ESTIMATION OF WATER RESOURCES LOADING INTO THE DAM RESERVOIR

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ABSTRACT

Estimation of water resources loading into the dam reservoir is an important study that will provide a new approach to water environment improvement. The SWAT model simulation between 2000 and 2010 indicated that various potential landuse sources exist within the Kase River Dam area. Considering the total loading of pollutants to Kase River Dam, the potential contributions of tributary must be considered. The tributary loadings are related to landuse activities that occur in the watershed, include agricultural, forest and urban area. The greatest pollutant transport of TN and TP into tributary streams occurs in the Hokuzan Fork area. The Hokuzan Fork area is the big contributor of nutrients to its stream reaches in the Kase River Dam, simply because of its large size (55 % of total watershed area). The transport of nutrients to stream reaches is much lower in the Nakahara Fork area with TN 8319.13 kg and TP 580.75 kg respectively. Subwatersheds 6, 7 and subwatershed 8, which inside the Nakahara Fork contribute relatively little to their respective stream reaches. The outcome shows that the greatest sources of pollutant transport to stream reaches are from Rice field and Forest Mix, which dominate the Kase River Dam watershed. Rice field is seen to contribute significant amounts of all nutrients to stream reaches; this is due to the agricultural activity from this landuse.

Keywords: Water resources, Dam reservoir

INTRODUCTION

Tributary stream flows can transfer great amounts of sediment and associated pollutants to receiving water bodies both seasonally and annually. Therefore, when considering the total loading of pollutants to Kase River Dam these potential contributions must be considered. Computer simulation of rainfall and runoff provides a very useful methodology to examine tributary pollutant contributions. This studyis to estimate the nutrient export into the new Kase River Dam reservoir, and provides a discussion of the SWAT methodology to examine tributary nutrient source.

The Kase River Dam watershed is entirely located within Saga Prefecture, Japan, and is surrounded by the upstream section of the Kase River Basin Forest. Created in 2010, the reservoir is an impoundment of the Kase River at the upstream section. The Kase River flows through the basin, and pour the water into Ariake Sea. Kase River Dam is a multipurpose dam that provides storage for irrigation water, flood control protection, hydroelectric power generation, and also for recreational services.

The population in the Kase River basin about 130,000 people mostly concentrated on the inside and the downstream part. Currently land uses in the Kase Dam watershed are artificial coniferous forest and rice field. The land cover for the region was extracted from the Ministry of Land Infrastructure and Transport (MLIT) Japan (MLIT; http://www.mlit.go.jp).

METHODOLOGY

Nonpoint source loadings by stream flow to the Kase River Dam were estimated using ArcSWAT 2009. The SWAT model was developed to predict the impact of land management practices, such as vegetative changes, reservoir management, groundwater withdrawals, and water transfer, on water, sediment, and agricultural chemical yields in large complex watersheds with varying soils, land use, and management conditions over long periods of time. SWAT simulates hydrology, pesticide and nutrient cycling, erosion, and sediment transport. The model was developed by modifying the Simulator for Water Resources in Rural Basins (SWRRB) (Arnold et al., 1990) and the Routing Outputs to Outlet (ROTO) (Arnold, 1990) models for application to large, complex rural basins. SWRRB is a distributed version of the field-scale CREAMS model, and SWAT is an extended and improved version of

SWRRB.

The ArcSWAT 2009 requires digital elevation data (DEM), land use/land cover, soils, and meteorological data. Digital elevation data was taken from Nippon-III 50 m grid elevation of digital map.

After computing watershed topographic parameters, ArcSWAT 2009 uses land cover and soils data in an overlay process to assign soil parameters and SCS curve numbers. The land cover for the watershed area was taken from the MLIT. Soils information was clip from the MLIT website for Saga Prefecture.

Hydrologic Response Units (HRU) step was done in the modeling application. An HRU consists of a unique combination of land use/land cover and soil characteristics, and thus represents areas of similar hydrologic response. This step resulted in a highly detailed land use and soil SWAT database, containing many HRUs, which in turn represents a very heterogeneous watershed.

