A Case Study on the Correlation between Land Use Types and Water Quality of the Bang Pakong River in Chachoengsao Province, Thailand

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Abstract. Multiple human activities, like as urbanization, industrialization, and agricultural endeavors, are modifying the land use in Bang Pakong River, Chachoengsao Province, as a result of the rapid population rise. These land use changes in the province of Chachoengsao have led to the discharge of pollutants into the river. This study intends to evaluate the connection between land use changes and water quality in the Bang Pakong River's upstream (US), middle stream (MS), and downstream (DS) regions. GIS and statistical analysis were utilized to assess the relationship between land use change and the quality of the Bang Pakong River, including dissolved oxygen, total phosphorus, biological demand oxygen, and turbidity. The classification of land use types into five groups included urban land, agriculture, forest, water body, and miscellaneous land. The Spearman correlation was utilized to determine the relationship between land use changes and river water quality. Monitoring of water quality revealed a decline in the quality of the BPKR, which flows through the Chachoengsao Province, from 2008 to 2018. Changes in the land use of water bodies and forests have a positive effect on the water quality of middle and downstream streams. The land uses identified as important sources of total phosphorus and turbidity contamination in water were reduced in the forest and miscellaneous regions of the BPKR's upstream and middle streams. The transformation of agricultural land has an adverse effect on the water quality of middle stream. The results revealed that the conversion of forested land improved water quality, particularly the concentration of dissolved oxygen upstream. Furthermore, the findings provide a mechanism for evaluating river water quality, mitigating water pollution, and optimizing land use by utilizing landscape patterns.

Keywords: Land Use; Land Cover; Water Quality; Bang Pakong River; Water Contamination.

1. Introduction

Flowing eastward for 122 kilometers before emptying into the Gulf of Thailand, the Bang Pakong River (BPKR) is a major waterway in the eastern Thailand. The BPKR provides domestic water for urban areas, household consumption, industrial as well as agricultural activities. The contamination of surface water sources by a variety of anthropogenic factors, such as increased population, industrialization, cultivation, and an inadequate sewage treatment system, poses a significant risk to both human health and the environment [1]. Among these existing conflicts, natural factors such as seawater intrusion, riverbank erosion and flooding are also affecting the water quality of the BPKR river. Since the turn of the last century, the Thailand Eastern Seaboard Development Programme (ESDP) in the Bang Pakong River basin has been responsible for a significant increase in the amount of urbanization, industry, and infrastructural development. The flow of pollutants into the river in the Chachoengsao Province is a direct result of the types of land use changes described above. For instance, both treated and untreated wastewater from domestic, agricultural, and small to medium-sized industrial sources was also released straight into canals [2]. The high percentage of organic matter that is found in domestic sewage can add to the turbidity of water and reduce the amount of dissolved oxygen that is present in the water.

According to the research from Silva et al. [3], industrial and urban areas have the highest concentrations of organic pollution, as well as heavy metals and nutrients in waterways. In addition, it was discovered that farmhouse and paddy fields are responsible for roughly 70 percent of the feed, fertilizers, and nutrients that are introduced into the BPKR catchment areas [4]. Kupkanchanakul and Kwonpongsagoon [5] estimated that the total amount of wastewater generated by farming that has an impact on the water quality of the BPKR is roughly five million tons per year, which includes 1,030 tons of phosphorus and 3,250 tons of nitrogen. In the year 2020, Gorgoglione and her colleagues found that there was a correlation between the concentration of nutrients and the uses of build-up areas. Meanwhile, they also suggested that there is a significant connection between the levels of total phosphorus and the activities of agriculture. Oppositely, it has been shown that there is an inverse link between the forest in the catchment area and the overall amount of phosphorus in the water [6], Chen et al. [7] conducted the unanimous conclusion, a greater proportion of forest cover cloud improve water quality. Despite the fact that a report on the impact of changes in land use (LU) on the water quality in the BPKR river basin was published in 2018 [8]. There has never been an investigation into the potential long-term consequences of changes in land use and land cover on the water quality of the BKPR, which is a river that runs through Chachoengsao Province. As a result, this study was carried out in order to investigate the connection that exists between shifts in land use and variations in the quality of the water in the Bang Pakong River's upstream (US), middle stream (MS), and downstream (DS) areas. Furthermore, determining the relationship between land use and water quality is essential because it helps in the development of comprehensive management strategies and policies to mitigate the negative effects of land use change on water quality.

