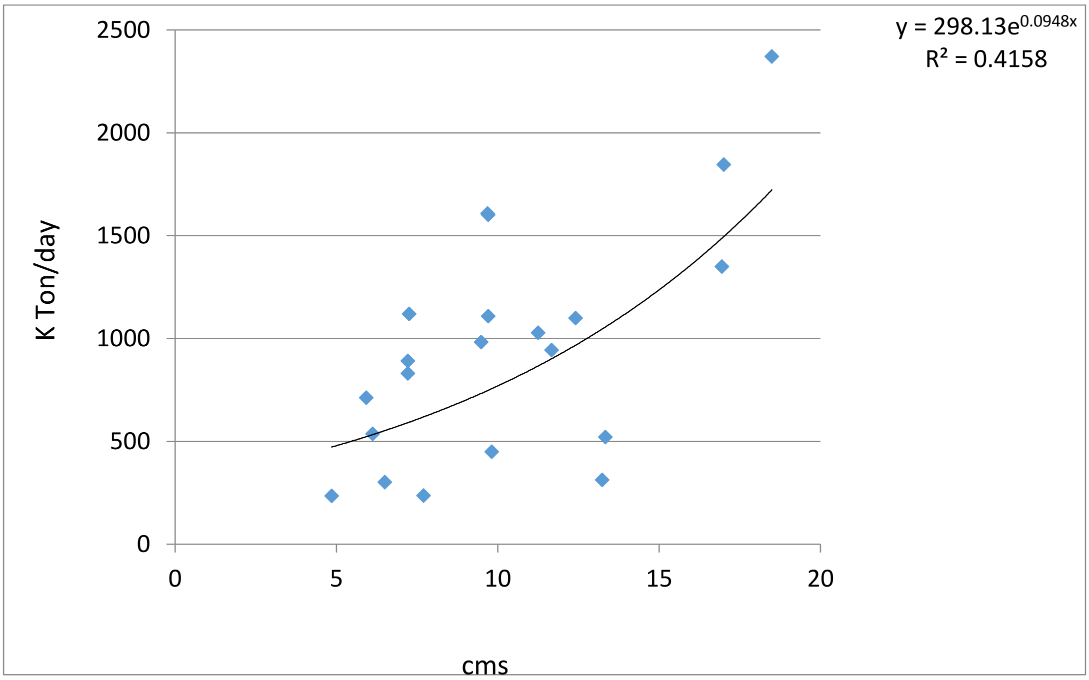

Figure 41. Whole Year Relationship in the Zishui River

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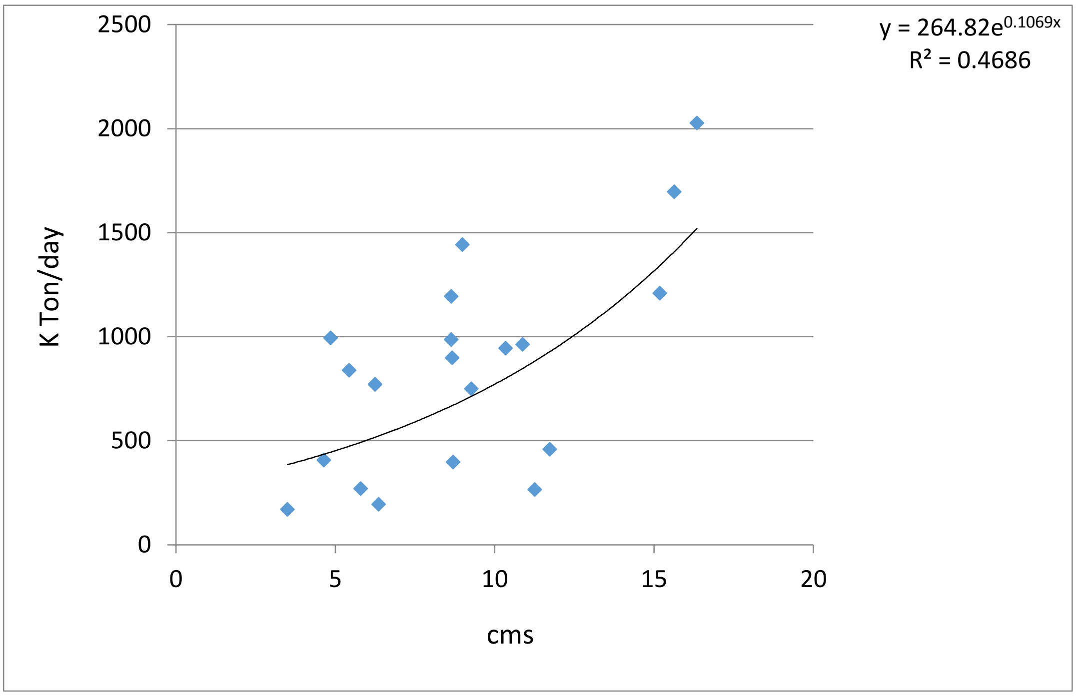

