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Assessment of pressures and impacts on water quality of a small Mediterranean stream using an integrated approach

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ABSTRACT

Water resources are under the threat of pollution from anthropogenic activities. The aim of this study is to present an integrated approach for analysis of pressures and impacts on the water quality. The application site is a small Mediterranean watershed, Acisu Stream, that is located in Antalya City of Turkey. This stream drains into the Mediterranean Sea and it has a high local impact on the sea water quality. An intense water quality monitoring program was conducted at twelve monitoring stations along the stream network with monthly intervals for a period of 1 y. The monitoring study involved onsite measurements and analyses of many physicochemical, bacteriological parameters and pesticides. The discharges of three wastewater treatments were the main sources of point pollution. The diffuse pollution of total nitrogen (TN) and total phosphorus (TP) were estimated on daily basis using MapShed watershed model and GIS. Cropland, septic systems and farm animals are the main sources of diffuse pollution. The areal loading rates of diffuse TN and TP were estimated at nearly 20 and 4 kg/ha/y. The contribution of cropland to TN and TP pollution loads was the highest among all sources and they were estimated at 58% and 67%, respectively. The pollution loads of TN (24.33%) and TP (21.99%) were also high for point sources. These pollution sources have an adverse impact on the water quality and there is a need for integrated management to improve water status both for the stream and the coastal water.

Keywords: Water quality; Diffuse pollution; Point sources; Pressures and impacts; Stream; Monitoring study

1. Introduction

The intense anthropogenic activities and the adverse impacts of global climate change cause increasing pressures on water resources. In many regions of the world, water resources are gradually decreasing and becoming polluted, and the communities facing water scarcity is increasing. Due to the limited water resources on the earth and the increase in water demand of people, the advances in technology facilitate to obtain fresh water even from sea water. However, the attempts to benefit from these very expensive methods are limited. Instead, management of existing surface and groundwater resources in a sustainable way is essential. Increasing population and water demand, climate change impacts, inadequate environmental protection

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measures and economic instability are among the main challenges of water resources management.

Diffuse and point sources of pollution need to be investigated well to preserve the good status of water resources [1,2]. The uncontrolled discharges of municipal and industrial wastewater into surface waters contain various pollutants, such as conventional (organic material, solids, nitrogen and phosphorus forms, coliforms) and emergent pollutants (priority and specific pollutants, heavy metals). These pollutants often cause harmful algal blooms, eutrophication, death of aquatic life and decline of biodiversity [3]. The intense anthropogenic activities and urban development alongside the rivers create an urgent water pollution problem which threatens the sustainability of the river ecosystem [4,5]. Therefore, reliable and detailed water quality management plans are needed to conserve water quality in surface waters [6]. By applying detailed monitoring studies and carrying out integrated studies of water quality assessment, management and modelling work, the best management options could be investigated to propose feasible and economical solutions [7–9]. In this respect, estimation of point and diffuse pollution sources are necessary to describe the potential pressures on water quality [10]. Additionally, realization of monitoring programs and assessment of the obtained water quality and quantity datasets are necessary to indicate the impacts of pressures [11].

The European Union Water Framework Directive (EU-WFD) [12], which came into force in December 2000, aims to ensure sustainable management of coastal, transitional, inland surface and groundwater resources for the protection and improvement of the aquatic environment, to achieve good water status and to prevent deterioration of the quality of water bodies. The analysis of pressures and impacts is an essential task of the River Basin Management Plans (RBMPs). The EU-WFD indicates point and diffuse sources of pollution, flow regime modifications by abstraction or regulation and morphological changes as a broad categorization of pressures whereas impact is the environmental effect of the pressures (such as fish kills and eutrophication) [13]. DPSIR (Driver, Pressure, State, Impact and Response) analytical framework was adopted and used for the analysis of pressures and impacts [14–16]. Additionally, several types of tools/models, such as pressure screening and assessment, quantification of pollution pressures, impact assessment and combined tools for pressures and impacts, were developed to support the analysis of pressures and impacts [13]. During the last few decades, several quantification tools have been developed to estimate nutrient losses to river basins within Europe [17–21] and outside Europe [22–25]. These quantification tools, being developed for different tasks and regions, differ in their complexity, data requirements and resolution in time and space [26]. Process-orientated dynamic quantification tools (such as SWAT, INCA, STICS-MODCOU, EPIC and others) normally require many detailed temporal and spatial input data sets. Such detailed data are not available in many cases and assumptions or use of default values are required. However, empirical and quasi-empirical approaches such as MITERRA, GREEN, MONERIS, SLAM or statistical models could be applied as viable alternatives [27]. These empirical models are based on catchment characteristics, obtained from digital maps and statistical reports. These models are applied to quantify regionally differentiated nutrient emissions and the resulting loads in surface waters.