2. Methodology

2.1 Study Area

The Bang Pakong River Basin encompasses 10,707 km^2 and flows into the Gulf of Thailand.The research region, the main Bang Pakong River that flows through Chachoengsao Provinces, has a total length of 122 kilometres and an elevation range between 0 and 20 metres above sea level. In 2013, the estuary of the Bang Pakong River encompasses a total area of 12,382 ha. Nearly half of the land area is devoted to agricultural use, followed by areas for urban and construction use (28.6%), forest area (11.7%), water bodies (8.4%), and miscellaneous land (1.7%). In 2019, there are 201,858 people that live in riverside communities. Eleven water quality monitoring stations were divided into three categories: US (BK11,BK13, BK15), MS (BK04, BK06, BK07, BK08, BK09), and DS (BK01, BK02, BK03) based on their location along the river's path (Figure 1).

2.2 Data Collection

The water quality data including dissolved oxygen (DO), total phosphorus (TP), biological oxygen deamod (BOD) and turbidity (TUR) of the BPKR which was monitored during 2008 to 2018 was obtained from the Pollution Control Department (PCD), Thailand. In addition, the data on the annual land use changes of the same timeframe as the water quality data was obtained from the Land Development Department (LDD). The data of land use was presented every three years

2.3 Date Analysis

In this analysis, it was assumed that the primary sources of contamination in the BPKR were 10 kilometers distant from the river, with all potential contaminating variables accounted for, hence preventing or minimizing future pollution. The data was further reclassified using ArcGIS 10.2 into five major classes, different types of LU were considered including urban and built-up land (U), agriculture (A), forest (F), water body (W), and miscellaneous land (M). Buffer zones (10 km) were created by ArcGIS, the areas of five different land use types are demonstrated in Figure 1. Regarding to the water quality data obtained from 11 monitoring stations (Figure 1), the locations of monitoring stations were classified into the upstream (US) zones, middle stream (MS) zones, and downstream (DS) zones of the river. The descriptive statistics of four water quality parameters were calculated using SPSS 22. The statistics accounts for annual averages and standard deviations of water quality dataset (2008-2018). The annual acreage (km^2) of each land use type was also estimated. Analysis of variance (ANOVA) was performed to examine significant ($p<0.05$) variances between WQ parameters and different streams of river. Following the method suggested by Tian et al. [2019], Spearman correlations were used to determine the effects of different land use types on water quality. The p value of 0.05 was considered statistically significant (Sig. 2-tailed).