Figure 42. Flood Season Relationship in the Zishui River

T. The Results of the Yanshui River

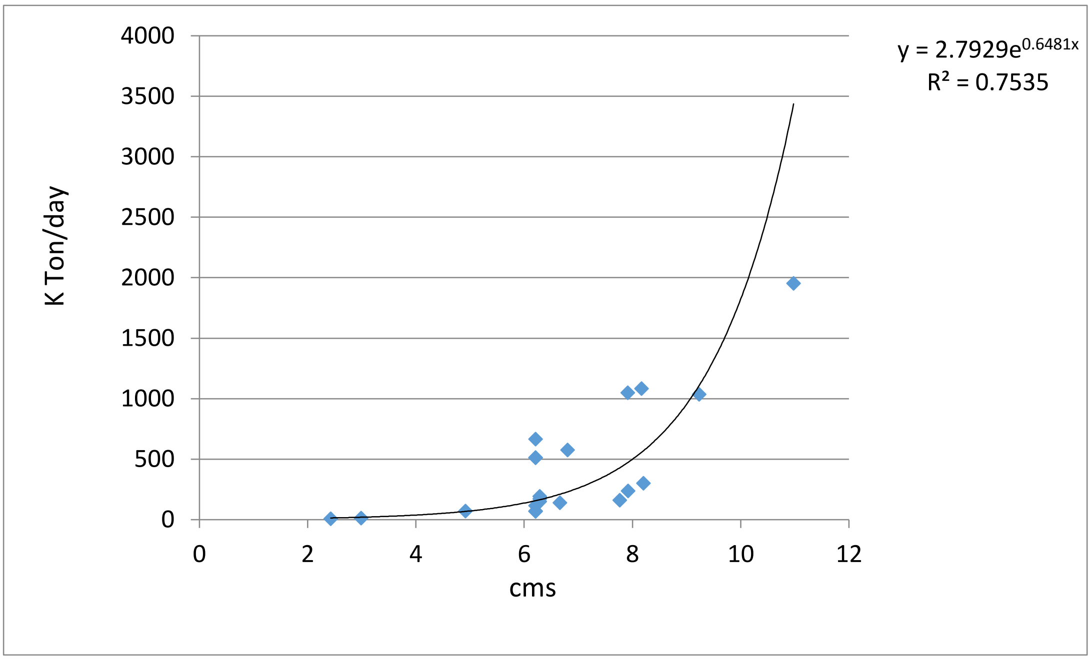

Figure 43. Whole Year Relationship in the Yanshui River

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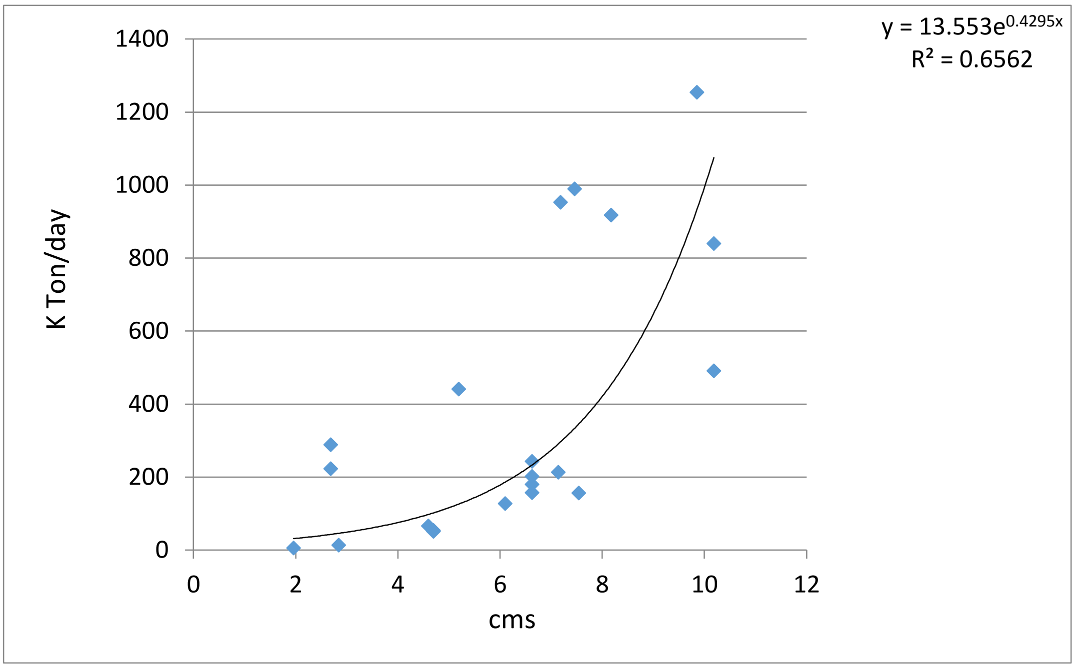

