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Assessment of relationship between land uses of riparian zone and water quality of river for sustainable development of river basin, A case study of U-Tapao river basin, Thailand

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Abstract

The main objective of this study is to find the relationship between land use patterns of riparian zone of the river and water quality parameters. Various water quality parameters were collected from 10 monitoring stations of U-tapao River in the year 2000 to 2011 as secondary data. Land use data as the percentage of land of 100 m riparian zone along the river network were derived from using Geographical Information Systems (GIS) and they were linked with water quality data. Analysis of variance, correlation analysis and stepwise multiple regression analysis were used to investigate spatial and temporal variations and the interrelationships between land uses and water quality parameters. Water quality parameters: temperature (TEMP) and dissolved oxygen (DO) showed spatial variation, whereas TEMP, suspended solid (SS) and fecal coliform bacteria (FCB) showed seasonal variation. Land uses: agriculture, urban, and grass land showed spatial variation, whereas only agriculture and grass land showed annual variation. Urban land showed significant positive correlation with TEMP, SS and dissolved solid (DS) and negative correlation with pH. Similarly, agriculture showed significant positive correlation with SS and DS and negative correlation with TEMP and DO. In the study, water quality parameters were predicted by using multiple regression models and understanding of these relationships can help policy or decision makers to develop suitable land use practices on the riparian zone for sustainable development of a river basin.

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1. Introduction

River water can be contaminated by human activities in two ways: point sources and non-point sources pollutions. Point sources pollutants are directed and released into water bodies in man-made pipes, whereas non-point source pollutants are washed from the earth's surface by storm runoff and enter water bodies of their own accord [1].Generally, non-point sources are difficult to detect since they encompass large areas in drainage basins and involve complex biotic and abiotic interactions [2]. Many studies have demonstrated that non-point source pollution, like diffuse pollutants due to land use practices, is one of the major causes of contamination of river [1-5].

Pollution prevention requires a better understanding of water quality and the impact by land use and land cover in the basin level as well as riparian zone area [3]. Riparian buffers, especially undisturbed vegetated riparian zones adjacent to rivers, might mitigate nutrients, sediment from surface and groundwater flow through the processes of deposition, absorption and denitrification [3]. Recent attention has focused on riparian buffer zone areas for filtering, sediment, nutrients and pesticides entering from agriculture and urban lands [4]. For effective restoration of water quality of river, the policy makers or managers should focus on riparian zone area and understand interrelation of land uses and water quality [4]. The objectives of this study are to evaluate spatial and temporal variations of land uses in riparian zone and investigate its relationship with water quality to develop sustainable land use practice in the river basin.

2. Tools and Methods

2.1. Study area

The study was conducted at U-tapao River basin, a sub-basin of Songkhla Lake Basin located in southern Thailand. The basin is about 60 km long from north to south, and 40 km wide from west to east. The longitude and latitude of basin is 100º 10' through 100º 37' E and 6º 28' through 7º 10' N, respectively (Fig.1). U-tapao River is one of the most important rivers of Songkhla Lake Basin which originates from Bantad Mountain and flows through Hatyai municipality before emptying into the outer part of Songkhla Lake. During its course of 90 km, it receives pollution loads from both point and non-point sources [6]. The climate of the basin is influenced by two seasonal monsoons as well as tropical depressions and temperature of the area which varies between 24ºC and 32º C throughout the year. In the basin, more than 75% of area is covered by agricultural land use, whereas only 13% forest land is located mostly in mountainous areas.

2.2. Water quality and land use data

Secondary water quality data of 10 monitoring sites (Fig. 1) from the year 2000-2011 were collected from Regional Environment Office 16, Songkhla. The water quality parameters for this study were temperature (TEMP), pH, biological oxygen demand (BOD), dissolved oxygen (DO), electrical conductivity (EC), suspended solid (SS), dissolved solid (DS), turbidity (TUR), fecal coliform bacteria (FCB), nitrite (NO_2), nitrate (NO_3), ammonia (NH_3) and total phosphorous (TP). For the land use data, land uses composition within the 100 m buffer zones along river were extracted from the land use/cover map, provided by land use department of Thailand using GIS software. The original land use data set with 37 land use types were aggregated into five broad categories: agriculture, forest, urban, grass and water body. Percentages of these broad land use types were used to find the relationship of land uses and water quality parameters in 100 m riparian zone scale.

