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Integrating Land use and Water quality for Environmental based land use planning for U-tapao River Basin, Thailand

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Abstract

Land use changes are the results of complex interactions such as policy, management, economics, culture, human behavior, and environment. The purpose of this study was to examine the impact of land use changes on surface water quality of river. This study integrated a decade of available land use and water quality data to examine relationships between land use changes and surface water quality. Both cross-sectional and longitudinal studies were conducted to evaluate the impact of land use on water quality of river. The study noted significant relationship between water quality and land use and the abilities of land use indication to explain water quality. Urban and agriculture land uses had strong positive relationship with concentrations of water pollutants. Forest land use had positive relationship with water quality. The results identified the clear relationship between land use and the water quality indicators which can be used in environmental protection and land use planning. The findings of this study will be useful for policy makers, planners, and researchers to unveil the pollution, to adapt environmental and land use polices for sustainable development of river basin.

Key words: Land use; River basin; Sustainable development; Water quality

1. Introduction

Land use and water resources are unequivocally linked. The types of land and the intensity of its use have a strong influence on receiving water resource [1]. Whether the source is natural or results from human activities, the impact of any land use practices on either the quantity or quality of water can be substantial [2]. Changes in land use and land management practices are primarily responsible for the alteration of receiving water quality [3].

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As water drains from the land surface, it carries the residues from the land. As a result, the quantity of water available for runoff, stream flow and ground water flow, as well as the physical, chemical, and biological processes in the receiving water bodies can be affected [4]. It is, therefore, conceivable that there is a strong relationship between land-use types and the quantity and quality of water [5].

An increasing population, developmental pressures, lack of land use planning, and competition for water resources, continually contribute to the degradation of water resources [6]. Agricultural areas occupying larger portion of landscape are one of the important sources of pollution when rainfall carries sediment, nutrients, or chemicals to streams [7]. Urban development causes substantial modification to flood runoff timing and volume as well as to water quality. Urban areas are rapidly changing entities, shaped by a range of local and global forces often beyond the control of local plans and planners [8]. Sustainable basin development has become widely recognized goal for human society as deterioration of environmental and social conditions in many areas of the world continues [8]. Sustainable development means taking care of ecological, social, and economic aspects of development. It includes the conservation of resources for the future generation. The lack of sustainable environmental based planning leads to degradation of environment [9]. Land use affects the quality of water bodies to a great extent. The relative impact of different types of land use on the water quality need to be ascertained and quantified [10].

Present study was carried out to use river-basin based approach to examine possible statistical and spatial relationships of land use on the quality of surface water. This study addressed water resources and associated land uses by exploring the interrelationships between human activity on the land and its impact on water quality.

2. Data Collection and Methodology

2.1. Study area

U-tapao is a sub-basin of Songkhla lake basin located at southern part of Thailand. The basin is about 60 km long from north to south, and 40 km wide from west to east, and total coverage is about 2,305 square kilometers (Fig. 1). Climate of basin is influenced by two seasonal monsoons as well as tropical depressions. The south-west monsoon lasts from May to October and the north-east monsoon lasts from November to January. The average annual runoff at Hat-Yai, which is located the lower part of basin, is 385 mm (25 m^3/s) with a pronounced seasonal variation with minimum flows in April-May and maximum in November-December. Under continuous economic and social developments, natural resources and environments in the basin have been affected significantly. The forested and large-scale paddy areas have been converted mainly into large scale rubber plantation and human settlements. These changes have impacted negatively on the ecological integrity and hydrologic processes in the basin [11].

U-tapao river, the most important river in the basin is 68 km long and approximately 3–8 m deep. This river originates from Bantad mountain and flows through Hatyai municipality before emptying into the outer part of Songkhla Lake. The discharge ranges from less than 6 m^3/s in the dry season to more than 90 m^3/s in the rainy season. Like other rivers, U-tapao is affected from point and non point sources pollution of the basin. Major sources of waste discharged into the U-tapao river are from rubber, parawood, and seafood processing industries at the rate of 41,000 m^3/day. The effluents have high organic contents. Water resources within the U-tapao river basin have become degraded due to high population growth rate and changes in land use patterns [12].