Figure 44. Flood Season Relationship in the Yanshui River

U. The Results of the Erren River

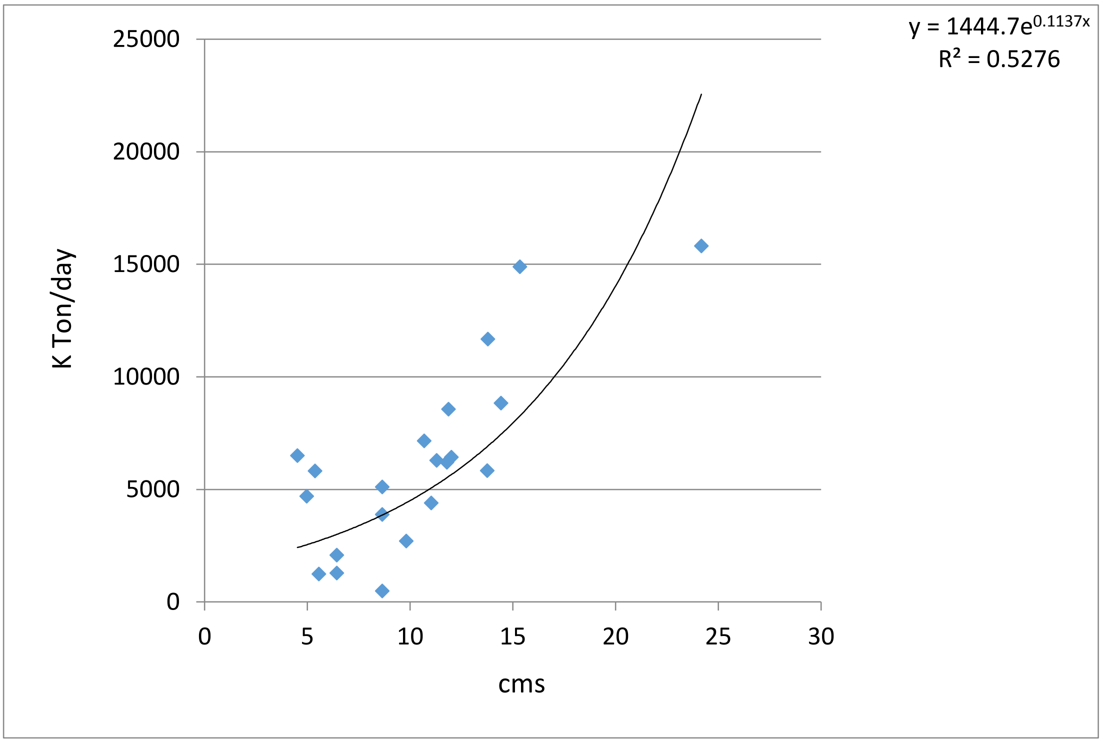

Figure 45. Whole Year Relationship in the Erren River

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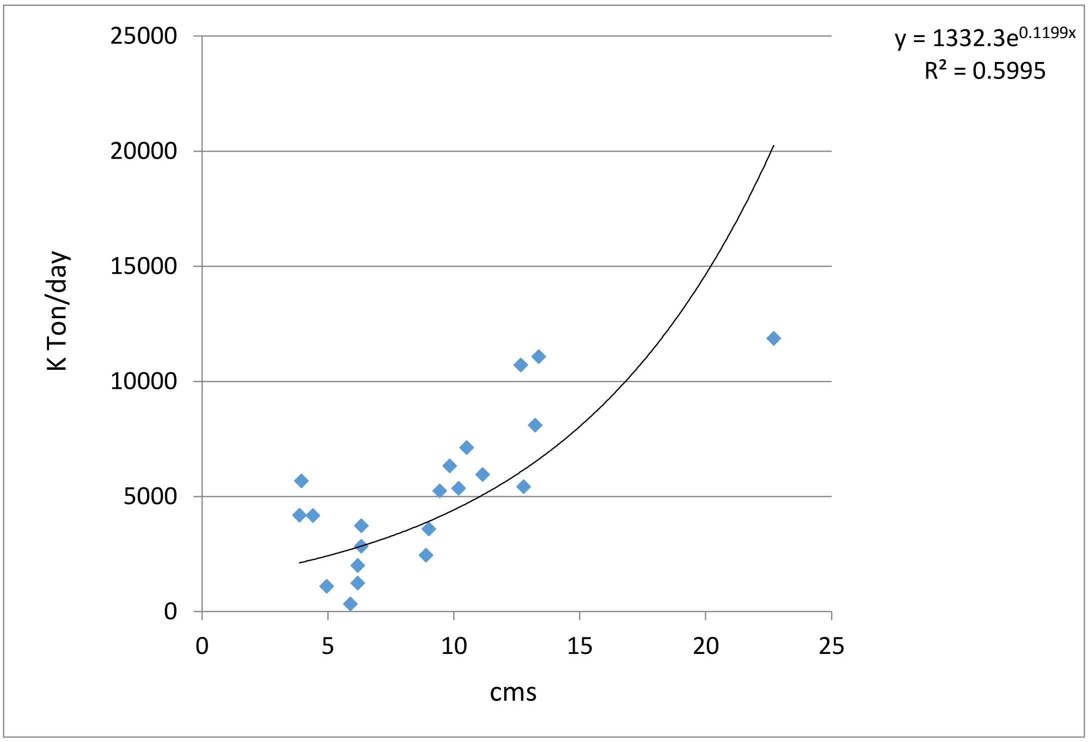