For run the simulation, SWAT requires daily precipitation, temperature, relative humidity, solar radiation, and wind speed data. ArcSWAT will search and find the station closest to the mean center of each subwatershed, and assign that station's meteorological parameters to the subwatershed. Daily precipitation data were downloaded from the Japan Meteorological Agency (JMA) website for the Furuyu, Kanjimbashi, and Gonggenyama stations. Daily data are available for these stations from January 1979 to December 2010. Temperature, relative humidity, solar radiation, and wind speed were taken from Saga Meteorological Observatory from 1979 to 2010.

The SWAT model produces (HRU) reports that describe the annual contribution of runoff, sediment, and associated pollutants from individual HRUs to subwatershed stream reaches. These HRU data may be used to provide information about the source area contribution to the overall pollutant loading from the watershed.

RESULTS AND DISCUSSIONS

Evaluation of land use and area characteristics of the watershed

Figure 1 shows the subwatersheds delineated by the ArcSWAT and used in this study. Figure 2 and Table 1 lists the respective land use and area characteristics of each of these subwatersheds. The result shows that the subwatershed 6 area is the largest area in the Kase River Dam watershed, draining 2462.7369 hectares and representing 23 percent of the total watershed area. The second and third largest areas are subwatershed 5 and 2 drain 1861.3709 hectares and 1703.8703 hectares, respectively, and account for approximately 17 percent and 16 percent of total watershed area, respectively. Combined, subwatersheds 1,2,3,4,5, and subwatershed 9 represent Hokuzan Fork and combined subwatershed 6,7, and subwatershed 8 represent Nakahara Fork (Figure 3). These area will used for following tributary source nutrient loading analysis. The dominant land use types in these subwatersheds are Forest Mix, Rice Field, and Forest Evergreen representing 63.39, 11.44, and 9.02 percent of the cover in the watershed (Figure 4).

Evaluation of tributary stream nutrient transport

The SWAT model produces (HRU) reports that describe the annual contribution of runoff, sediment, and associated pollutants from individual HRUs to subwatershed stream reaches. These HRU data may be used to provide information about the source area contribution to the overall pollutant loading from the watershed.

For each subwatershed, SWAT produces reports that describe the total annual transport by runoff of sediment and associated pollutants into the subwatershed stream reach from unique combinations of land use and soil type. Estimates of Total Nitrogen and Total Phosporus are made. Table 2 summarizes the nutrient transport according to land cover and land use for each tributary area. Urban area including Residential, Transportation, Commercial, Institutional, and Industrial are modeled as a mix of impervious area.