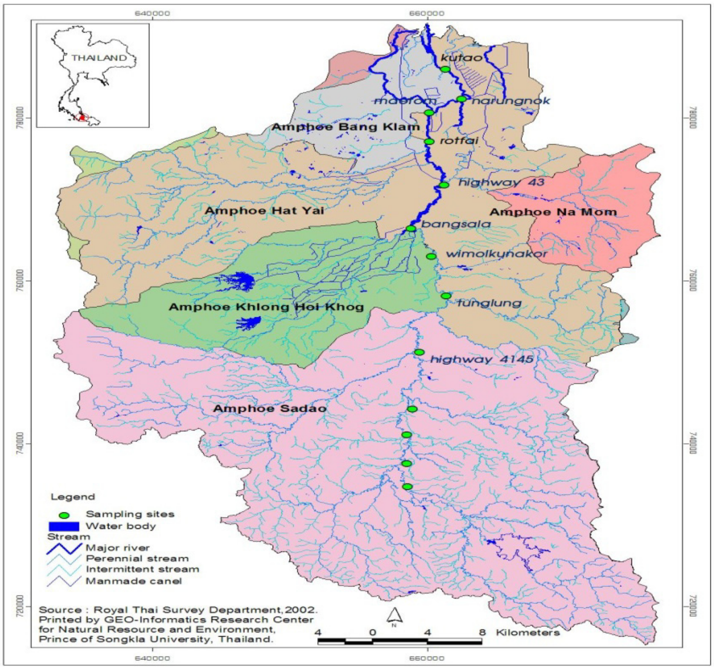

Fig. 1. Boundary of U-tapao river basin and water quality sampling sites

2.2. Materials and methods

Both statistical and geographic information systems (GIS) analyses were employed to examine the statistical and spatial relationships of land use and the water quality in receiving water on a regional scale. In this research, ArcView GIS was used to aggregate, synthesize and analyze large databases, and to identify spatial relationships (Sliva & Williams, 2001).

Water quality data from the year of 2001-2010 were collected from existing monitoring framework done by the Regional Environment Office 16, Songkhla. Water quality monitoring stations were located at nine sites throughout the U-tapao river basin (Fig.1). The water quality parameters for this study were temperature (TEM), pH, electrical conductivity (EC), suspended solid (SS), biological oxygen demand (BOD), and dissolved oxygen (DO). Four types of land use were analyzed; forest, agriculture (rubber plantation, paddy field and shrimp farm), urban (residential and industrial), water body (lake, river, wet-land and reservoir). Digital data of land use were obtained from Southern Remote Sensing & GIS Centre, Thailand. The descriptive statistics were used to explain land use and water quality parameters. Pearson's correlation coefficient was used to examine the strength and significant of the relationships among land use and water quality parameters. One-way ANOVA was performed at 5% level of significant to test whether mean values of water quality parameters of different monitoring stations vary or not [13].

3. Results and Discussion

3.1. Results

Overall, the study area was dominated by agriculture land use (more than 75%) and less than 13% land use was forest. Mean and standard deviation (SD) of temperature of U-tapao river was 27.71 ^{0}C and 0.66 ^{0}C and minimum and maximum values were 26.2 ^{0}C and 28.9 ^{0}C, respectively. Similarly, mean and SD of pH value of river was 6.83 and 0.19. Mean and SD of SS were 55.19 mg/L and 3.14 mg/L and minimum and maximum values were 11 mg/L and 151 mg/L, respectively. Mean and SD of BOD were 2.46 mg/L and 0.57 mg/L and mean and SD of DO were 3.68 mg/L and 1.08 mg/L. Water quality parameters like TEM, EC, SS and DO showed significant difference on spatial level ($p < 0.05$) (Table 1). In addition, water quality parameters of river were found to be changing on different time interval (Table 2) with significant difference for temperature, pH, EC, BOD, and DO ($p < 0.05$) except for SS.

