Human Activities and Land Cover Effect to Stream Water Quality of Chanthaburi River, Thailand

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Abstract

Understanding human activities and land cover influence on stream water quality is critically important for river management and restoration. Chanthaburi River is the main river of Chanthaburi Watershed, which is important for domestic use, irrigation and cultivation, is effected by various land cover along its River. Human activity have a significant influences on the acceleration or deceleration of pollution rate at the source, therefore, in dealing with non-point source pollution, the challenge is to identify activities that result in significant degradation of stream water quality. The study was conducted within stream water tributaries to Chanthaburi River in Chathaburi watershed. The aims of this study was to investigate human activities and land cover effect to stream water quality. Water samples, collected during dry and wet seasons at locations chosen on the basis of their dominant land cover, physical, chemical and biological contamination were analyzed.

The results revealed Human activities and land cover had major effect to stream water quality of Chanthaburi River. Our results suggested that urban land cover had significant affect water quality in the study area. DO, BOD, NO_3-N, NH_3-N and PO_4^{-3}-P parameters showed significant variation on spatial. Result also confirmed that streams water quality of River is polluted due to human activities in urban areas influent. This confirmation was attributed to the values of NO_3-N, NH_3-N and PO_4^{-3}-P TCB and FCB which were substantially high from dry to wet season of stream water in urban area.

Keywords: Human Activities, Land Cover, Stream Water Quality, Chanthaburi River

1. Introduction

Water quality degradation is one of the most uninterrupted, and in most cases, visible signs of human effects on the natural environment. Water quality comprises the physical, chemical, and biological characteristics of a water body. The water body acquires these characteristics from a suite of complex interactions among the water, atmosphere, soils, and lithology. The deterioration of water quality due to unsustainable human activities has become a key environmental concern. Human activities affect both water quality and quantity. Human activities change land cover, which changes the water balance and usually changes the relative importance of processes that control water quality.

The health of the stream waters, rivers and lakes can be directly related to the type of land cover and associated land use in watershed. Initial waters are associated with mainly undisturbed forested watersheds. The level of impact on water quality becomes higher as land uses intensify through the activities of agriculture, timber harvesting, residence, industry and recreation. Human activities can affect water quality directly and indirectly. Direct effects are those that change water quality through the addition of some chemical constituent, physical characteristic, or biological component. The discharge of wastewater to a stream directly affects the stream chemistry, the application and leaching of fertilizer affects surface water (Norman 2005).

Chanthaburi River is the main river of Chanthaburi watershed is a located in Chanthaburi province, which is important for domestic use, irrigation and cultivation, is effected by various land cover along its River. Land cover in Chanthaburi watershed including urban and built-up, agricultural, forest, water body and miscellaneous. The different types of land cover were tested to analyze their effects on the stream water quality. Human activity have a significant influence on the acceleration or deceleration of pollution rate at the source, therefore, in dealing with non-point source pollution, the challenge is to identify activities that result in significant degradation of stream water quality of Chanthaburi River.

The important issues that effect on stream water quality is affected by human interference related to urbanization and settlement pattern may also impact on water quality in urban stream (Paul and Meyer, 2008). Nevertheless, agricultural, which is the important driving factor to land cover, spread through the natural forest area for long time (Chatewutthiprapa 2017). The impact of land use land cover on the stream water quality variability are important sustainable development of Chanthaburi province (Soytong, Janchidfa et al. 2016) . Knowing the influence of human activity and land cover on stream water quality of watershed is critically important for river management and restoration.

This research is motivated by the fact that human activities such as rapid urbanization, intensive agriculture, and deforestation have increased land cover changes and their effects on stream water quality of Chanthaburi River. Therefore this research was investigated human activity and the spatial of land cover effects on stream water quality of Chanthaburi River. Knowing the key of human activity and land cover type that effects on stream water quality, as well as to visualize the major source and process of water quality pollution in Chanthaburi River and benefit to proper river management and restoration