In Turkey, many national and regional projects were carried out in the last 10 y to improve the water status in terms of quantity and quality at river basin scale following the principles of the EU-WFD. A research project (TUBITAK Project No: 119Y267) has been initiated to investigate the pressures and impacts in a small Mediterranean watershed, namely Acisu Stream, which is located in Antalya City of Turkey. The aim of this study is to present an integrated approach for estimation of point and diffuse pollution sources and assessment of their impacts on the receiving water quality. The outcomes of this study will contribute to the protection of the stream, which is very prone to pollution from various anthropogenic activities [28].

2. Materials and methods

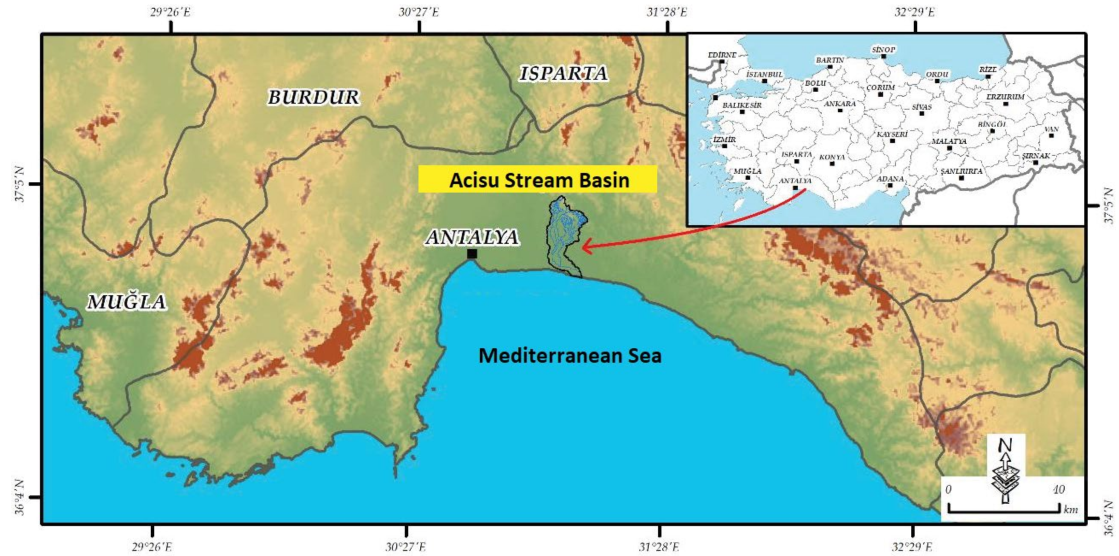
2.1. Study area

Acisu Stream is in the southwest of Turkey, and it discharges directly to the Mediterranean Sea, as shown in Fig. 1a. The stream basin area has mixed land use for residential, agricultural and tourism activities (Fig. 1b). The total drainage area of the stream is 378 km^2 and the length of the stream is approximately 40 km.