Table 1: Mean and Standard deviation (SD) of water quality parameters (WQP) of nine monitoring stations

WQP		Monitoring Stations									F	p
		I	II	III	IV	V	VI	VII	VIII	IX		
TEM	Mean	28.04	27.88	27.95	27.86	27.91	27.65	27.63	27.47	27.04	2.20	0.03
	SD	0.55	0.59	0.60	0.50	0.69	0.72	0.70	0.65	0.58		
pH	Mean	6.76	6.78	6.82	6.82	6.85	6.88	6.85	6.88	6.84	0.41	0.90
	SD	0.20	0.18	0.26	0.21	0.18	0.17	0.17	0.13	0.16		
EC	Mean	4304.0	488.0	289.0	204.00	197.00	213.00	221.00	215.00	129.00	2.84	.000
	SD	529.00	404.2	213.2	77.30	71.30	81.60	76.70	75.90	23.30		
SS	Mean	30.80	24.79	31.53	33.91	31.62	19.17	25.61	18.47	37.69	5.28	0.00
	SD	10.28	8.26	10.51	11.30	10.54	6.39	8.53	6.16	12.50		
BOD	Mean	2.51	2.56	2.34	2.50	2.74	2.33	2.53	2.70	1.93	1.66	0.12
	SD	0.39	0.49	0.56	0.37	0.63	0.50	0.70	0.69	0.58		
DO	Mean	4.21	2.96	2.86	3.30	4.30	3.88	3.38	3.86	4.28	9.85	0.00
	SD	0.44	0.94	1.00	0.89	0.52	1.00	1.61	1.03	0.87		

Note: Monitoring stations: I-Kutao, II-Narungnok, III-Maetom, IV- Rotfai, V-Highway 43, VI-Bangsala, VII-Wimolkuanakorn, VIII-Tunglung & IX-Highway 4145

For the case of water quality parameters of U-tapao river basin, some parameters of water quality showed the relationship to each other (Table 3). Negative relationship between water temperature and pH value (r= - 0.30, $p < 0.01$) and positive relationship between water temperature and conductivity (r = 0.22, $p < 0.05$) were detected. For SS, negative relationship with temperature and positive relationship with pH value and BOD were found. BOD showed negative relationship with DO (r = - 0.23, p< 0.01). So, it can be referred from these results that there exist relationships among or within water quality parameters of river in spatial and temporal basis.

Table 2. Mean and Standard deviation of water quality parameters from 2001 to 2010

WQP		Year									F	p
		2001	2002	2004	2005	2006	2007	2008	2009	2010		
TEM	Mean	27.85	28.48	28.63	28.08	27.31	27.50	27.63	26.80	27.12	26.148	0.001
	SD	0.32	0.46	0.32	0.25	0.18	0.46	0.27	0.34	0.44		
pH	Mean	7.00	6.85	6.60	6.90	6.63	6.66	6.83	6.93	7.11	30.102	0.001
	SD	0.05	0.14	0.07	0.10	0.05	0.08	0.11	0.05	0.13		
EC	Mean	120.0	169.0	414.0	195.0	807.0	315.0	196.0	184.0	585.0	9.066	0.001
	SD	13.72	416.80	534.78	428.92	193.34	238.69	28.22	126.58	935.42		
SS	Mean	49.11	43.33	35.66	41.55	79.55	61.66	33.22	47.66	105.0	0.913	0.513
	SD	19.2	31.33	20.50	6.04	16.44	40.20	29.90	14.90	9.72		
BOD	Mean	2.40	2.57	2.54	2.32	2.23	3.31	1.90	2.23	2.64	6.189	0.001
	SD	0.36	0.70	0.44	0.70	0.36	0.38	0.42	0.37	0.28		
DO	Mean	4.21	2.96	2.86	3.30	4.37	3.88	3.38	3.86	4.28	3.016	0.006
	SD	0.44	0.94	1.08	0.89	0.52	1.00	1.61	1.03	0.87		

Analyzing the average changing land use area (in percentage) from year 2001 to 2010 of basin with average values of water quality parameters of river, the results indicated that land-use types were significantly correlated to many water quality variables in the basin (Table 4). For example, SS and BOD had positive relationships with agriculture (r = 0.61, $p < 0.05$ & r = 0.59, $p < 0.01$) and urban-build up land (r = 0.58, $p < 0.01$ & r = 0.44, p < .01) and they were also negatively related to forest (r = -0.46, $p < 0.05$ & r = -0.68, $p < 0.01$) and water body (r = -0.32, $p < 0.01$ & r = -0.23, $p < 0.01$). Agriculture and urban-build up land had negative relationship with dissolved oxygen (r = -0.31, $p < 0.01$ & r = -0.25, $p < 0.01$) where as forest and water body had positive relationship with dissolved oxygen (r =0.24, $p < 0.01$ & r = 0.31, $p < 0.01$). In addition, forest land use had negative relationship with pH (r = - 0.23, $p < 0.01$).