2. Materials and Method

2.1 Study Area

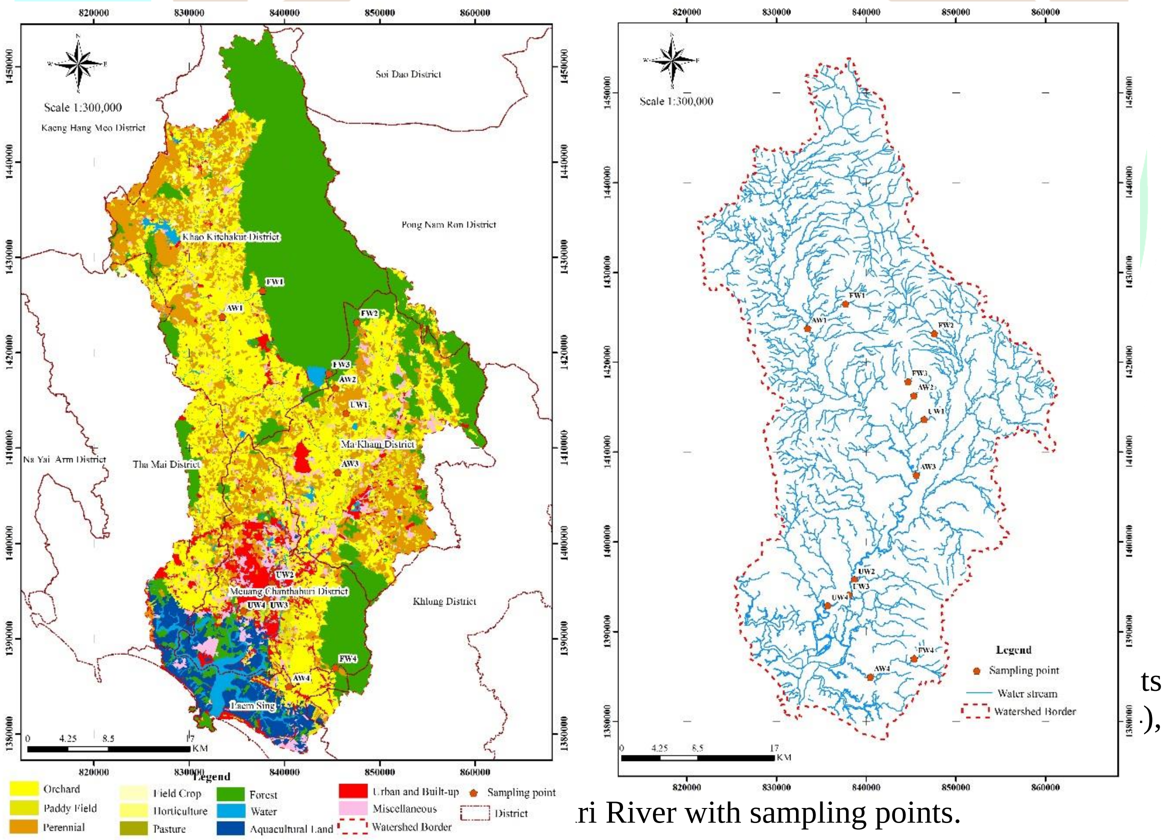
The study was conducted within stream water tributaries of Chanthaburi River, which is significant due to the presence of forest, agriculture and urban in Chanthaburi watershed which located in Chanthaburi province. It is in the eastern part of Thailand. Chanthaburi River is the main river of the watershed that originated from Khao Soi Dao, flowing through various communities and finally discharging into the sea at Ban Pak Nam, Laem Sing District, which is important for domestic use, irrigation and cultivation, is effected by various land cover along its River.

2.2 Land Cover Analysis

The land cover information was based on a digital land use map for 2018 provided by Land Development Department (LDD). According to the original land use map included 70 classes. In order to simplify and facilitate the statistical analysis, we regrouped them into 11 classes including forest, urban and built-up, miscellaneous, water and agriculture including paddy field, field crop, perennial, orchard, horticulture, pasture, aquaculture land. The spatial analysis was conducted in ArcMap 10.4 software (ESRI, Redlands, CA, USA), as well as were employed to map the land cover type of Chanthaburi watershed.

2.3 Water Sample Collection

Water samples were collected at twelve sampling points of stream water tributaries of Chanthaburi River with following dominant land cover including forested areas, agricultural areas and urban areas, as they are prominent areas where water quality was likely to be affected by land cover and human activities. Selection these sampling points were examined for dominant land cover and socio-economic activity, using Google Earth image and field observations before sampling sites were chosen. The samples were collected at the depth of 0.3 m below the water surface. The water samples were collected during both seasons, the dry season (March 2020) and the wet season (July 2020). Physical, chemical and biological quality were tested. Water sampling points are shown following in Figure 1.