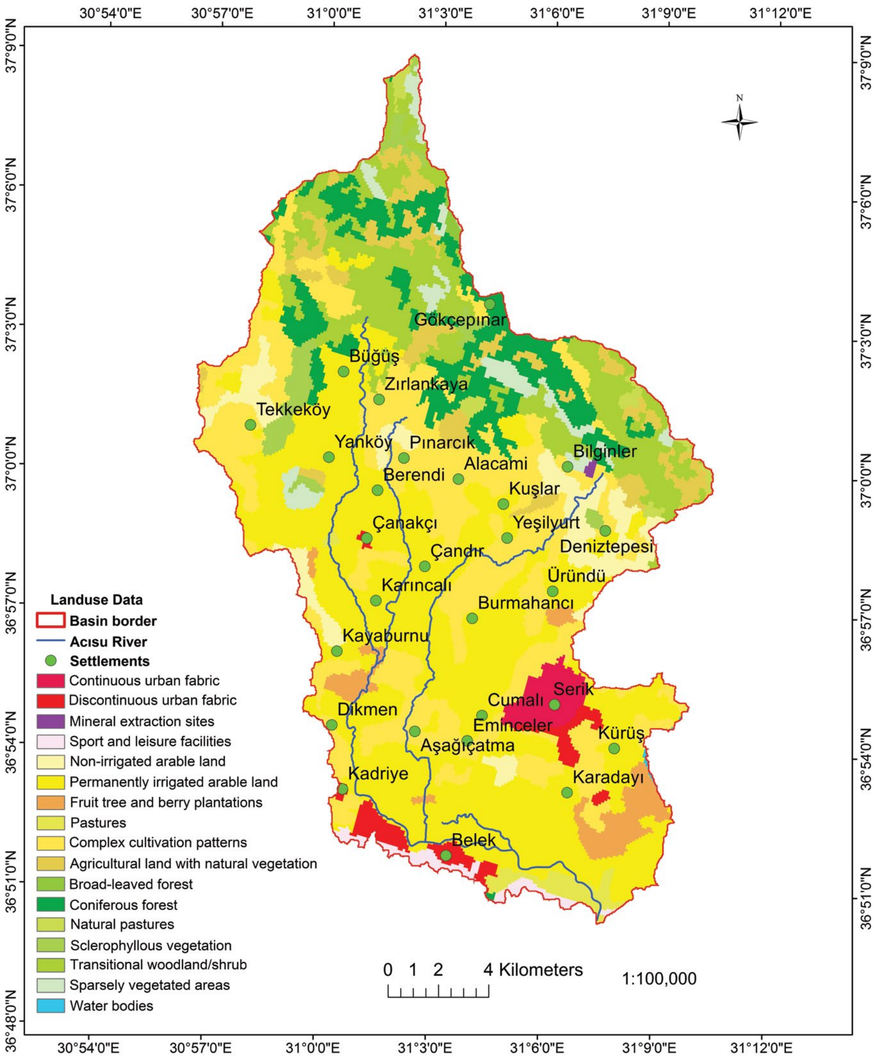
Acisu Stream Basin has a typical Mediterranean climate with mild air temperatures and high precipitation rates in winter whereas the summer months are dry and hot with high evaporation rates. The average air temperature in the basin is 19.8°C and the annual total precipitation and evaporation rates are 997 and 1,208 mm, respectively. Land elevations in the basin vary between the sea level and 1,464 m altitude above the sea level. The average flow rates at the upstream and downstream sections of Acisu Stream were measured as 0.05 and 6.32 m^3/s for the period between October 2020 and September 2021 [28]. The agricultural lands and forests constitute the majority of land use/cover in the north of the basin. The irrigation water is mainly supplied from the stream and the upper stretch of the stream becomes stagnant and even dry due to over abstraction of irrigation water and reduced precipitation in dry periods. There are also three wastewater treatment plants (WWTPs) in the basin that directly discharges to the downstream section which is very close to the Mediterranean Sea coast. The downstream section of the study area is mainly used for urban settlements and tourism activities. The main residential areas in the basin are Aksu and Serik districts. Belek town, which is in Serik district of Antalya Province, is a well-known tourism destination with many hotels located along the Mediterranean Sea coast. Intense tourism and agricultural activities cause point and diffuse pollution and create significant pressures on both water quantity and quality.

2.2. Monitoring studies and data collection

Twelve measurement and sampling stations were selected for monitoring studies at Acisu Stream, (Fig. 2)



(a)



(b)

Fig. 1. (a) The locations of Antalya Province and Acisu Stream Basin in Turkey (adapted from Fural [29]) and (b) land use/cover map.