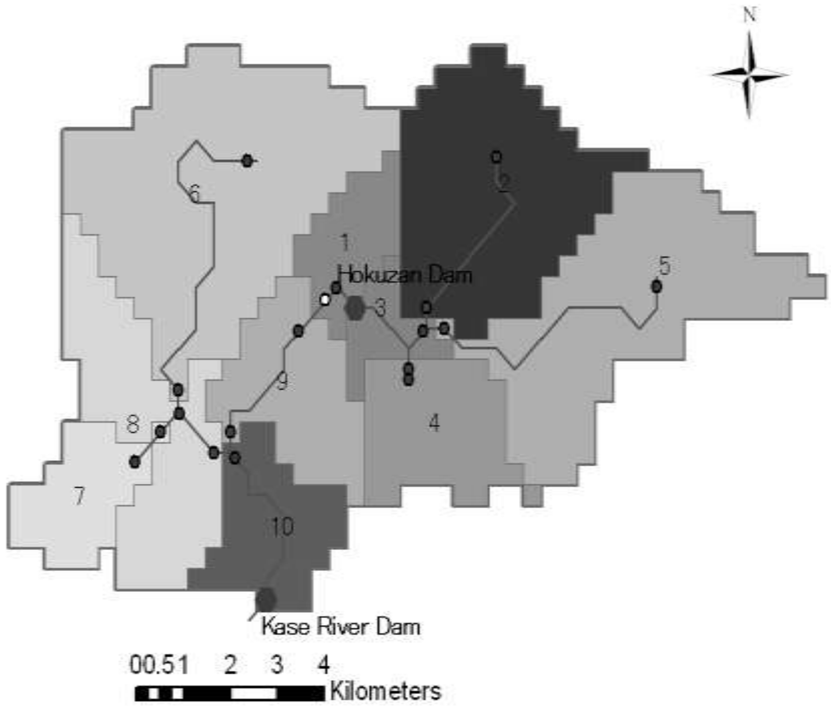

Figure 1 Watershed delineation in SWAT model

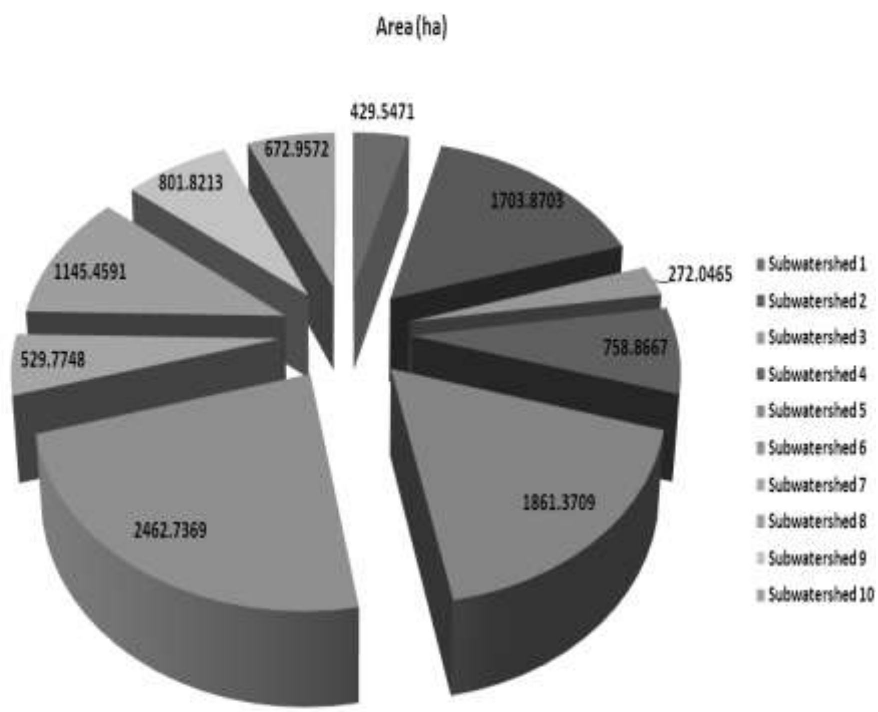

Figure 2 Area characteristics of subwatersheds.