2.3. Analysis of data

Descriptive statistics were used to analyze the basic characteristics of land uses and water quality parameters of the river. Analysis of variance (ANOVA) was used to test spatial and temporal variations of water quality parameters and land uses. Pearson's correlation analysis was used to study the relationship between various land use types and water quality variables at 5% level of significance. Further linking of land uses and water quality parameters, the stepwise multiple regression analyses with water quality as dependent variable were carried out to assess relationship among the land use composition within the 100 m riparian buffer zone. To identify the best predictive model for each water-quality variable, regression equations were compared with R^2 values, which showed the amount of variation in the dependent variable explained by the independent variables. All the statistical analyses were performed using SPSS 16.0 for windows
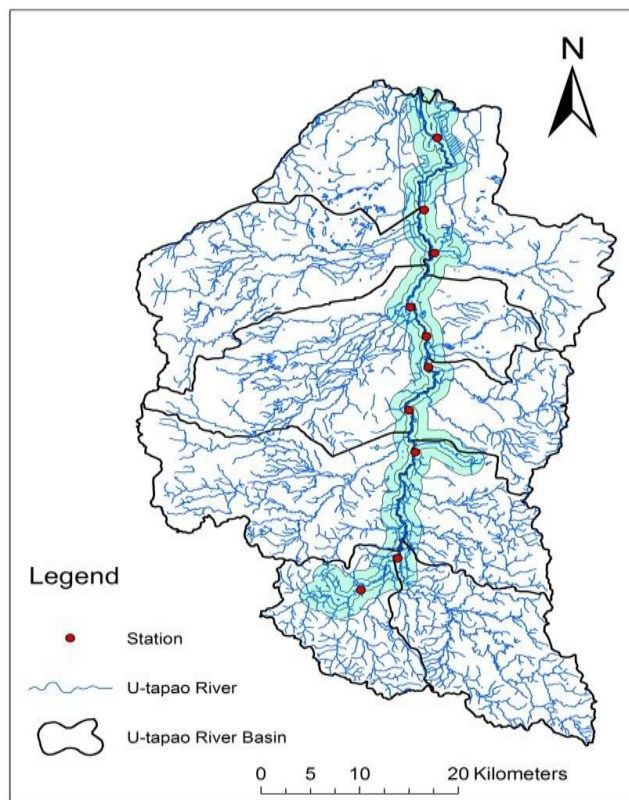

Fig. 1. U-tapao river basin (URB) and ten monitoring stations along the river

3. Results and Discussion

3.1. Water quality parameters of U-tapao River

The descriptive statistics of water quality parameters of U-tapao River basin is explained in Table 1. By analyzing the spatial variation of water quality parameters, only TEMP and DO showed the significance spatial variation (F = 7.29, p <0.05 & F = 3.76, p <0.05). TEMP, SS and FCB showed significant seasonal variation (t = 5.48, 2.70 & 2.80, p <0.05). Correlation analysis showed TEMP had significant positive correlation with BOD and significant negative correlation with DO (r = 0.25, p <0.05 & r = -0.33, p <0.05). For pH, there was only significant positive correlation with DO (r = 0.37, p <0.05). DO had significant negative correlation with BOD and NH_3 (r = -0.25, p <0.05 & r = -0.32, p <0.05). TP showed significant positive correlation with NO_2 and NH_3 (r = 0.53, p <0.05 & r = 0.37, p <0.05). Like other river systems, some water quality parameters showed the significant variations on seasonal and spatial level and the relationship to each other [7-8].

Table 1. Descriptive statistics of water quality parameters (WQP).