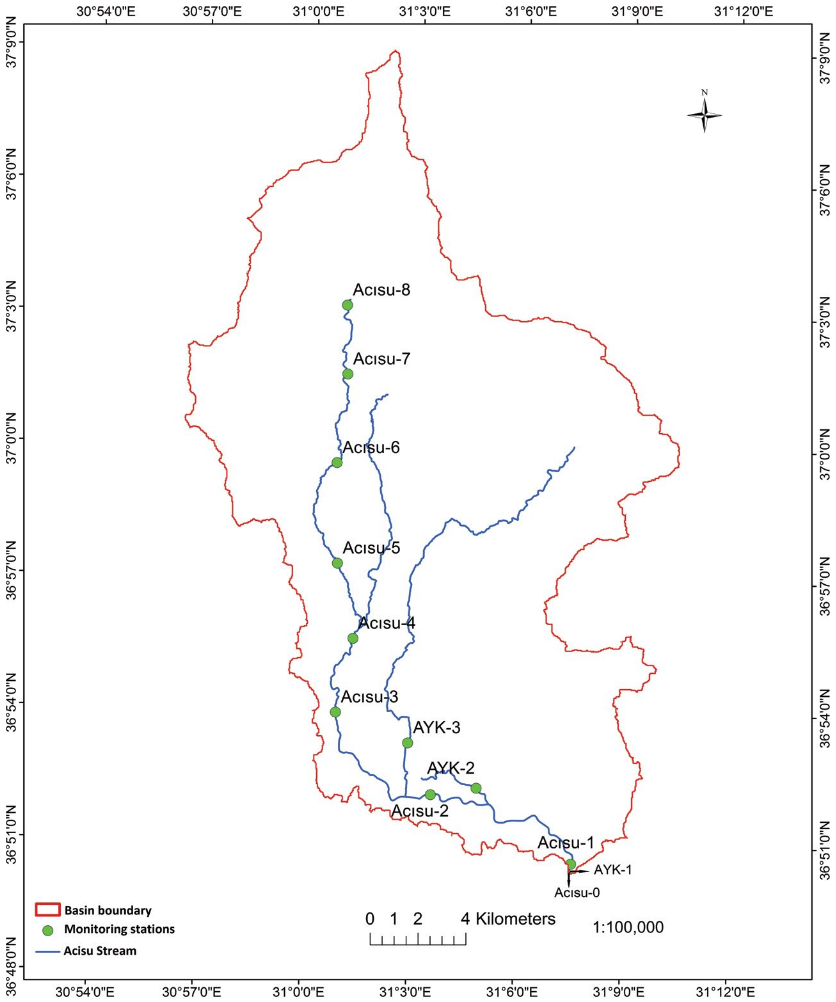


Fig. 2. Locations of monitoring stations.

considering the criteria of the EU-WFD, the tributaries and drainage channels in the basin. Measurements and analyses of many physicochemical and bacteriological water quality parameters and pesticides were conducted monthly at all monitoring stations that continued for a period of 1 y starting from September 2020.

The stream flow rates, discharges from the main connections and tributaries (irrigation channels, drains, etc.) were measured by the State Hydraulic Works 13th Branch in Antalya. The monthly wastewater discharges and the wastewater characteristics were obtained from Antalya Metropolitan Municipality – Water and Wastewater Administration and a private operating company. The meteorological datasets of daily minimum and maximum air temperature and daily total precipitation were obtained from the Antalya Regional Meteorological Branch for the closest meteorological stations to the study area. Detailed information about agricultural practices within the stream basin (such as types and amounts of fertilizers and pesticides used at agricultural fields) were collected from Antalya Provincial Directorate of Agriculture. All the collected datasets were utilized for assessment of water quality and quantity at Acisu Stream and MapShed model application.

2.3. Methods of measurement, sampling and analyses

For the monitoring study, a 10 L composite water sample was collected manually from three lateral points and depths (surface, mid and bottom) at each station. Pre-sterilized 100 mL volume amber glass sample bottles were manually dipped into water at the middle cross section of the stream for bacteriological analyses of total coliform (TC), fecal coliform (FC) fecal streptococcus (FS) and *Escherichia coli* (*E. coli*). Collected water samples were transferred to the laboratory in cold boxes on the same day in accordance with the international standards of ISO 5667-6, ISO 5667-2 and ISO 5667-3 [30–32]. Analyses of bacteriological parameters, anions, cations, chemical oxygen demand (COD) and 5-d biochemical oxygen demand (BOD_5) were performed on the same day of sampling. Temperature, pH, electrical conductivity (EC), salinity, dissolved oxygen saturation and concentration, and Chlorophyll A were measured on-site by a multi-parameter probe. Color was determined as true color at the wavelengths of 436, 525 and 620 nm using UV/VIS spectrophotometer and 10 mm path length [33]. For determination of suspended solids concentration, water samples were filtered through tare weighted glass fiber filter papers and then the papers were dried to a constant weight in a drying cabinet at a temperature of 103°C–105°C. Total alkalinity and bicarbonate were determined by the titrimetric method [34]. COD values were determined by the open reflux method and BOD_5 values were determined by 5-day incubation and measurement of oxygen consumption [34]. Pesticides were analyzed at an accredited specialized laboratory.