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2.4 Water Quality Parameters Analysis

The water quality parameters were chosen to be measured, which are important indicators of water pollution influenced by anthropogenic activities. Water temperature (TEM º C) and electrical conductivity (EC, µs·cm) were measured in situ using conductivity meter, dissolved oxygen (DO mg/L) was measured in situ using a portable oxygen. Other water quality parameters were analyzed in the laboratory. Biochemical oxygen demand (BOD mg/L) were detected by azide modification, orthophosphate (PO_4^{3-}-P mg/L) were detected by molybdenum blue method, total kjeldahl nitrogen (TKN) was using kjeldahl method, nitrate (NO_3-N mg/L) was using cadmium reduction method, ammonia (NH_3-N mg/L) was measured using phenate method , total coliform bacteria (TCB) was detected by standard total coliform fermentation technique and fecal coliform bacteria (FCB) was detected by standard total coliform fermentation technique and thermotolerant (fecal) coliform procedure. The pretreatment and determination of the parameters in the laboratory followed standard methods for the examining water and wastewater, which were provided by American Public Health Association (APHA), American Water Works Association (AWWA) and Water Environment Federation (WEF) (APHA, AWWA and WEF, 23rd Edition, 2017). For seasonal variation analysis, all data were divided into categories: dry season and wet season. These were compared with water quality standards for surface water in Thailand (WQS), (PCD, 1994).

2.5 Statistical Analysis

Descriptive statistic were used to analyze the mean characteristic of stream water quality parameters. One way analysis of variance (ANOVA) was used to test spatial (sites) had any significant effect on the physical, chemical and biological water qualities. Principle component analysis was used to identify the sources of pollution. The 5% level of significance (or 95% confidence interval) was set for entire study. Statistical analysis was performed by using IBM SPSS Statistic for windows. (Version 20.0; SPSS Inc, Chicago, IL, USA) (Gu, Hu et al. 2019).

3. Results and Discussion

3.1 Land Cover of Chanthaburi watershed

The analysis showed that land cover of Chanthaburi watershed was mostly of agriculture is 53.74% of the total area, which including paddy field, field crop, perennial, orchard, horticulture, pasture, aquaculture land. Subordinate were forest, urban and built-up, miscellaneous, and water about 32.67% 5.45 %, 4.58% and 3.56% respectively, land made up the vast majority of total area. Percentage of land cover of study area are shown following in **Table 1**. According to land cover investigation can be divided the twelve sampling points into three groups of relatively similar sites to represent land cover parameters. Considering their dominant land cover types, the three point of groups defined as forest dominated points, agriculture dominated points and urban dominated points, which the vast majority of total area.

Table 1. Descriptive statistics for the land cover in Chanthaburi watershed

Land cover	Square kilometer (Km^2)	Percentage (%)
Forest	**528.22**	**32.67**
Agriculture	**868.96**	**53.74**
Paddy field	31.60	1.95
Field crop	7.08	0.44
Perennial	262.07	16.21
Orchard	495.72	30.66
Horticulture	1.82	0.11
Pasture	0.43	0.03
Aquaculture land	70.24	4.34
Urban and built-up	**88.04**	**5.45**
Miscellaneous	**74.04**	**4.58**
Water	**57.49**	**3.56**
Total	**1616.75**	**100.00**

The results of numerous comparisons indicated that there were variations in most of the stream water quality parameters between the urban land (UW) and forest land (FW) groups **(Table 2)** and **(Figure 3).** Even though most of the stream water quality parameters that were collected in the agricultural land (AW) had higher concentrations than those in the FW, no significant variations were detected, except NO_3-N in wet season. The mean values of NO_3-N in the UW were significantly higher than in the FW in the dry and wet seasons ($p < 0.05$). The concentration of DO in the UW was significantly lower than in the FW, during wet season ($p < 0.05$). While the mean concentrations of BOD and NH_3-N in the UW were significantly higher than in the FW ($p < 0.05$). In case of TEM, FCB and TCB, no significant spatial variations were detected. However the clearly indicated contamination of water quality parameters in the UW were TCB and FCB due to the mean concentrations of TCB and FCB in the UW reached 160,225.00 MPN/100 ml and 21,767.50 respectively, in the dry season, which a serious pollution problem as compared with the standard value class 3. Mean values of stream water quality parameters among forest-dominated sites (FW), agricultural sites (AW) and urban-dominated sites (UW) in the dry and wet season. The variance results of the *Duncan* tests among the three groups are indicated by the letters and significant difference ($P \leq 0.05$) are indicated by different letters (a-c) was shown in **Figure 3**.