Figure 46. Flood Season Relationship in the Erren River

V. *The Results of the Siougulian River*

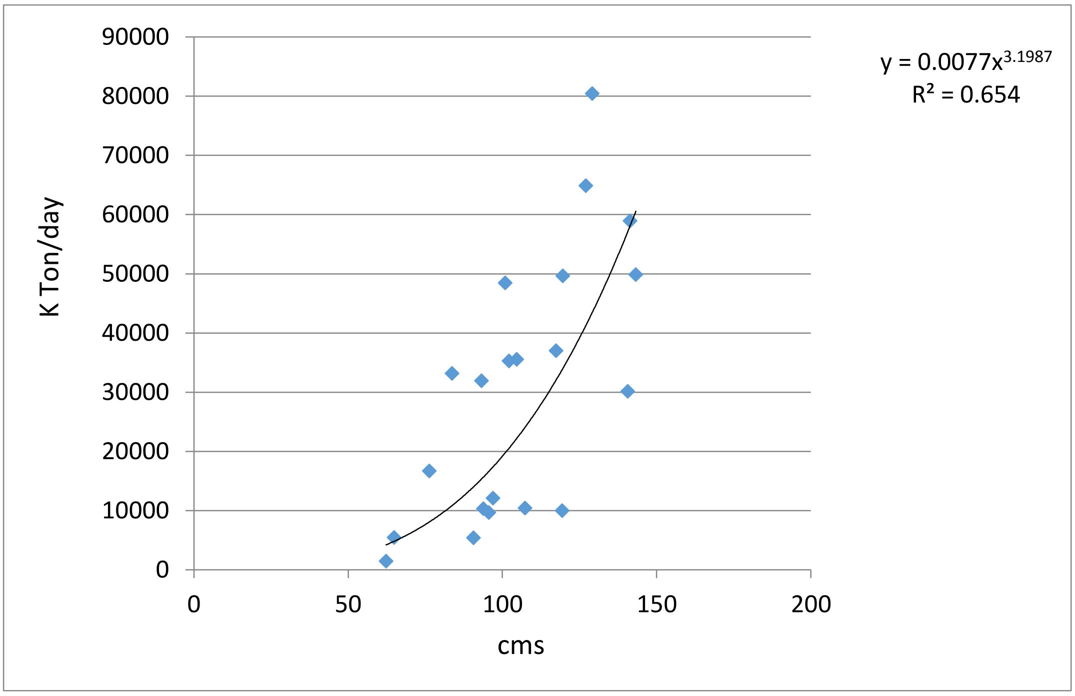

Figure 47. Whole Year Relationship in the Siougulian River

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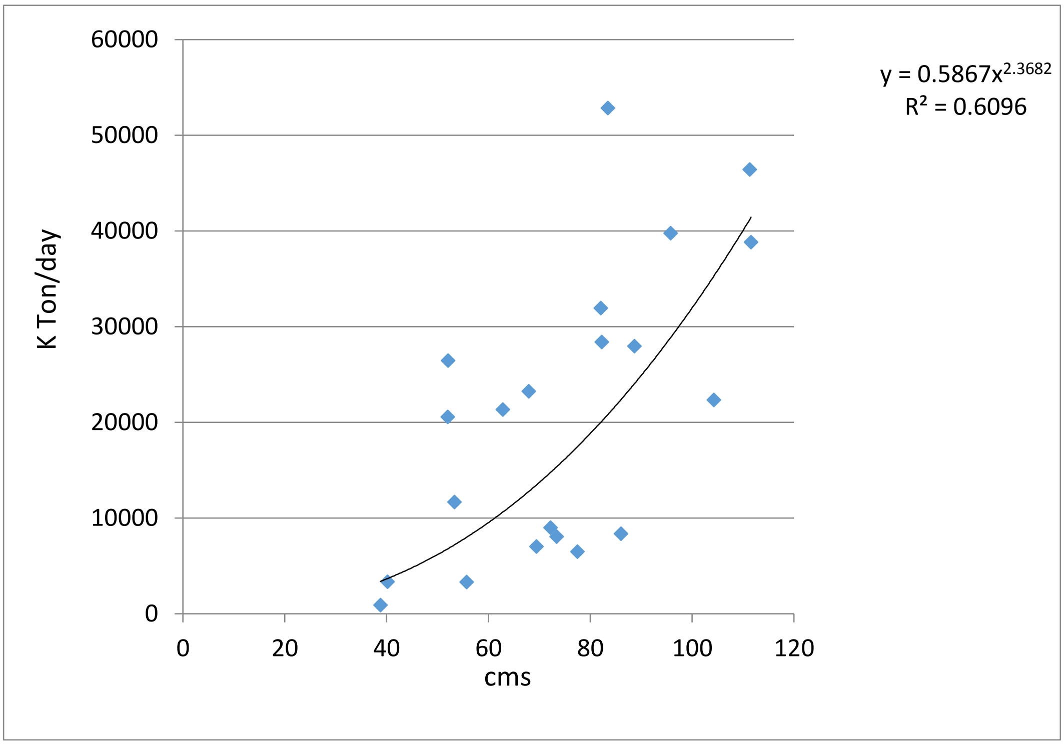