2.4. Estimation of diffuse pollution loads

In this study, MapShed model was selected to simulate surface runoff and diffuse pollution of nitrogen (N), phosphorus (P) and sediments from Acisu Stream Basin. MapShed is a GIS-based hydrological model coupled with pollutant transport model [35]. On hydrological side, the model utilizes SCS Curve Number Method to simulate precipitation and flow relation whereas soil erosion is calculated by the Universal Soil Loss Equation. Basically, the model combines pollutants inside the eroded soil and surface flow to calculate pollutant concentrations. The advantage of MapShed model is its ease of use and it relies on input datasets that are less complex than those required by other watershed-based water quality models such as SWAT, SWMM, and HSPF [36]. The MapShed model has been approved by the US Environmental Protection Agency (EPA) as a good "intermediate" model that includes algorithms to simulate many of the key mechanisms that control nutrient and sediment fluxes within a watershed [37]. The main input data sets required for the model are transport, nutrient and animal. Additionally, locations of meteorological stations, basin boundary, map of stream network, soil map are required in GIS shape files whereas map of land use/cover and digital elevation map are required in GIS grid files. The weather data requires daily minimum and maximum air temperatures and daily precipitation rates for the simulation period. MapShed model was applied to Acisu Stream Basin for a period of 3 y (1st of Jan., 2019 – 15th Oct., 2021) and the details of this work are given elsewhere [28].

3. Results and discussion

3.1. Point sources of pollution

There are three wastewater treatment plants (Belek-2, Serik and Bogazkent WWTPs) discharging at Acisu Stream and one of its tributaries. The yearly average wastewater flow rates, and the influent and effluent characteristics (COD, BOD, total suspended solids (TSS), total nitrogen (TN) and total phosphorus (TP) concentrations) of all WWTPs are presented in Table 1. The yearly average wastewater flow rates of Belek-2 WWTP were in the range of approximately 17,000–20,000 m^3/d in 2019. However, due to the COVID-19 pandemic in 2020, tourism activities in the study area were adversely affected and the wastewater flow rates decreased approximately to 12,000 m^3/d. In comparison to the pre-pandemic years of 2018 and 2019, the discharge flow rates showed a significant decrease in 2020. Serik WWTP discharges into one of the tributaries of Acisu Stream, called East Batak Creek. For Serik WWTP, the highest monthly flow rate was recorded as 34,645 m^3/d in January 2019, and the lowest flow rate was 11,823 m^3/d in May 2018. In fact, the wastewater flow rates were not affected by the COVID-19 pandemic for Serik WWTP because this facility serves mainly for residential areas. Due to lock-down measures of the pandemic, the local people were not allowed to leave their homes for specific periods in 2020 which caused an increase in the household water consumptions and wastewater volumes. The monthly flow rates of Belek-2 and Serik WWTPs are depicted in Fig. 3 for the last 3 y.

Annual average values of COD and BOD_5 concentrations in the effluents of Belek-2 and Serik WWTPs were approximately in the range of 20–30 mg/L and 7–10 mg/L, respectively. Additionally, the annual average TSS concentration in the effluent was less than 10 mg/L and the annual average values of TN and TP concentrations were approximately 10 and 3 mg/L, respectively. The highest concentrations of TN and TP discharged into Acisu Stream were reported as 26 and 5 mg/L, respectively, in the last 3 y. Moreover, the highest concentrations of COD, BOD_5 and TSS observed in the plant effluents in the last 3 y were 77, 29 and 32 mg/L, respectively.

Table 1
Yearly average wastewater flow rates (Q), influent and effluent characteristics of three WWTPs for the years 2019 and 2020

Parameters	Q (m^3/d)	Influent (mg/L)					Effluent (mg/L)				
		COD	BOD	TSS	TN	TP	COD	BOD	TSS	TN	TP
Belek-2 WWTP											
2019	20,177	499.7	282.5	229.5	30.1	6.5	22.7	7.4	6.4	6.5	1.6
2020	12,063	370.2	184.3	152.3	25.3	3.5	32.6	10.1	9.2	11.3	2.1
Serik WWTP											
2019	22,245	388.8	186.4	182.5	33.3	3.6	23.7	7.8	5.5	11.2	2.3
2020	24,799	350.3	189.4	161.6	35.7	3.4	34.8	10.0	6.5	10.4	2.7
Bogazkent WWTP											
2019	11,000	480	182	196	–	–	28	12	13	–	–
2020	7,505	–	–	–	–	–	21	11	7	–	–