Table 2. The Mean value of stream water quality parameters with the following dominant land cover during dry and wet season

Parameters	Forest		Agriculture		Urban		WQS (Class 3)
	Dry Season (Mean ± S.D.)	**Wet Season (Mean ± S.D.)**	**Dry Season (Mean ± S.D.)**	**Wet Season (Mean ± S.D.)**	**Dry Season (Mean ± S.D.)**	**Wet Season (Mean ± S.D.)**	
Temperature (° C)	27.00 ± 2.40	27.55 ± 3.24	27.83 ± 1.53	28.25 ± 0.33	30.43 ± 1.81	29.30 ± 0.28	-
EC (μs·)	40.53 ± 5.25	39.13 ± 10.31	83.08 ± 58.39	68.00 ± 25.54	38.40 ± 3.83	112.05 ± 44.44	-
DO (mg·L)	7.63 ± 0.75	7.93 ± 0.22	5.48 ± 1.85	7.00 ± 0.28	6.00 ± 0.58	5.30 ± 0.59	≥ 4.0
BOD (mg/L)	0.68 ± 0.45	0.50 ± 0.35	1.40 ± 1.19	0.28 ± 0.20	0.80 ± 0.48	0.80 ± 0.14	≤ 2.0
PO_4^{3-}-P (mg/L)	0.01 ± 0.01	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.02 ± 0.01	0.03 ± 0.04	-
NO_3-N (mg·L)	0.09 ± 00	0.09 ± 0.01	0.09 ± 0.00	0.16 ± 0.03	0.09 ± 0.00	0.14 ± 0.02	≤ 5.0
NH_3-N (mg·L)	0.00 ± 0.00	0.06 ± 0.00	0.08 ± 0.10	0.08 ± 0.01	0.18 ± 0.12	0.16 ± 0.01	≤ 0.5
TCB (MPN/100 ml)	22,672 ± 22,337	844 ± 783	11,875 ± 14,309	5,925 ± 3,925	160,225 ± 226,967	8,875 ± 10,195	≤ 20,000
FCB (MPN/100 ml)	1,205 ± 898	134 ± 219	1,433 ± 1,094	809 ± 1.073	21,767 ± 23,228	2,355 ± 3,699	≤ 4,000

Note: S.D. = Standard Deviation;