Figure 48. Flood Season Relationship in the Siougulian River

W. ***The Results of the Hualien River***

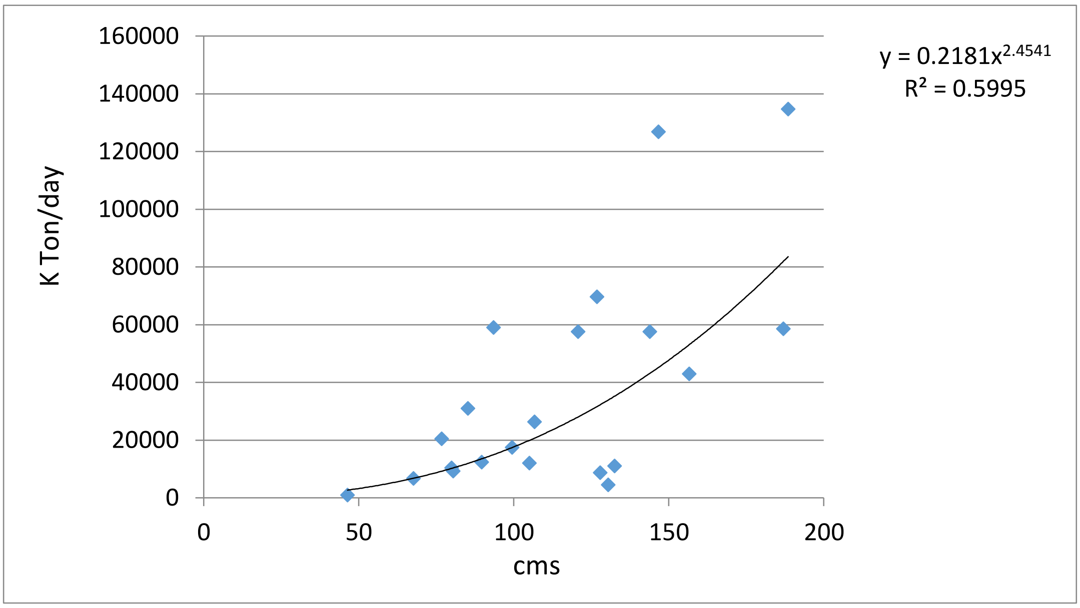

Figure 49. Whole Year Relationship in the Hualien River

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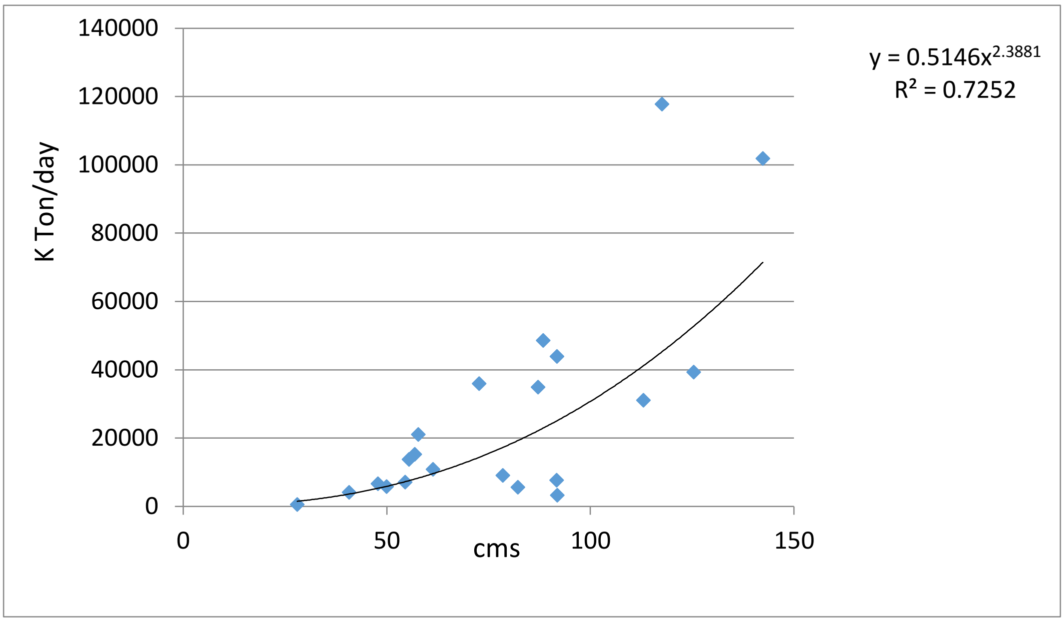

Figure 50. Flood Season Relationship in the Hualien River

X. ***The Results of the Heping River***

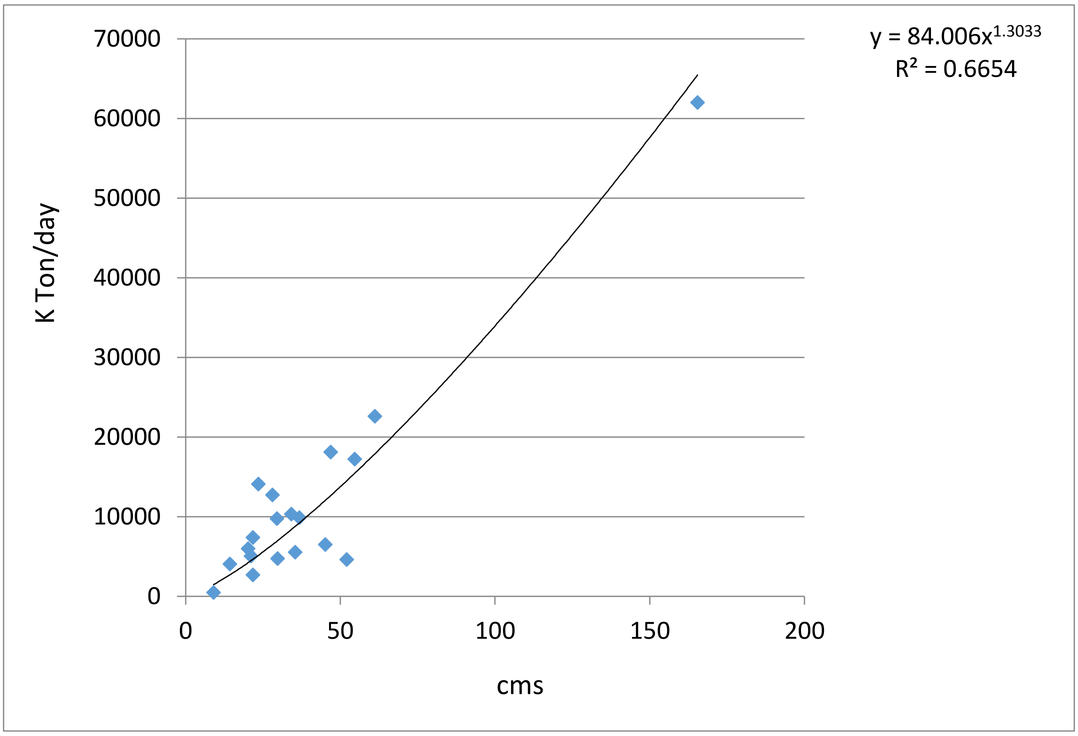

Figure 51. Whole Year Relationship in the Heping River

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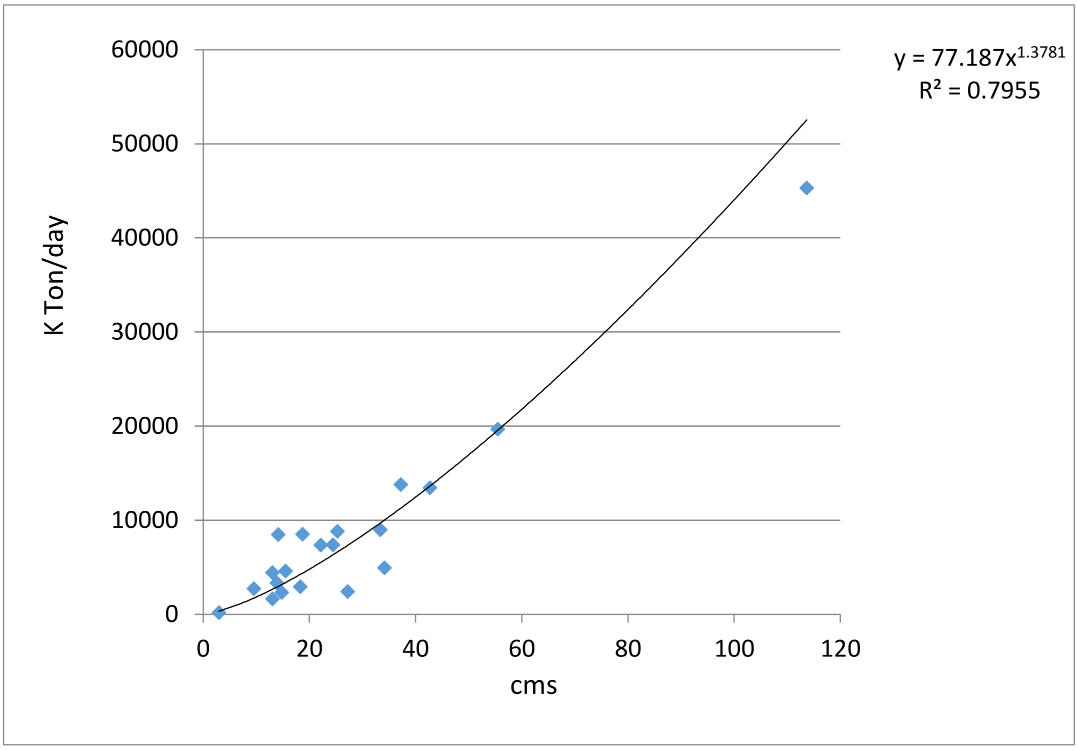