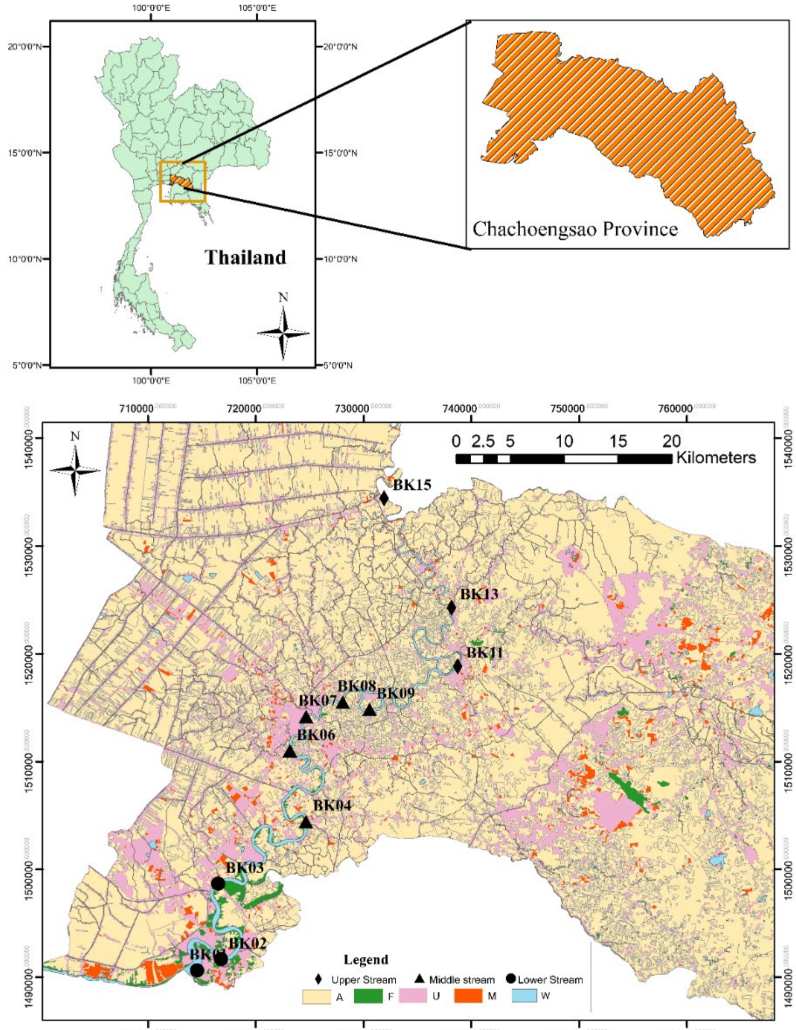

Figure 1. The location of the Bang Pakong river in Chachoengsao Province and the water quality monitoring sites along the river

3. Result and Discussion

3.1 Land Use Change (2008-2018)

The cover areas (km^2) of the five land use types have been computed and changing proportion of each land use types has been summarize in figure 2. Due to the fact that the statistics do not alter each year, they are reported every three years, nevertheless, there are some distinctions between 2008 and 2018. According to the data, agricultural land (i.e., paddy fields, orchard, and farmhouse) account for the biggest percentages of the total area within the upstream, middle stream and downstream zones. The proportion of agricultural land in 2008 is 86.85% and it decreased to 83.11% in upstream. The proportion of agricultural land declined from 2008 to 2018 in both upstream and downstream of the BPKR, whereas it increased 73.7 km^2 from in middle stream zones. In addition, the areas of build-up land (i.e., city, village, industries) have declined in middle stream and upstream and expanded in downstream from 52.64 km^2 to 70.59 km^2 (2008-2018). The forest land (mangrove)showed the smallest portion and enhanced with a slow trend (0.997 km^2 in US, 2.6928 km^2 in MS) in middle stream and upstream. It is statistically possible that the area of water sources is in a positive state of growth during the study years for all streams of the BPKR. The area of miscellaneous land (i.e., rangeland, marsh and swam) raised sharply in upstream, from 7.747 km^2 to 30.362 km^2, and it also increased 23.5 km^2 at middle stream in 2018. According to the results of the study, the receding agricultural area in the middle and lower reaches is an important factor, which contributes to the increase in construction land.