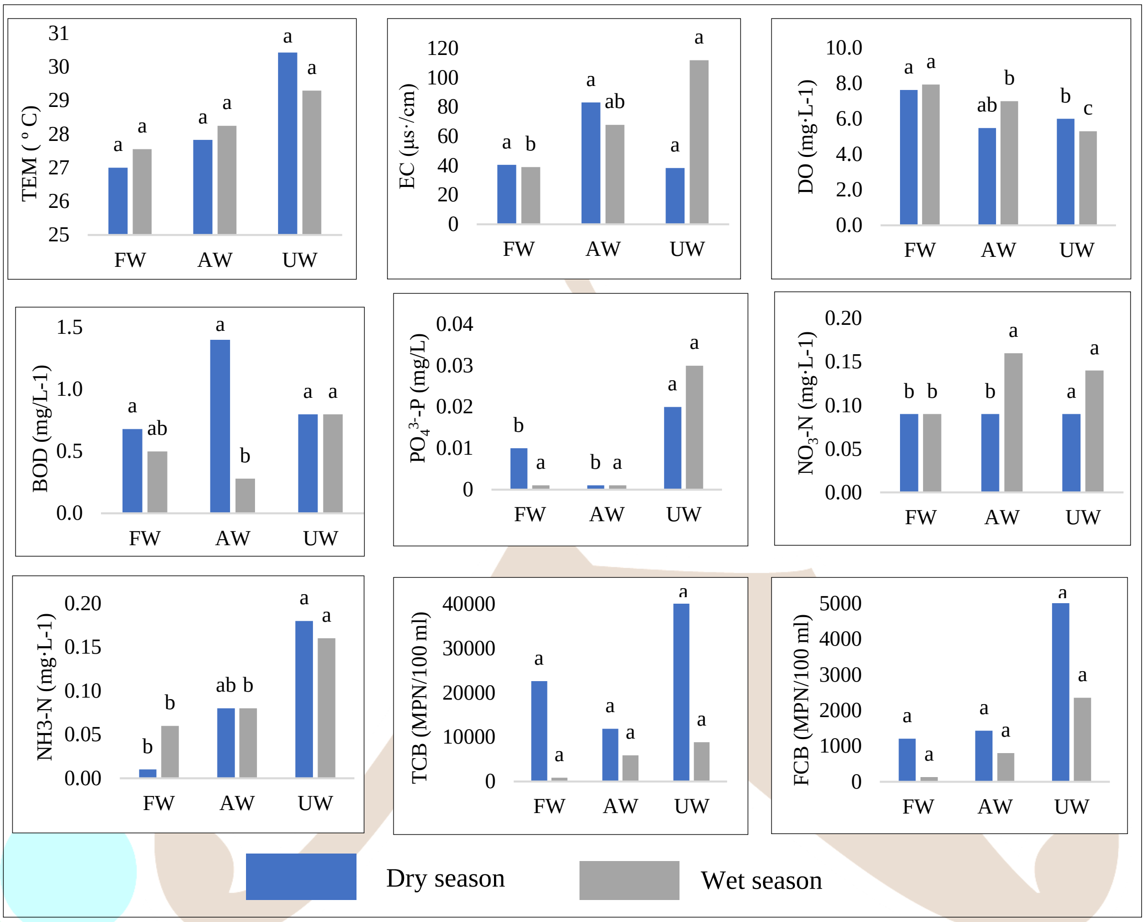

Figure 3. Mean values of stream water quality parameters among forest-dominated sites (FW), agricultural sites (AW) and urban-dominated sites (UW) in the dry and wet season. The variance results of the *Duncan* tests among the three groups are indicated by the letters and significant difference ($P \leq 0.05$) are indicated by different letters (a-c).

3.2 Effect of Land Cover on Stream Water Quality of Chanthaburi River

The variance analysis demonstrated urban land cover had a significant negative effects on stream water quality, while the forested land cover can benefit on water quality in the study area, as have been demonstrated by a number of studies (Ding, Jiang et al. 2015, Pullanikkatil, Palamuleni et al. 2015, Gu, Hu et al. 2019). The results showed that stream water quality in forested land were positively with higher concentration of DO compared to urban land cover in both seasons, indicating that forest was the most important land cover type influencing water quality. This is forest can significantly decrease pollutants discharge to stream water by intercepting water runoff, mitigating soil erosion, and increasing physical absorption (Dai, Zhou et al. 2017). As was the case of nutrient, a low concentration of PO_4^{3-}-P, NO_3-N and NH_3-N in forested land in both seasons might be the result of low human activities input and a high retention of nutrients in forest. In case of Total coliform bacteria (TCB) include bacteria that are found in the soil, in water that has been influenced by stream water, and in human or animal waste. Fecal coliform bacteria (FCB) are the group of the total coliforms that are considered to be present specifically in the gut and feces of warm-blooded animals. TCB and FCB were detected in forest land cover, where there are no human settlements upstream of sampling points. FCB were identified could be from wildlife in the forest due to those sampling points were characterized by evergreen forest. However, at sampling point FW1, FW2 and FW4, there are waterfall attractions and there are campgrounds and a few restaurants, including touristic activities such as swim, picnic, and walk around the forest areas and may defecate where there are no sanitation facilities available. This is cause of detected high concentration of TCB in forested land cover.

High input of nitrogen into the water streams from fertilizer in agricultural affects water quality, indicating higher concentration of NO_3-N in agricultural land cover during wet season when compared with other land use in study area **(Table 2) (Figure 3)**. This is source pollution from fertilizer runoff from agricultural land and households, domestic wastewater, due to the area around these sampling points were characteristic by mix orchard and a few residences. It reflects the conditions of drainage of intense agriculture. The results were corresponding to general observation in many regions (Zhang, Dudgeon et al. 2010, Calijuri, Castro et al. 2015, Pullanikkatil, Palamuleni et al. 2015). Although, NO_3-N loading in agricultural land were higher than other land use, but concentration value of NO_3-N were acceptable. Nevertheless, the results revealed that agricultural land cover in study area were lightly effect of the spatial variations on stream water quality of Chanthaburi River, which there were low concentration of pollution. Moreover, the influence of agricultural land on stream water quality depends on management practices. However, most of parameters in agricultural land were higher concentrations than those in forest land, despite the truth that no significant difference was gained. The effects of agricultural runoffs should not be overlooked.