Figure 52. Flood Season Relationship in the Heping River

DISCUSSION AND CONCLUSIONS

Discussion

The Sediment yield and controlling factors:

Run-off

Rivers result from run-off of water from the continents. River water itself has primarily originated from precipitation, some of which is lost through evaporation, groundwater recharge, etc. In addition, geographical heterogeneity such as the presence of a landmass with high relief also induces large river flows. Geographical differences in rainfall distribution arise primarily due to relief, with the windward sides of mountains receiving large amounts of rain and the leeward sides very little. Water flow is important in determining the river energy and thus the scouring capacity of rivers, but it alone is not a deciding factor for sediment concentrations in rivers. Seasonality of water flow controls the sporadically high sediment loads in rivers. The small rivers in the Pacific island oceans are good examples of rivers carrying huge sediment loads. For example, the subtropical climate of Taiwan, with an average of four typhoons per year and mean annual precipitation of 2.5 m per year, combined with frequent earthquakes, together drive rapid mass-wasting

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and result in high sediment flux in the rivers. Sediment yield of some of the smaller rivers in the Pacific island oceans is enormous, as most of the sediment eroded from these basins is directly dumped into the adjacent seas, whereas large river basins store sediments in their channels as large rivers with large basin area and extensive river banks help in deposition of sediments on the channels at reduced flow.

Effective Discharge

The effective discharge, the recurrence interval of 1–2 years and well below the bankfull not channel forming discharges but channel-maintaining discharges at a given site in a river can be best defined as a range of discharges that are able to transport the largest fraction of sediment load in the long-term. The effective discharge represents a balance between sediment supply and transport and influences the channel morphology in a major way; an increase in sediment supply is likely to result in a decrease in effective transport and hence aggradation and vice versa.

Relief

Measurement of suspended sediment discharge divided by drainage area and corrected for dissolved load, bed load and flood discharge, results in an estimate of regional denudation. Numerous problems are associated with such estimates, the most important being that measurements commonly are based on samples collected from stations far off from the seas inward land, for lack of discharge measurement stations. Many studies have pointed to the significant influence of basin elevation and morphology on river sediment fluxes, but only a few mathematical relationships are available. Relief is a major factor as it induces greater mechanical erosion.

Geology

The role of geology (Figures 53 and 54) in mechanical erosion is less understood. However, the influence of lithology on mechanical erosion rates is probably high with respect to channel erosion, but less important with respect to hill slope erosion because the outcropping lithologies are normally covered with soils. Rivers flowing over crystalline terrains erode with difficulty, whereas unconsolidated sedimentary rocks yield greater sediment loads to rivers. In the Taiwan orogen, despite low relief, highest erosion rates are observed where weak substrates occur.

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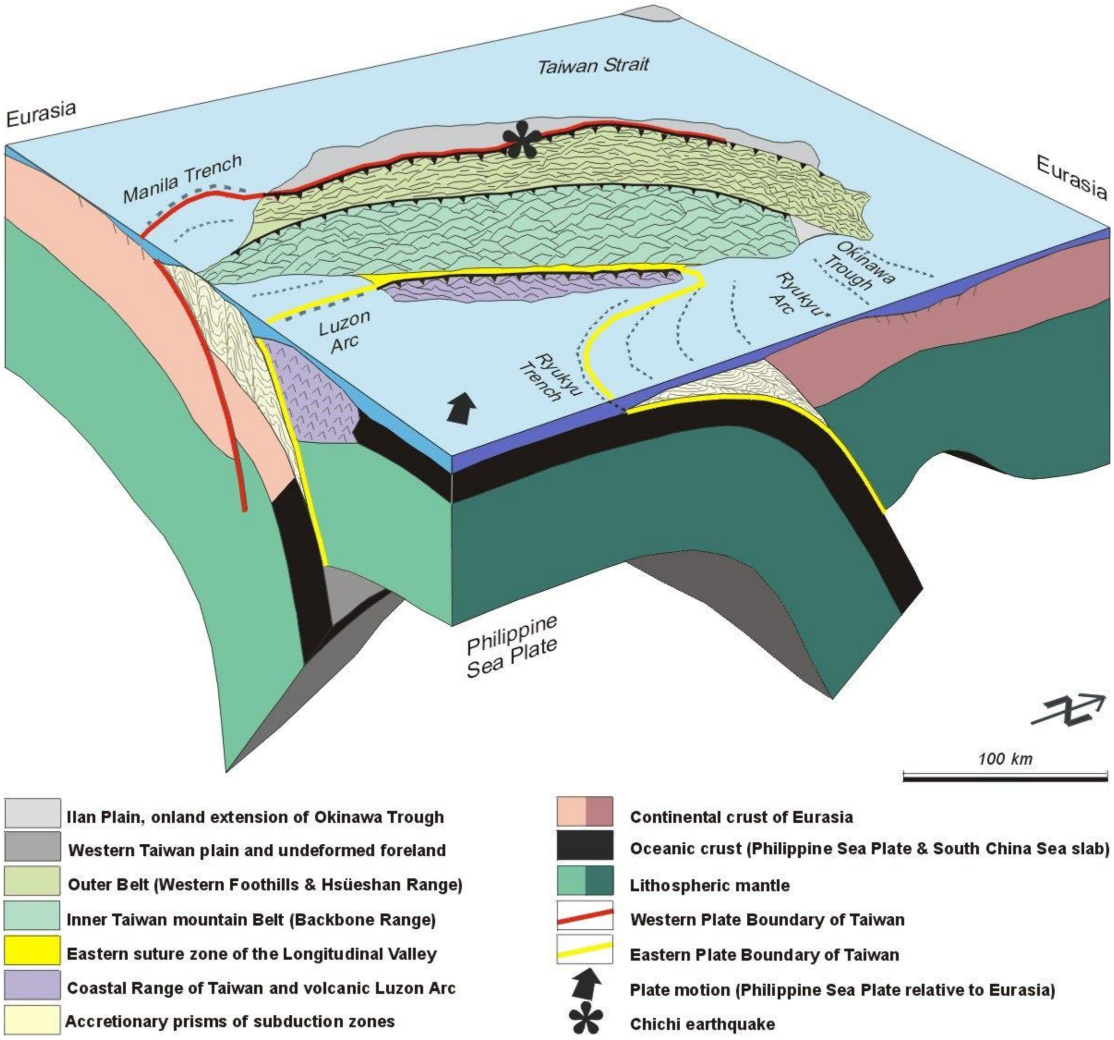