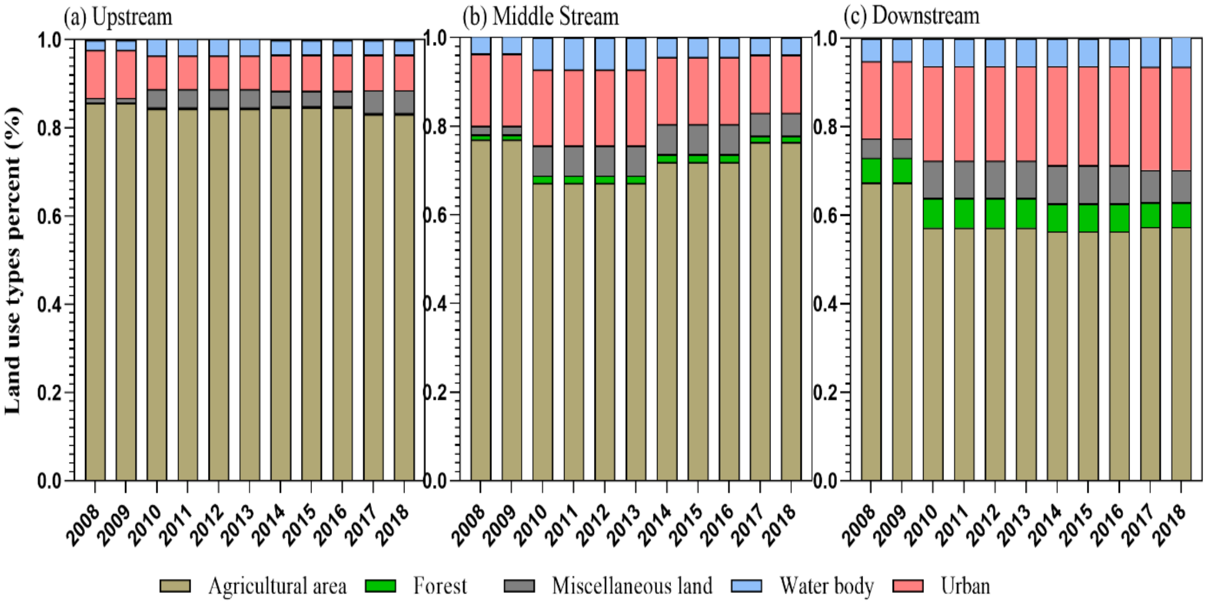

Figure 2. Percentages of land-use types from 2008 to 2018 along the river

3.2 Characteristics of Water Quality

Overall, the notable spatial-temporal variations in all water quality parameters of interests were found (Figure 3). There is not significant difference between DO and different stream ($p > 0.05$). The concentration of dissolved oxygen has showed similar changing trend in all streams but DO has higher concentration at middle stream and upstream zones, but in 2018, DO level below the WQ Standard of Thailand (4 mg/L). Figure 3(b) showed that downstream has a great level in TP than other zones of the river. There was a significant difference between TP concentration and river streams ($p < 0.01$). It is interesting to observe from Figures 3(a) and 3(b) that the concentration of DO decreases as the concentration of TP increases. The reverse relationship between DO and TP was found and was in good agreement with Tahiru et al. [9] who found the low DO concentration at any sampling site with high levels TP. The more organic compounds that contaminate a water body, the more oxygen is used to degrade them, lowering the dissolved oxygen level in the water [10]. ANOVA analysis has revealed a significant difference between the middle stream and downstream of the river for BOD concentration. Higher level of BOD bacteria was found especially at the MD monitoring sites, as the BOD are derived from abundance of nutrients which are normally condensed in the built-up areas [6]. The proportion of urban land at the DS sites was found to be increased from 17.50% to 23.33% (2008 to 2018). A raising in turbidity was found since 2011 due to the discharge of sewage and sludge from factories and urban areas into BPKR [9,11]. However, the were not significant differences among the upstream, middle stream, and downstream of river. This phenomenon has been observed by Yadav et al. [6] who reported that high suspended particles were primarily from industry, and that domestic sewage, which has a high proportion of organic matter, might enhance turbidity. With a larger proportion of urban land in DS sites, TP concentration and water turbidity were higher than the sampling sites located at the MS (13.11%) and US (7.98%).