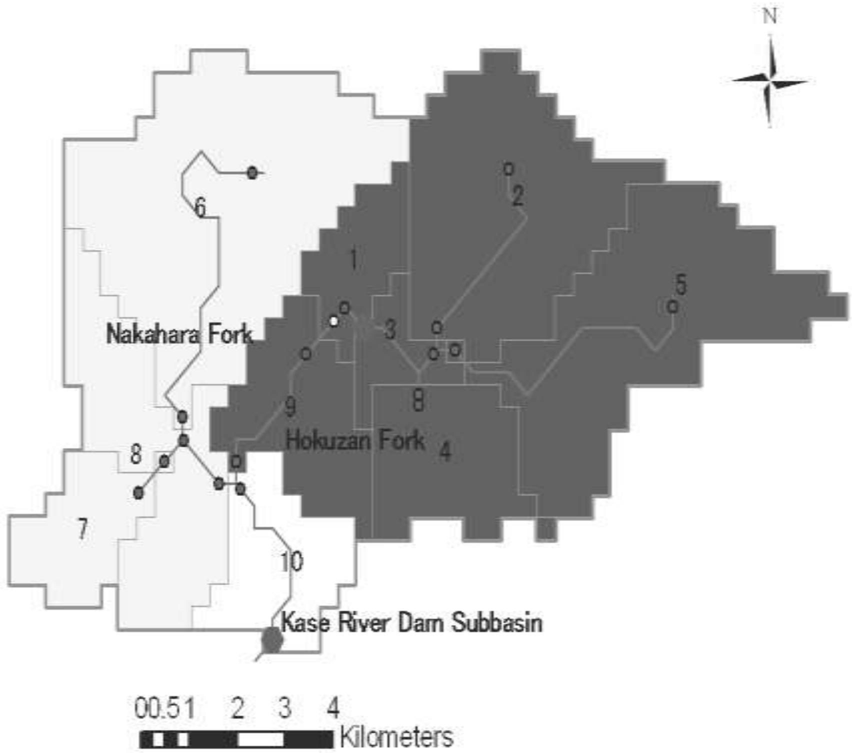

Figure 3 SWAT modeling tributary area

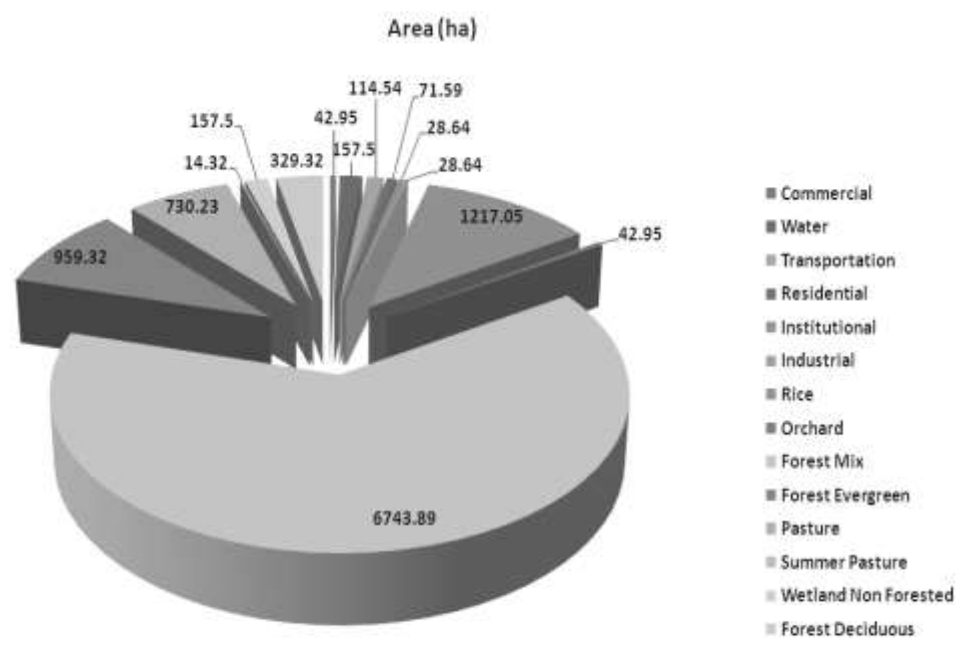

Figure 4 Land use area in the watershed

Table 1 Tributary nutrient load

	Hokuzan Fork	Nakahara Fork
Area (ha)	5829.2	4137.8
Total Nitrogen	13,757.6	8319.1
Total Phosphorus	868.4	580.7
TN/area	2.36	2.01
TP/area	0.149	0.140

Table 2 Subwatershed land use and area characteristics

Subwatershed 1 **SWAT Land Use**	**SWAT Code**	**Area (ha)**	**Subwatershed**
Rice	RICE	85.9094	20
Forest Mix	FRST	257.7283	60
Forest Evergreen	FRSE	71.5912	16.67
Pasture	PAST	14.3182	3.33
	Total subwatershed area	429.5471	100
Subwatershed 2 **SWAT Land Use**	**SWAT Code**	**Area (ha)**	**Subwatershed Percentage**
Rice	RICE	200.4553	11.76
Forest Mix	FRST	1002.2767	58.82
Forest Evergreen	FRSE	143.1824	8.40
Pasture	PAST	85.9094	5.04
Commercial	UCOM	28.6365	1.68
Water	WATR	57.2730	3.36
Transportation	UTRN	28.6365	1.68
Residential	URBN	14.3182	0.84
Institutional	UINS	14.3182	0.84
Wetlands Non Forested	WETN	71.5912	4.2
Forest Deciduous	FRSD	57.2730	3.36
	Total subwatershed area	1703.8703	100