Figure 53. Plate Tectonic Situation of Taiwan (Courtesy of J. Angelier)

Basin area

Basin area alone is not a determining factor of sediment yield. Smaller basins generally exhibit steeper slopes and steeper stream gradients than large basins and thus aid in large sediment yields, whereas large basins show low slopes and low stream gradients, and hence result in low sediment output. Basin area integrates several factors such as gradient, storage capacity, etc. which influence sediment yields.

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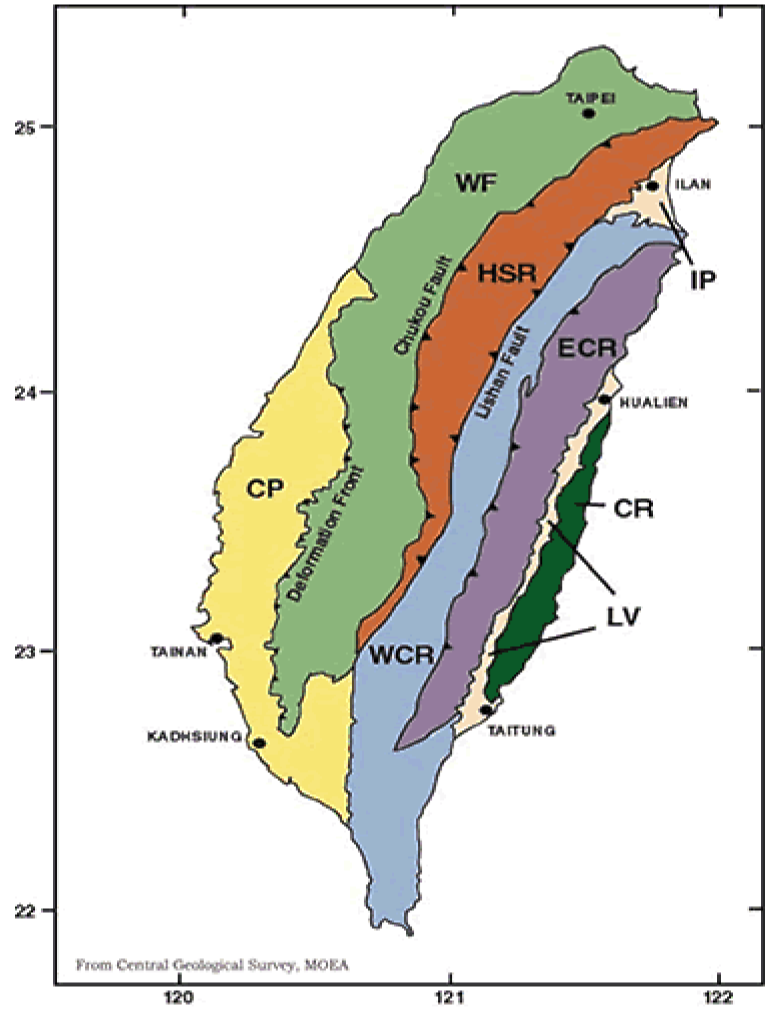

Figure 54. The geology 0f Taiwan described in different separated items (CGS. MOEA.)

Temperature

Sediment discharge is related to basin relief, basin area and temperature. the polar rivers with sub-zero temperatures show the lowest values in sediment yield whereas tropical rivers with temperatures of more than 30°C have extreme sediment yields.

Climate

Land and water are closely linked through the water cycle. Energy from the sun drives this and other natural cycles in the river basin. Climate – the type of weather a region has over a long period of time – determines how much water comes to the watershed through seasonal cycles. The seasonal pattern of precipitation and temperature variation control streamflow and water production. Although the amount of precipitation can vary from year to year, the earth has a finite amount of water which cannot be increased. Some precipitation infiltrates the soil and percolates through permeable rock into groundwater

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storage called aquifers. Natural groundwater discharge is a major source of water for many streams. Climate affects water loss from a watershed as well as providing water. In hot, dry, or windy weather, evaporation loss from bare soil and from water surfaces is high. The same climatic influences that increase evaporation also increase transpiration from plants. Transpiration draws on soil moisture from a greater depth than evaporation because plant roots may reach deeper into the available moisture supply. Transpiration is greatest during the growing season and least during colder weather, when most plants are relatively dormant. Climate strongly affects soil formation. Rainfall causes leaching – the movement of dissolved particles through soil by the water. Rainfall also transports soils, through the erosive power of runoff. Soil plays a major role in determining which plants will establish a protective vegetative cover in the catchment.