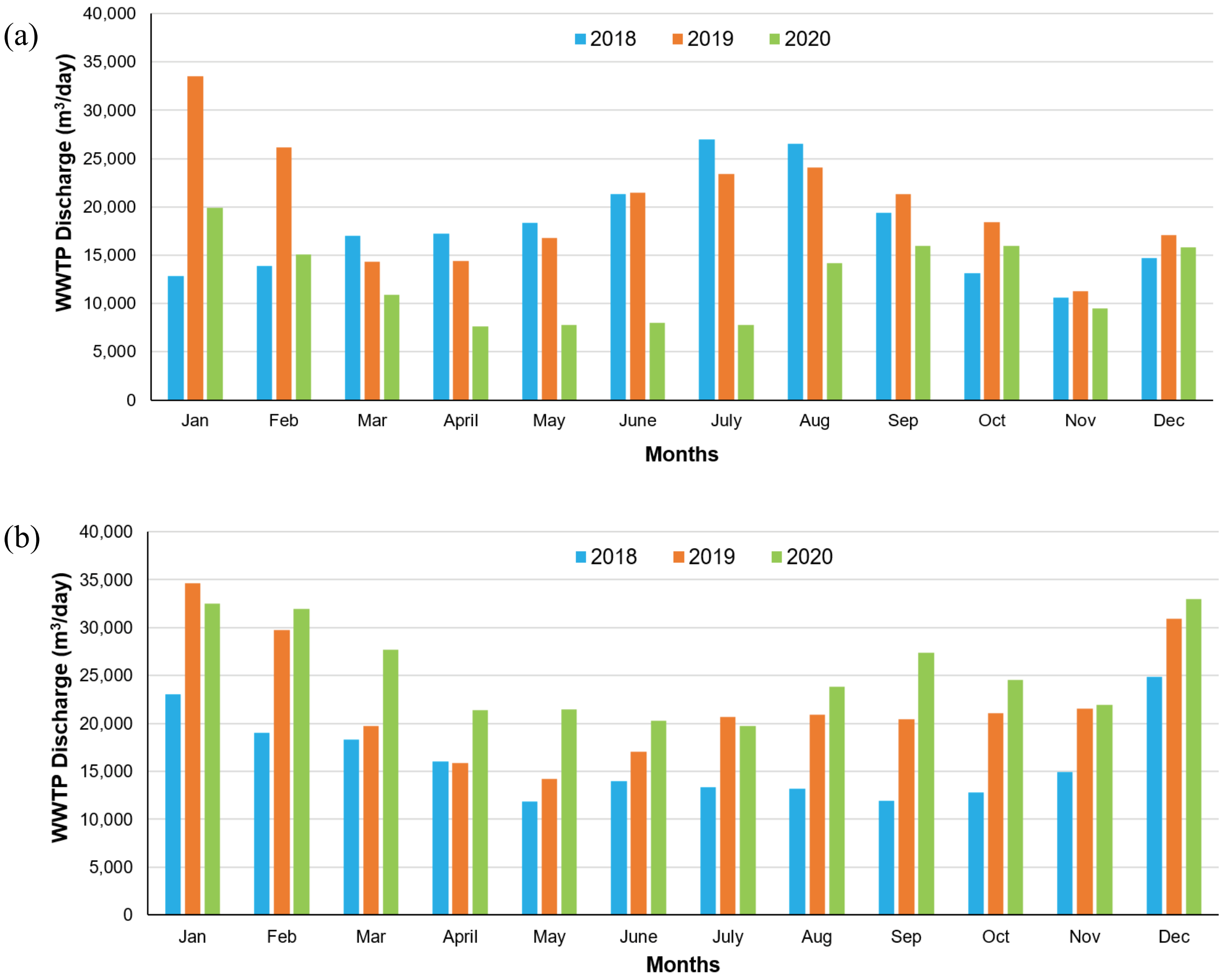


Fig. 3. Monthly wastewater discharge flow rates of (a) Belek-2 and (b) Serik WWTPs in the last 3 y.

The effluent from Bogazkent WWTP is discharged at a location very close to river mouth of Acisu Stream where it flows into the Mediterranean Sea. This WWTP mainly serves for some hotels in the region and the flow rates were reported as 11,000 m^3/d for 2019. However, the WWTP flow rates were observed to decrease in 2020 due to COVID-19 pandemic (Table 1). The grab samples of wastewater taken in August, September and December 2019 demonstrated a wide temporal variation for the WWTP influent. The analyses of bacteriological parameters were also performed in the grab effluent samples in September 2019. In this monitoring study, the analyses results were at the level of 30; 8,000; 11,000 and 8,000 cfu/100 mL for FS, FC, TC and *E. coli*, respectively. For another grab effluent sample taken in the same month, very low numbers of indicator organisms were reported. These results show that the effluent is disinfected from time to time. Additionally, 24-h composite effluent samples were taken from Bogazkent WWTP and the analyses results were generally <30 mg/L for COD, <11 mg/L for BOD_5 and <15 mg/L for TSS. Although the WWTP effluent characteristics comply with the related national wastewater discharge criteria (25 mg/L for BOD_5, 125 mg/L for COD and 35 mg/L for TSS), as defined in the Urban Wastewater Management Regulation, the influent and effluent characteristics showed wide variations especially in the summer season.