Urban land cover had stronger effect on water quality compared to forested land and agricultural land. The influence of residential land cloud be attributed to point source and non-point source pollution associated with domestic sewage and discharge (Gu, Wang et al. 2015). The low concentrations of DO in urban in wet season may be attributed to the discharge of organic meter into the water body, due to located in municipal zone, represents the drainage from the district of Chanthaburi, which incomplete treatment. While mean value of BOD in urban was highest in wet season relate to significantly lowest mean value of DO in wet season. Such fact contributes to increase the organic matter content, which consumes DO during degradation (Calijuri, Castro et al. 2015). High input of orthophosphate and nitrogen into the stream water from wastewater in urban areas affects stream water quality (Zhang, Dudgeon et al. 2010). Urban land cover was identified as the strongest contributor of PO_4^{3-}-P, NO_3-N and NH_3-N in stream water of Chanthaburi River. This may have been highly influenced by point source, as well as non-point source pollution.

3.3 Effect of Human Activities on Stream Water Quality of Chanthaburi River

Our study suggested that most of the pollution sources were related to human activities, indicating high concentration of PO_4^{3-}-P, NO_3-N and NH_3-N in urban compared to other land cover in both seasons, except agricultural land in wet season **(Table 2).** This effects might be the result of high anthropogenic inputs and a low retention of nutrients in urban land (Bu, Meng et al. 2014). This is indicative of the accumulation pollution due to community activities, discharge of raw household sewage, municipal wastewater, and fertilizer runoff from rice farming activities. Furthermore, a shortage of wastewater treatment infrastructure in suburban areas also contributes to increased orthophosphate and nitrogen levels. It reflects the conditions of drainage of an anthropic area with sparse agriculture.

Although TCB and FCB parameters no significant in spatial, but mean values of TCB and FCB in urban areas were higher than other land use due to indicate pollution from urban areas, where settlements are close to the stream and raw sewage or partially treated sewage being discharged into the stream. The large amounts of sewage are discharged into the water streams with incomplete treatment, which is a particular issue in tropical Asian watersheds with dense populations (Dudgeon, 1992). This also accords with the finding from previous study in other country that changes in water quality have been influenced mainly by untreated sewage in major cities (Abraham 2011). In addition the municipal zone and downstream zone with river linear settlement pattern and population density on the riverbanks affected the water quality index, indicating by DO, TCB and FCB (Lamprom, 2018).

3.4 Major Pollution

The pollution load was highest at downstream of stream water of Chanthaburi River, represent urban land cover, indicating high concentration of PO_4^{3-}-P, NO_3-N, NH_3-N, TCB and FCB in urban land cover indicate pollution from urban areas, which are affected by residential activities where settlements are close to the Chanthaburi River and sewage may be discharged into the stream water. FCB and TCB during dry season were filthy more than wet season, for the reason that the increased water quantity resulted in the dilution of the substance in stream water. As have been demonstrated by a previous study urban land cover is more strongly influenced to these parameters in the dry season due to the stream water in low flow are more affected by point-source loads from urban land (Ihunwo, 2018; Wongaree, 2019). The discharges from point sources in urban areas can be considered to be a constant source of pollution. The pollution become diluted with the increased water discharge and high flow velocities during the wet season. The pollution lowest at upstream of stream water of Chanthaburi River, represent forested land, which are forested and sparsely populated, however on these sites were touristic activities (FW1, FW2 and FW4), the human activity was effected on stream water quality that demonstrated high value of TCB parameters in the dry season, contributing to pollution on the stream water quality of Chanthaburi River.

4. Conclusion

Study findings indicate that urban rather than agricultural land cover primarily affects stream water quality of Chanthaburi River. Although the values of water pollution is still acceptable to surface water quality standard of Thailand, stream water of Chanthaburi watershed shows signal of TCB and FCB contaminations due to indicate pollution from urban areas, where settlements are close to the river, dense population and sewage may be discharged into the water stream, contributing to pollution on the stream and river. Therefore, urban areas should be critical areas of water stream restoration or management. Stream water management or restoration have to control human activities in using any land use type, it is recommended that waste discharge into the stream water in urban areas be reduced through better waste management and should treat wastewater on site before discharge into the water stream to limit the discharge of TCB and FCB through removal of point-source waste discharges in urban areas, especially in the dry season.

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