Table 2 (continued)

Subwatershed 3 SWAT Land Use	SWAT Code	Area (ha)	Subwatershed Percentage
Water	WATR	71.5912	26.32
Institutional	UINS	14.3182	5.26
Forest Mix	FRST	157.5006	57.89
Forest Evergreen	FRSE	28.6365	10.53
	Total subwatershed area	272.0465	100
Subwatershed 4 **SWAT Land Use**	**SWAT Code**	**Area (ha)**	**Subwatershed Percentage**
Water	WATR	14.3182	1.89
Residential	URBN	14.3182	1.89
Rice	RICE	85.9094	11.32
Orchard	ORCD	14.3182	1.89
Forest Mix	FRST	501.1383	66.04
Forest Evergreen	FRSE	28.6365	3.77
Pasture	PAST	28.6365	3.77
Wetlands Non Forested	WETN	14.3182	1.89
Forest Deciduous	FRSD	57.2730	7.55
	Total subwatershed area	758.8667	100
Subwatershed 5 **SWAT Land Use**	**SWAT Code**	**Area (ha)**	**Subwatershed Percentage**
Rice	RICE	171.8189	9.23
Forest Mix	FRST	1116.8226	60
Forest Evergreen	FRSE	229.0918	12.31
Pasture	PAST	14.3182	0.77
Commercial	UCOM	14.3182	0.77
Transportation	UTRN	57.2730	3.08
Residential	URBN	14.3182	0.77
Industrial	UIDU	28.6365	1.54
Wetlands Non Forested	WETN	57.2730	3.08
Forest Deciduous	FRSD	128.8641	6.92
Orchard	ORCD	14.3182	0.77
Summer Pasture	SPAS	14.3182	0.77
	Total subwatershed area	1861.3709	100

Table 2 (continued)

Subwatershed 6 SWAT Land Use	SWAT Code	Area (ha)	Subwatershed Percentage
Rice	RICE	272.0465	11.05
Forest Mix	FRST	1832.7345	74.42
Forest Evergreen	FRSE	114.5459	4.65
Pasture	PAST	128.8641	5.23
Transportation	UTRN	28.6365	1.16
Residential	URBN	28.6365	1.16
Wetlands Non Forested	WETN	14.3182	0.58
Forest Deciduous	FRSD	28.6365	1.16
Orchard	ORCD	14.3182	0.58
	Total subwatershed area	2462.7369	100
Subwatershed 7 **SWAT Land Use**	**SWAT Code**	**Area (ha)**	**Subwatershed Percentage**
Rice	RICE	85.9094	16.22
Forest Mix	FRST	300.6830	56.76
Forest Evergreen	FRSE	100.2277	18.92
Pasture	PAST	28.6365	5.41
Forest Deciduous	FRSD	14.3182	2.70
	Total subwatershed area	529.7748	100
Subwatershed 8 **SWAT Land Use**	**SWAT Code**	**Area (ha)**	**Subwatershed Percentage**
Rice	RICE	200.4553	17.50
Forest Mix	FRST	658.6390	57.50
Forest Evergreen	FRSE	114.5459	10
Pasture	PAST	171.8189	15
	Total subwatershed area	1145.4591	100
Subwatershed 9 **SWAT Land Use**	**SWAT Code**	**Area (ha)**	**Subwatershed Percentage**
Rice	RICE	114.5459	14.29
Forest Mix	FRST	558.4113	69.64
Forest Evergreen	FRSE	28.6365	3.57
Pasture	PAST	57.2730	7.14
Forest Deciduous	FRSD	42.9547	5.36
	Total subwatershed area	801.8213	100

Table 2 (continued)

Subwatershed 10 **SWAT Land Use**	**SWAT Code**	**Area (ha)**	**Subwatershed Percentage**
Water	WATR	14.3182	2.13
Forest Mix	FRST	357.9560	53.19
Forest Evergreen	FRSE	100.2277	14.89
Pasture	PAST	200.4553	29.79
	Total subbasin area	672.9572	100

Table 3 Subwatershed annual pollutant transport (kg) to stream reaches summarized by land use