3.2. Fertilizers and pesticides

Agriculture is an important sector for the economy of Turkey. In Serik district, agriculture is practiced at all seasons and for twelve months. Accordingly, the use of fertilizers and pesticides continues all along the year. Table 2 presents total amounts of fertilizers and pesticides used in Serik district in 2020 for four periods where each period covers 3 months. While the total amount of fertilizers used in the district was 4,890 tons in 2019, it exceeded five thousand tons in 2020. The total amount of pesticides used in the district was 226 tons in 2019 and it increased to 255 tons in 2020. The use of fertilizers and pesticides varied during the periods where the use of fertilizers was highest and the use of pesticides was lowest in the first period. Usually, the farmers use high amounts of fertilizers in winter season to increase their crop yields and they apply high amounts of pesticides mainly in summer season to protect crops/plants against diseases.

Table 2
The amounts of fertilizers and pesticides utilized in Serik district in 2020

	Period 1	Period 2	Period 3	Period 4	Yearly
	Jan-March	April-June	July-Sep	Oct-Dec	Total
Fertilizers (ton)	1,990	891	1,084	1,076	5,041
Pesticides (ton)	49.03	67.70	78.94	59.68	255.35

3.3. Pollution loads for diffuse and point sources

The pollution loads of point sources were computed using the yearly average wastewater flow rates (Q) and the effluent characteristics of three WWTPs for the year 2020, as presented in Table 1. The effluent concentrations of TN and TP were estimated as 10 and 3 mg/L, respectively, for Bogazkent WWTP where extended aeration activated sludge type of biological treatment process is applied with N and P removal. The distribution of TN and TP diffuse pollution loads were estimated by the MapShed model and the results are presented in Table 3.

The main sources of diffuse TN and TP pollution loads were cropland, septic systems and farm animals. The areal loading rates of diffuse TN and TP pollution loads were estimated at nearly 20 and 4 kg/ha/y which are considerably high values. The distribution of pollution loads for diffuse and point sources are shown in Fig. 4 for TN and TP for the year 2020.

In the study area, the contribution of cropland to total TN and TP pollution loads was the highest among all sources and estimated at 58% and 67%, respectively. The pollution loads of TN (24.33%) and TP (21.99%) were also high for point sources. In case of both TN and TP pollution loads, the contribution from septic systems and farm animals were also significant with respect to other sources of pollution (urban areas, open land, disturbed land, and forests) where the contribution of farm animals to TP pollution loads was higher than septic systems.

Table 3
Distribution of TN and TP diffuse pollution loads for sources and pathways in 2020

Sources/Pathways	Total N	Total P
	kg/y	kg/y
Source loads		
Hay/Pasture	8,015.9	3,128.8
Cropland	407,219.9	128,471.1
Forest	4,158.2	1,466.0
Disturbed land	29.7	12.6
Open land	1,633.8	556.6
Urban areas	4,853.7	610.6
Farm animals	41,137.3	9,766.5
Septic systems	65,777.7	4,670.1
Source loads total (kg/y)	532,826.2	148,682.3
Pathway loads		
Stream banks	755.8	322.8
Subsurface/Groundwater	220,486.2	1,937.6
Total watershed mass load (kg/y)	754,068.2	150,942.7
Total watershed area (ha)	37,818	
Areal loading rate (kg/ha/y)	19.9	3.99

3.4. Impacts on water quality

The results of monitoring study for the upstream and downstream monitoring stations are presented in Table 4. Acisu-6 was selected as the upstream station because Acisu-7 and Acisu-8 stations, which are on the upstream of Acisu-6, were stagnant or dry at many sampling sessions. The water quality was gradually impaired towards the downstream due to diffuse and point sources of pollution. The mixing of stream and sea water at the stream discharge point to the Mediterranean Sea caused significant increases in EC and the major ions. The concentrations of parameters indicating organic pollution (COD, BOD_5, TOC) and nutrients (NH_4–N, NO_3–N, TN, PO_4–P and TP) were considerably higher at the downstream in comparison to the upstream water quality. Additionally, the bacteriological quality was impaired at the downstream section of Acisu Stream due to discharges of three WWTPs.