WQP	Mean	SD	Minimum	Maximum
Temp(^{0}C)	28.40	1.08	26.60	30.68
pH	6.75	0.51	5.55	8.90
EC(μcm/s)	461.96	1681.60	11.25	12798.00
DO(mg/L)	3.85	1.02	1.75	6.37
BOD(mg/L)	3.34	1.24	1.30	6.48
SS(mg/L)	69.09	46.08	17.00	284.66
DS(mg/L)	132.38	63.49	37.00	269.50
TUR(NTU)	69.28	30.31	34.6	129.00
FCB(mpn/100ml)	27683	46134	723	167300
NO3(mg/L)	1.52	0.81	0.60	2.62
NO2(mg/L)	0.37	0.51	0.016	2.00
NH3(mg/L)	1.29	0.37	0.39	2.71
TP(mg/L)	1.06	1.04	0.074	4.48

3.2. Land use and land cover composition in the riparian zone

Even though forest land is distributed on the outer side of the basin, there is no forest land in 100 m riparian zone. Analysis showed agriculture was the dominant land use in riparian buffer zone areas (Fig. 2). In 2000, most of the zones (ST-1, ST-2, ST-3, ST-4, ST-7 and ST-8) had more than 95% agriculture land use, but only ST-9 had less than 55% land use as agriculture. By comparing land use distribution of basin from 2000 to 2009, all zones had shown dramatic decrease of agriculture land use about 5.12% (ST-3) to 45.5% (ST-8). For the case of urban land use, ST-7 zone showed minimum increment (about 0.3%), whereas ST-8 zone showed the highest increment (about 36.1%), but, exceptionally, ST-3 zone showed the decrease of urban land of about 4.16%. In 2000, only ST-6 zone had grass land of about 21%. In the case of spatial variation land uses, agriculture, urban and grass land uses, those showed the significant variation (F = 6.27, 8.23, & 3.56, p <0.05). For the case of annual variation, only agriculture and grass land showed significant variation (F = 4.8 & 3.85, P <0.05). For the case of correlation, only agriculture land showed significant negative correlation with urban and grass land (r = -0.89 & -0.51, p <0.05). The variations on spatial and temporal level of land use pattern showed the changing pattern of land use and the negative correlation between agriculture land and urban land expressed urbanization process in riparian zone.

Table 2. Pearson's correlation coefficient between land use and water quality parameters.

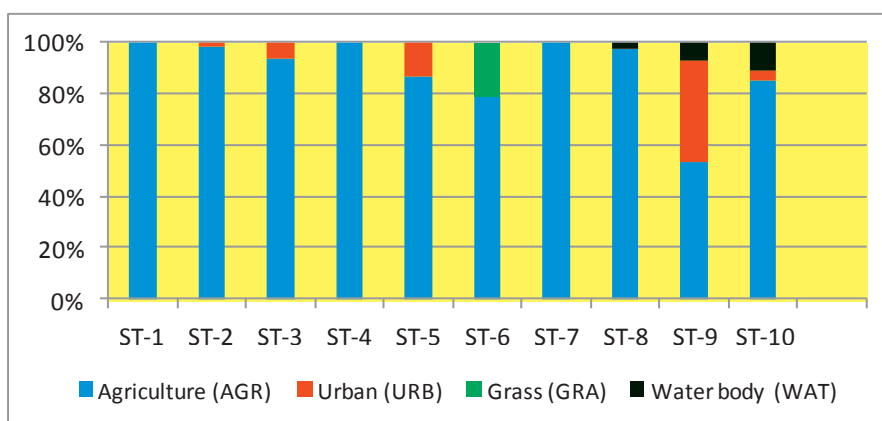| WQP	AGR	URB	GRA	WAT
TEMP	**-0.44**	**0.50**	-0.05	**0.40**
pH	0.20	**-0.26**	0.14	-0.12
EC	0.10	-0.13	-0.16	0.15
DO	**-0.21**	-0.01	0.21	-0.18
BOD	0.37	0.11	0.14	0.17
SS	**0.47**	**0.48**	0.23	-0.13
DS	**0.69**	**0.72**	0.28	-0.24
TUR	0.05	-0.14	0.09	**0.33**
FCB	0.20	-0.23	-0.24	0.03
TP	-0.00	0.29	**-0.85**	0.12
NO3	0.15	-0.24	-0.22	**-0.43**
NO2	-0.23	0.25	0.02	-0.27
NH3	-0.11	0.12	0.03	0.24

Note: $p < 0.05$ (Bold)

Fig. 2. Land use distribution in 100 m riparian zone along the river on ten monitoring stations in the year 2000