Vegetative Cover

Plant cover benefits a river basin in a number of ways. The canopy intercepts rain and reduces the force with which it strikes the ground, thereby reducing erosion. The canopy also reduces wind velocity and therefore wind–caused soil loss. Grasses, shrubs and trees make up the major plant cover types in a catchment, and all are important to catchment management. Plants also modify and develop the soil. Plant roots create soil spaces, which help increase a soil's ability to store water. Rotting leaves from plants add organic matter to soil, which also increases water–holding capacity. Plant debris also slows surface runoff and protects the soil surface from rainfall–caused erosion. Soil depths and moisture–holding capacities are usually lower on steep slopes, and plant growth rates are often slower. When leaves and twigs fall, they decompose and are eventually incorporated into the soil. Before decomposing, this litter protects the soil surface from rain and evaporation, improves infiltration of water and slows down surface runoff. Stems and roots lead water into the ground. Roots open up soil spaces for water retention and drainage, add organic materials to the soil and remove chemicals from the water. Roots take water and minerals from the soil to the rest of the plant. These minerals are again consumed or fall back into the soil through leaves and dead plants. In some cases, through this process plants can remove what would become water pollutants.

Human influence

Among all the categories of human influences that alter sediment loads in rivers, none exerts as much influence as the reservoirs. Together with land-use changes, deforestation and soil conservation practices, natural sedimentary cycle has been greatly altered. River impoundments provide important benefits to society through flood control, power

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generation, water storage and release for agriculture, industry and domestic supplies. The adverse environmental effects include dislocation of human populations, silting of reservoirs, reduce sediment flux to the oceans, downstream scouring of channels, life cycle and habitat of aquatic organisms, eutrophication, anoxia and toxic conditions. Most of the examples of recent changes in the annual sediment loads of the world's rivers introduced above relate to specific anthropogenic impacts such as catchment disturbance and dam construction. People can have a great impact on the health of a watershed, as described above. Not only do we use more water than other creatures, but we make major changes to river basins individually and collectively – some of which are beneficial, and some of which can do serious harm. In general, we have modified watersheds so much that many no longer perform many of the useful functions that protect and support our communities.

Longer-term records of sediment load

The lack of longer-term records of sediment load for many world rivers, and particularly those in developing countries that are likely to have been influenced by land clearance and related catchment disturbance in the recent past, makes it difficult to estimate the magnitude of the increase in sediment load for those rivers that might be expected to be characterizedby increasing loads. However, available information on the amount of sediment deposited in the world's reservoirs provides some basis for estimating the potential magnitude of the overall decrease in flux associated with dam construction. There is currently considerable uncertainty associated with existing estimates of the amount of sediment sequestered behind dams on the world's rivers.

Beach groundwater table

Beach groundwater table was highly affected by the patterns of rainfall distribution which were significantly increased and decreased in the wet period and dry period, respectively. The increasing of beach groundwater level has led the beach to become more saturated and enhanced the offshore sediment transport during the wet season as the profile was eroded. However, during the dry season, the beach was accreting and the groundwater level was lower in comparison to the groundwater level during the wet season. For the swash water depth and velocity profiles, data during the wet period was higher than the dry period due to higher wave energy and saturation level effect on infiltration processes on the beach surface. Due to saturated beach condition, the swash velocities for backwash was slightly lower than up-rush in the wet period but significantly lower or none during the dry period. The relationship between tides and groundwater level will also be an important factor.

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Conclusions

The In many ways, sediment transport dynamics in mountain environments differ from those of the lowlands. The high relief and the steep slopes are an obvious feature of mountain areas. The cold climate is another factor controlling runoff and erosional processes, and the distribution of vegetation is also controlled by the prevailing climate.
As expected, the analysis showed that there is a positive relationship between suspended transport rates and streamflow. High R^2 values in the suspended load transport rates - stream discharge relationship are observed. The suspended sediment measurements are not very precise because the concentration of the suspended sediment, in contrast to the stream discharge, was not determined separately for each subsection of the cross section considered. The above concentration was determined only in the middle of the cross section considered.

Most extreme sediment transport events, regardless of whether they are tied to mass movements or transport in rivers, cannot be measured directly. Accurate volumetric estimates are among the greatest uncertainties in quantifying extreme mass-transport events.

Sediment rating curves, which are fitted relationships between river discharge (Q_w) and suspended-sediment concentration (C), are commonly used to assess patterns and trends in river water quality. In many of these studies, it is assumed that rating curves have a power-law form (i.e. C=a Q_w^b where a and b are fitted parameters). Two fundamental questions about the utility of these techniques are assessed in this paper: (i) how well to the parameters, a and b , characterize trends in the data, and (ii) are trends in rating curves diagnostic of changes to river water or sediment discharge? As noted in previous research, the offset parameter, a , is not an independent variable for most rivers but rather strongly dependent on b and Q_w.

Because of the broad popularity and utility of sediment rating curves, they will likely continue to be an important tool in the assessment and description of river sediment loads. Although sediment rating curves can provide important graphical and mathematical descriptions of river data and their trends with time, several limitations are inherent in their use.

It was shown that trends in sediment rating curves were not diagnostic of unique river water or sediment discharge conditions. For these reasons, it is concluded that trend analyses with

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sediment rating curves must be accompanied with assessments of the time-dependent rates of river water and sediment discharge.

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