Hokuzan Fork **Land Use**	**Total Nitrogen**	**Total Phosporus**
Rice	3798.186	280.008
Forest Mix	3516.554	164.208
Forest Evergreen	1803.215	80.754
Pasture	1222.733	133.636
Urban	1483.852	73.884
Orchard	259.476	10.923
Summer Pasture	84.666	9.207
Wetlands Non Forested	815.405	85.028
Forest Deciduous	773.573	30.792
Total	13757.66	868.44
Nakahara Fork **Land Use**	**Total Nitrogen**	**Total Phosporus**
Rice	2947.970	221.297
Forest Mix	2565.911	153.651
Forest Evergreen	1305.980	69.486
Pasture	949.294	100.756
Urban	251.071	14.291
Orchard	68.412	3.904
Wetlands Non Forested	96.862	10.471
Forest Deciduous	133.626	6.892
Total	8319.13	580.75

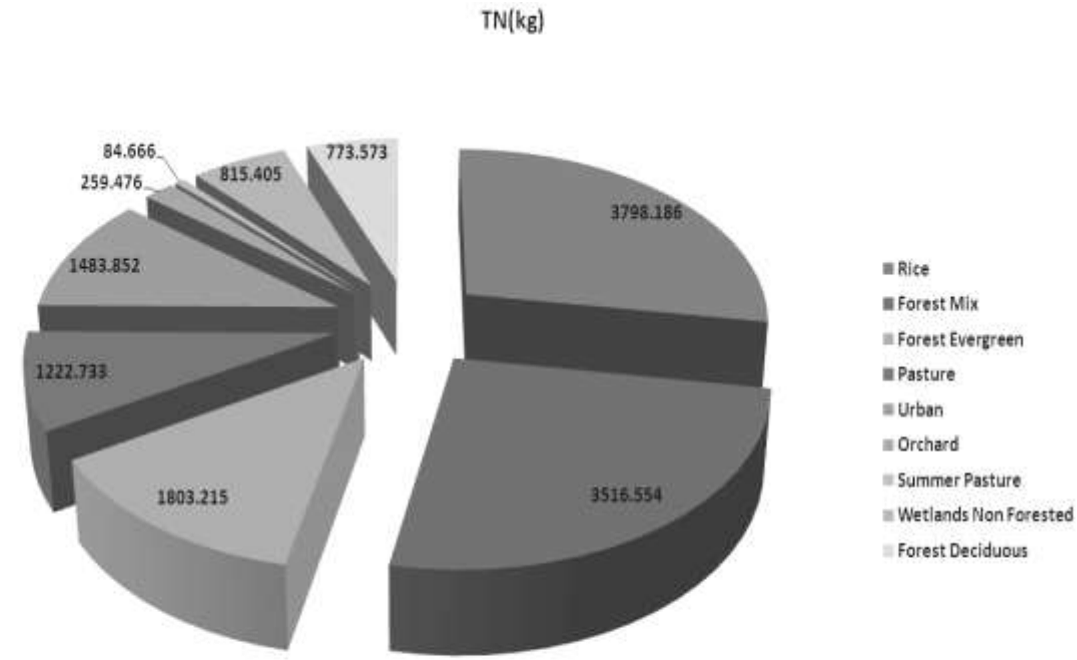

Figure 5 Hokuzan Fork annual TN transport (kg) to stream reaches summarized by land use.