3.3. Liking land use in the riparian zone and water quality parameters

Results from the correlation analysis indicated that land-use types were significantly correlated to some water quality parameters in riparian zone scale (Table 2). For example, urban land showed significant positive correlation with TEMP, SS and DS (r = 0.50, 0.48 & 0.72, p <0.05) and negative correlation with pH (r = - 0.26, p <0.05). Similarly, agriculture land showed significant positive correlation with SS and DS (r = 0.47 & 0.69, p <0.05) and negative correlation with TEMP and DO (r = -0.44 & -0.21, p <0.05). These results suggested that local urban land cover and vegetation extent could be the primary driving forces behind the variations in DO and TEMP. For the case of non-point source pollution, agriculture and urban lands were usually related to poor water quality [2-5]. In contrast, in this study, only urban land showed positive relationship with pollutants. It is very clear that most of the water quality variables were degraded from 2000 to 2011; urban areas were dramatically increasing in this period and their impact on water quality variable were quite obvious. So, it clearly explained that the main culprit of deteriorating water quality is the changing pattern from agriculture land to urban land which has the potential to generate large amount of non-point source pollution from storm water discharge. There existed significant negative correlation between grass land with TP (r = -0.851, p <0.05)

and it was widely accepted that grassy area filtered runoff pollutants of river or stream. In general, riparian vegetation helped to reduce the pollution load of the river [3]. Since, there is no forest in riparian zone that might be one of the causes of increasing pollution in the river.

Due to the relationship between pollution loading and composition of the land uses in the riparian zone, there would be a potential for improving water quality if the role of different land use combination were known. To address this issue, the predictive water quality model based on land use pattern can be implemented in riparian zone level. In this study, the regression analysis was used to predict water quality variable on changing land use patterns of the riparian area. To determine the combination of land uses for water quality estimation, backward stepwise method was carried out. By this method, five water quality parameters were estimated on the basis of contributions of different land use types on riparian zone scale (Table 3). For the case of TEMP, urban and water body were used as predictors ($R^2 = 0.38$). For DO, agriculture, urban and grass land uses were used as predictors ($R^2 = 0.87$). Similarly, for BOD, agriculture and urban land uses were used as predictors ($R^2 = 0.62$). For SS and DS, only urban land use was used as predictor ($R^2 = 0.43$ & 0.52). From regression analysis, TEMP showed sensitivity on changing urban and water body, whereas SS and DS were only sensitive on changing urban land. DO showed sensitivity on agriculture, urban and grass land, whereas BOD showed sensitivity only on agriculture and urban land uses. In this study, urban land use appeared to have the greatest effect on water quality since it showed the sensitiveness on all five water quality parameters.

Table 3. Regression equations.

Dependent	Independent	Equation	R^2
TEMP	URB/WAT	TEMP=27.647+0.032URB+0.05WAT	0.384
DO	AGR/GRA/URB	DO = 16.852-2.121AGR-0.127URB+0.031GRA	0.871
BOD	AGR/URB	BOD=14.956-1.412AGR-0.053URB	0.623
SS	URB	SS=57.819+1.45URB	0.430
DS	URB	DS=72.11+0.1634URB	0.527

4. Conclusions

Over the last decade, the combination of different factors affected the water quality of U-tapao River and turned it into a polluted ecosystem. Among them, the changing pattern of land uses in riparian zone had a considerable impact on water quality. It was found that there was significant decrease of agriculture land use, whereas significant increment of urban land use in riparian zone area and such changes have considerably influenced on runoff quality and quantity of river and may be responsible for the increase of various pollutants. The study also indicated that the lack of forest in riparian zone might be another reason of increasing pollution in river. Therefore, maintaining and developing vegetation in riparian buffer zone areas is considered an important step to control non-point source pollution due to surface runoff.

In the study, all four types of land uses showed significant relationship with water quality parameters and the knowledge of these relationships is very important to manage healthy ecosystem of the river. Water quality parameters, like temperature, dissolved oxygen, biological oxygen demand, suspended solid and dissolved solid, were predicted by using regression models on various combinations land use indicators on riparian zone. It was noticed that urban land use was the most important parameter to predict water quality premasters. Altogether, regression models successively linked the land use and water quality parameters and provided a simple but effective analytical approach for predicting water quality. This study not only helps to better understanding of relationship between land use and water quality, but also helps to select the appropriate parameters for effective river basin management. Overall,

the study illustrated the importance of integrating land uses and water quality parameters of riparian zone for sustainable development of river basin.

Acknowledgements

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