3.2 Discussion

Over the last ten years, the combination of different factors affected the water quality of U-tapao river and turned it into a polluted unnatural habitat and altered ecosystem. Among the factors that polluted the river, the most important ones are: rapid, unplanned urban and industrial expansions; domestic and industrial waste discharged into the river; agricultural pollution, and other non-point resources such as run-off from streets and highways [8]. As per the current water quality standards, the water of U-tapao river does not fall on drinking water quality standard and can be regarded as a polluted river in terms of many parameters like temperature, pH, conductivity, SS, BOD, and DO [4].

There are a wide variety of industries on the side of river (i.e., rubber, food processing, wood etc.). Liquid wastes from most of these industries are being directly discharged into the river without proper treatment. Obviously, the river has been adversely affected by these discharges. Based on the result of this study, pH values in all of the nine sites were deviating from neutral pH value towards slightly acidic (pH < 7) which is not good for aquatic life. The highest EC was recorded in monitoring site I which is located nearby the Songkhla Lagoon. Average DO of the basin was 3.68 mg/L with range 4.4 mg/L (maximum 5.9 mg/L and minimum 1.5 mg/L). DO is an indicator of a water body's ability to support aquatic life; hence, it is essential for good water quality. Its amount is directly related to the population size and community of aerobic bacteria the aquatic system can support. Generally, DO > 5 mg/L is considered favorable for growth and activity of most aquatic organisms; DO < 3 mg/L is stressful to most aquatic organisms, while DO < 2 mg /L does not support fish life [14]. Evaluating, the mean concentration of DO at nine sites, some areas of basin showed the stressful condition of aquatic life.

Table 3. Correlation matrix of water quality parameters

WQP	TEM	pH	EC	SS	BOD	DO
TEM	1					
pH	-0.30**	1				
EC	0.22*	-0.10	1			
SS	-0.50*	0.30**	-0.15	1		
BOD	0.13	-0.40	-0.07	0.27**	1	
DO	-0.68**	0.27**	-0.10	-0.9**	-0.23**	1

* p < .05,** p < .001

Results from the correlation analyses indicated that land-use types were significantly correlated to many water quality variables in the U-tapao river basin. Agriculture and urban land uses had positive correlation with SS and BOD and negative correlation with DO. But, forest and water body land uses had negative relationship with SS, BOD and pH and positive correlation with DO. It indicated that the percentage of increment of urban-build up land decrease the water quality of river and similarly, the percentage of increment of agriculture land use also decrease the water quality of river. The percentage of increment of forest and water body improves the water quality of river. Therefore, the results indicate that the land uses of river basin are very much linked with water quality of river. So, the policy maker should give proper attention on these issues for environment based land use planning of river basin.

Table 4. Correlation analysis on water quality variables and land use types in U-tapao river basin

WQP	Land-use types			
	Agriculture	Forest	Urban	Water body
TEM	-0 .29	-0.06	0 .07	-0.05
pH	0.03	-0.23**	-0.12	-0.16
EC	-0.07	0.00	0.22	-0.00
SS	0.61*	-0.46*	0.58**	-0.32**
BOD	0.59**	-0.68**	0.44**	-0.23**
DO	-0.31**	0.24**	-0.25**	0.31**

*p<.05, **p<.001

4. Conclusions

The results unequivocally showed that land uses were related to many of water quality parameters. These relationships were evident in a regional scale (U-tapao basin), both statistically and spatially. If land use changes in the future, the levels of contamination will be changed accordingly. Hence, future land development and management should be considered with care. This is especially the case if the land is going to be changed to agriculture or impervious urban lands. The pollution of the U-tapao river is mainly from the agriculture and urban-build area of the basin.

The study exhibits the importance of environmental based land use planning. Planners and policy-makers at different levels should bring stakeholders together, based on the understanding of land use and water quality relationship in a basin level to prevent pollution from happening and to plan for a sustainable future. To find the clear relationship between land use and water quality, it is recommended to adjust more water quality parameters and use sub-basin approach for analysis.

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