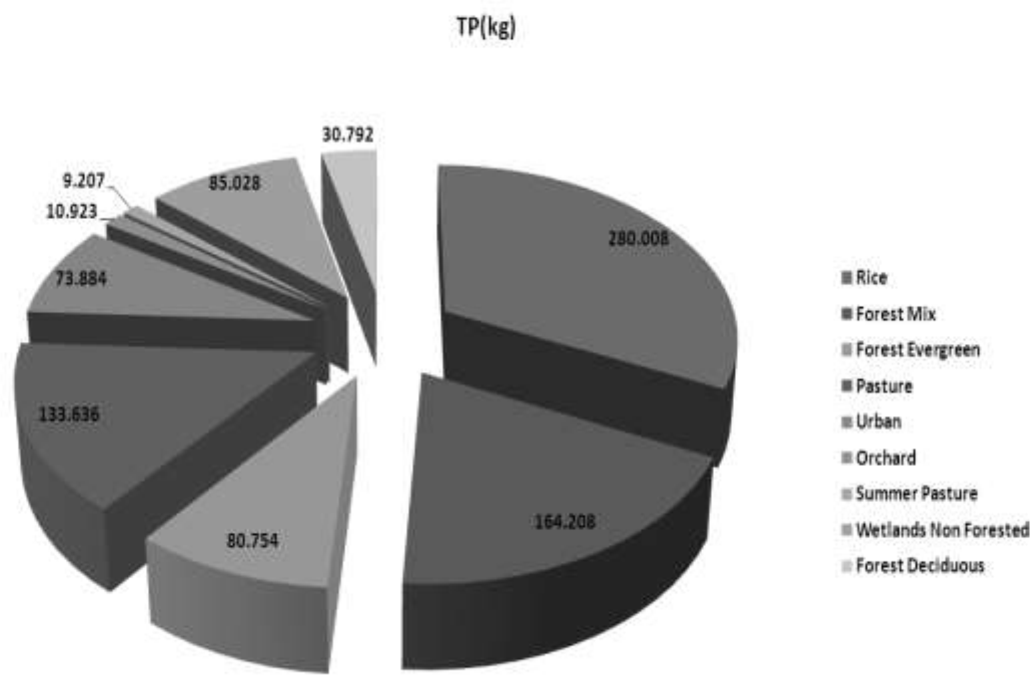

Figure 6 Hokuzan Fork annual TP transport (kg) to stream reaches summarized by land use.

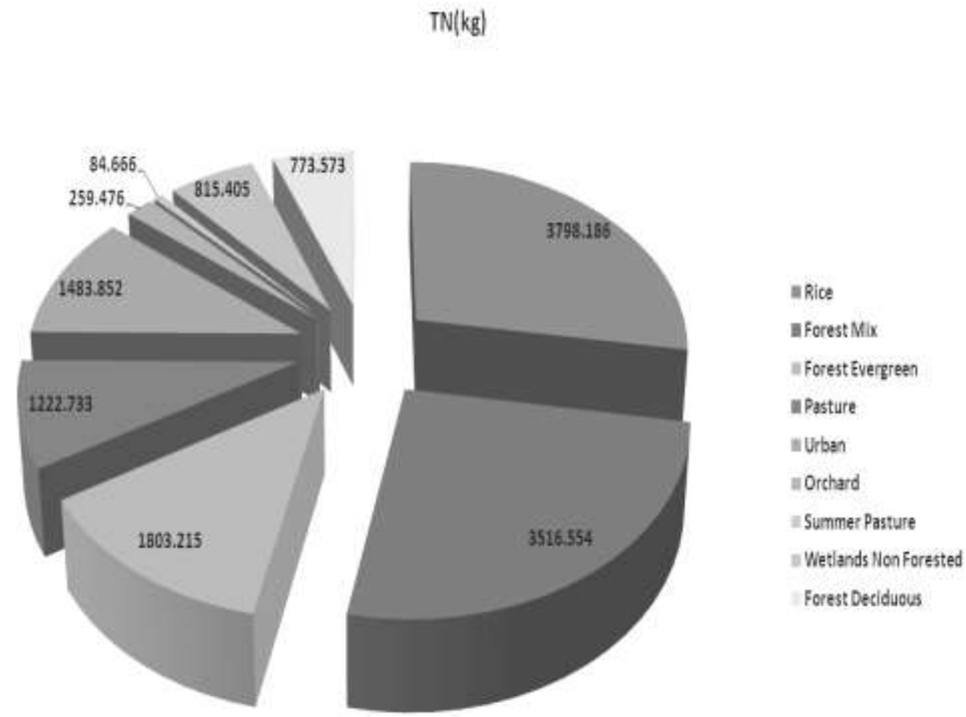

Figure 7 Nakahara Fork annual TN transport (kg) to stream reaches summarized by land use.