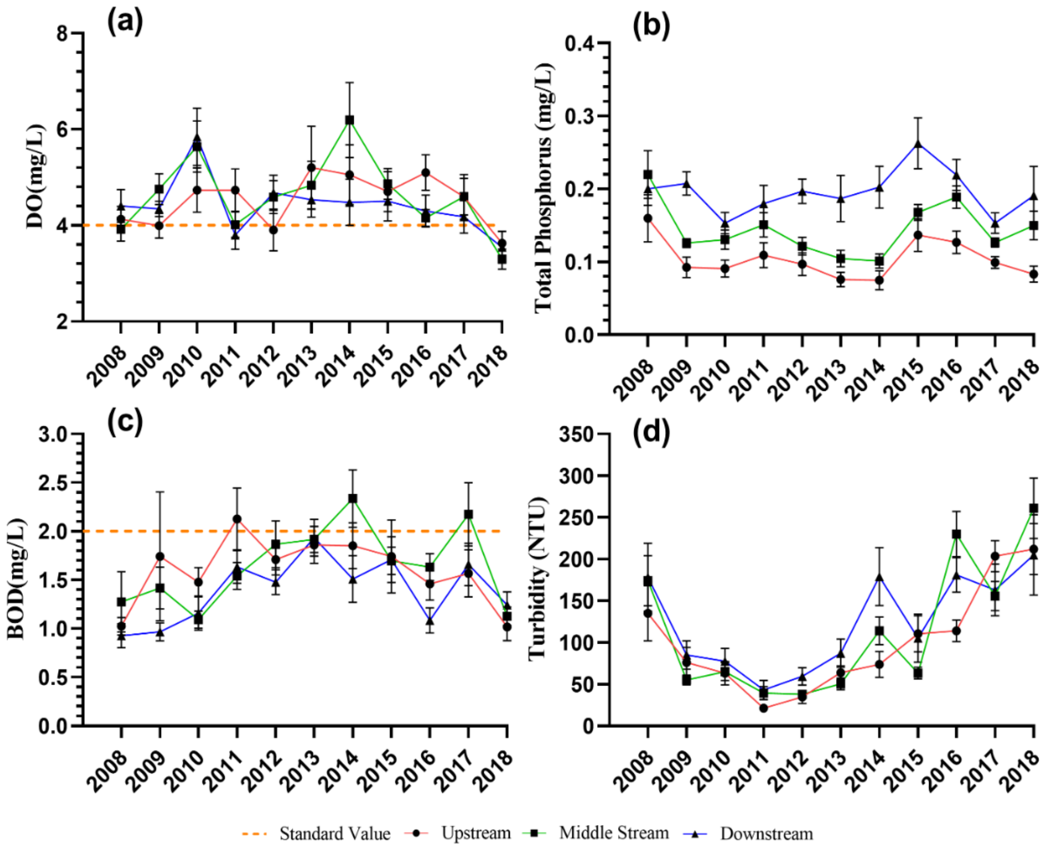

Figure 3. Annual water quality parameters among the upstream, middle stream, and downstream of river

3.3 Impact of Land Use on River Water Quality

The spearman correlations were used to determine the effects of different land use types on water quality. Table 1 summarizes the effects of land cover proportions on water quality of the BPKR. For TP, it presented significant negative correlations with miscellaneous land (M) upstream ($r = -0.577$, $p < 0.05$) and middle stream ($r = -0.595$, $p < 0.05$) sites. As the miscellaneous land area in the upper and middle stream grows, the concentration of total phosphorus is reduced. TP level also indicates a positive correlation with agricultural land and urban area in both upstream and middle stream. For turbidity, which indicates a significant positive correlation with the proportion change of agricultural land ($r = 0.644$, $p < 0.05$) at middle stream regions, and the significant negative correlations with portion of water body and forest land. In the middle stream of the river, the proportion of agricultural land has expanded and contributed the high level of turbidity. This has been comforted by Calderón Cendejas et al. [12], that agricultural activities had a detrimental influence on water quality in general, and there was a positive link between greater levels of turbidity and agricultural practices. A similar result has also been reported by previous studies for example Yadav at al. [6] indicated that agricultural activities had a detrimental effect on water and are positively correlated with increased turbidity levels. The actions will exacerbate soil erosion, while fertilizers and pesticides will introduce enormous amounts of nutrients into rivers via rainfall runoff, resulting in a decrease in river water quality, particularly for ammonia nitrogen and phosphate [7].