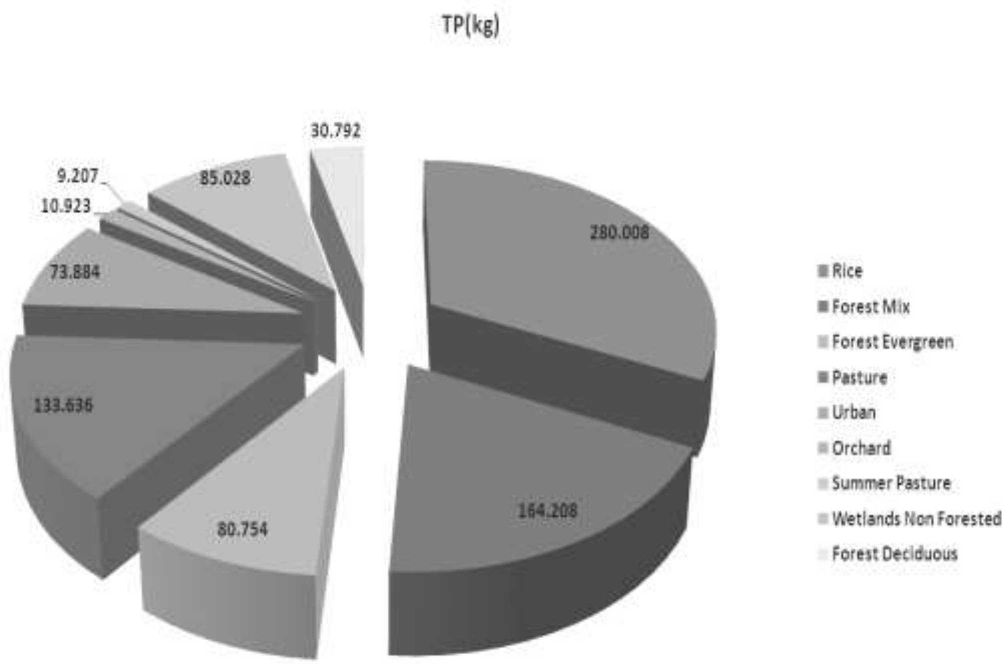

Figure 8 Nakahara Fork annual TP transport (kg) to stream reaches summarized by land use.

Figure 5 and Figure 6 show the Hokuzan Fork annual TN and TP transport to stream reaches summarized by land use, while Figure 7 and Figure 8 show the Nakahara Fork`s annual TN and TP transport to its stream reaches. Total Nitrogen (TN) consists of organic nitrogen and dissolved inorganic nitrogen. Total Phosphorus (TP) consists of organic phosphorus, sediment phosphorus, and dissolved phosphorus. The total amount of nutrients transported from a source to a stream reach is governed by subwatershed area. Table 2 shows that the greatest pollutant transport of TN and TP into tributary streams occurs in the Hokuzan Fork area. The Hokuzan Fork area is the big contributor of nutrients to its stream reaches in the Kase River Dam, simply because of its large size (55 percent of total watershed area).

The results also shows that the greatest sources of pollutant transport to stream reaches are from Rice field and Forest Mix, which dominate the Kase River Dam watershed. Rice field is seen to contribute significant amounts of all nutrients to stream reaches; this is due to the agricultural activity from this landuse.

The third and fourth most contributions of total nitrogen to stream reaches occur from Forest Evergreen (1803.215 kg) and Urban (1483.852 kg), while Pasture (133.636 kg) and Forest Evergreen (80.754 kg) contribute total phosphorus respectively.

CONCLUSIONS

The SWAT model simulation between 2000 and 2010 indicated that various potential landuse sources exist within the Kase River Dam area. Considering the total loading of pollutants to Kase River Dam, the potential contributions of tributary must be considered. The tributary loadings are related to landuse activities that occur in the watershed, include agricultural, forest and urban area. .

The greatest pollutant transport of TN and TP into tributary streams occurs in the Hokuzan Fork area. The Hokuzan Fork area is the big contributor of nutrients to its stream reaches in the Kase River Dam, simply because of its large size (55 % of total watershed area).

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