The forest land (F) in downstream also demonstrated a significant negative correlation with turbidity. This shows that the area of forest cover has a positive impact on water quality. Chen et al. [11] explained that forested areas with a high level of vegetation cover, rapid purification, interception and dilution, fewer human activities, and beneficial environmental circumstances in general. Forest area contributes significantly to soil erosion reduction, intercepting solid pollutants, and diluting pollutant concentrations. These are in accordance with Tahiru et al. [9] who found that forest can minimize the turbidity of water by lowering riverbank erosion. Table 1 also shows a significant positive correlation between the level of DO with the proportion of forest land in upstream and downstream zones, but DO level demonstrates negative correlation (r = -0.597, $p<0.05$) with agricultural land at DS sites. This suggests that forest expansion in the upstream region has a large positive effect on dissolved oxygen levels and that forests are crucial for water quality. As a result, forest restoration in the riparian areas is an efficient strategy to protect water bodies from harmful pollutants and improve water quality, to improve aquatic ecosystems, minimize threats to human health, and lower the cost of water purification for human use.

In addition, BOD demonstrates a significantly negative correlation with agricultural land and a positive correlation with urban land. Tian et al. [10] found the similar result in 2019, which reposted BOD content was positively related to urban area in Mun River, Thailand. The growth of cities and building land has resulted in an increase in the discharge of domestic sewage and industrial wastewater, all of which have a significant impact on water quality. Loading bacteria pollution (total coliform bacteria, fecal coliform bacteria) and nutrients form construction area, industries, and villages might raise the BOD centration.

Table 1. Correlation between proportions of land use types and water quality parameters

Research area	**LU types**	**Water quality parameters**			
		TP	**Turbidity**	**DO**	**BOD**
Up stream	**A**	0.498*	0.074	0.009	-0.083
	F	-0.285	-0.658*	0.633*	0.535
	M	-0.577*	-0.074	-0.009	0.083
	U	0.476**	0.579*	-0.209	-0.382
	W	-0.356	-0.791**	0.398	0.552
Middle stream	**A**	0.421*	0.644*	-0.392	-0.259
	F	-0.205	-0.220	0.363	0.475
	M	-0.579*	-0.220	0.363	0.475
	U	0.68*	0.651*	0.263	-0.173
	W	-0.486	-0.723**	0.414	0.281
Down stream	**A**	-0.018	0.181	-0.597*	-0.619*
	F	-0.297	-0.740**	0.707*	0.209
	M	0.007	-0.195	0.609*	0.351
	U	0.620*	0.202	0.014	0.365*
	W	-0.311	0.202	0.014	0.621

Remark: * Correlation is significant at the 0.05 level.

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4. Summary

The pattern of land use has a substantial impact on the variability of key water quality metrics. Overall, this study validated the effects of land use changes on the BKPR's water quality. Between 2008 and 2018, the land use structure in the study area changed substantially, with a notable decline in agricultural and urban land in the upstream and an increase in urban land in the downstream. In the meantime, the area of unclassified land, water bodies, and forest land grew in all three streams. From 2008 to 2018, the water quality of the BPKR in Chachoengsao Province decreased moderately along its watercourse. The types of land use that were identified as major contributors to total phosphorus and turbidity contamination in the water were reduced in the forest and other sections of the BPKR's upstream and middle stream. The increase of unclassified land demonstrated a negative connection with the total phosphorus concentration in both upstream and downstream regions. Due to an increase in agricultural land in the river's middle stream, turbidity and TP contamination have increased. Changes in forest regions upstream have a significant effect on water quality. Additionally, the increase in water body area in middle stream areas and the growth in forest land in downstream areas have a good impact on water quality indicators.

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