Many of the beaches in Turkey have Blue Flag awards due to the efficient operation of WWTPs all over the Turkish coasts and compliance with the requirements of the award, where exceptions are a few. The Turkish Ministry of Health and Blue Flag Organization in Turkey carry out routine monitoring studies along the beaches of Turkey and report the results of bacteriological analyses of sea water online in their web site (yuzme.saglik.gov.tr). The analysis results of TC, FC and FS at the river mouth of Acisu Stream is presented at Fig. 5 for 2018, which highly exceeded the guideline values at some of the monitoring sessions. Additionally, the bacteriological water quality at the river mouth of Acisu Stream is presented at Fig. 6 for *E. coli* and Intestinal Enterococci, as the revised parameters, for 2020. These results clearly show that, the bacteriological sea water quality is under the impacts of point discharges of three WWTPs which are located at the downstream section of Acisu Stream.

The analysis of pressures and impacts on the water quality of Acisu Stream was very helpful to investigate the main causes of water quality impairments. In fact, this analysis is an essential part of an integrated study for preparation of RBMPs as reported in the EU-WFD. In case of Acisu Stream watershed, there is an urgent need to control the discharges of three WWTPs to protect the sea water quality which is very important for the

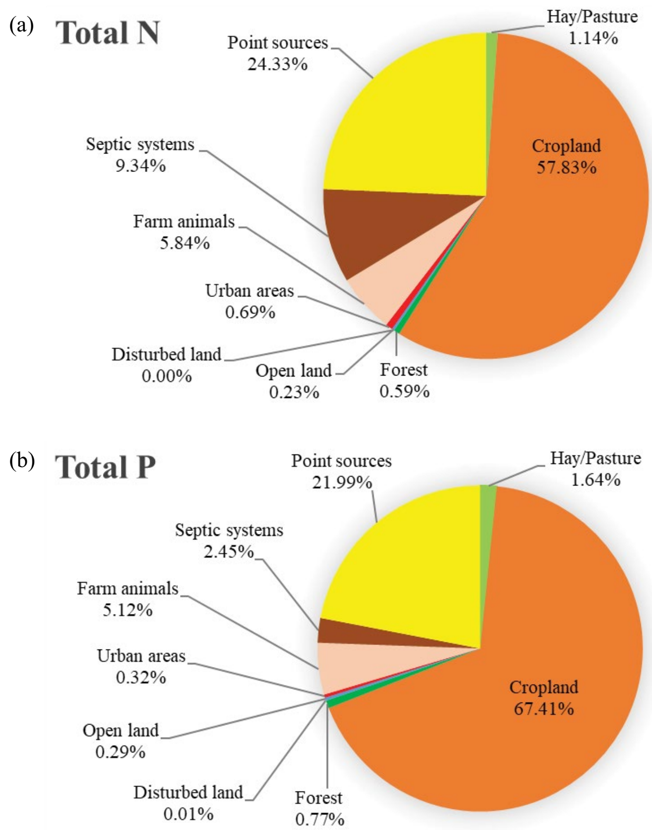


Fig. 4. Diffuse and point sources of pollution for (a) TN and (b) TP for the year 2020.

intense tourism activities and facilities at the study area. Actually, the local governmental bodies and stakeholders are highly interested in the protection of Blue Flag award for the coastal area and the beaches. As a result of this awareness, construction of a new WWTP was recently completed and this plant will be in operation very soon. There is also an on-going research for deterministic river water quality modeling of Acisu Stream and possible management options for control of diffuse and point pollution sources are under investigation. The findings of the modeling study will be used to recommend the best management options to improve conditions of water quality and quantity at Acisu Stream and the coastal water.

3.5. Discussion

There is no previous study to estimate point and diffuse pollution sources specifically in Acisu Stream watershed but in the study of Antalya Basin Protection Plan, conducted in 2013, the diffuse pollution sources were estimated for land use, agricultural practices, animal husbandry, atmospheric deposition, septic tanks and leachate from unsanitary solid waste landfill sites. As a result, TN and TP loads were estimated at 601–1,000 ton/y and 21–50 ton/y, respectively for the Serik district. Furthermore, TN loads from point and diffuse sources were reported as 17% and 83% and TP loads from point and diffuse sources were reported as 38% and 62%, respectively, for Aksu sub-watershed within Antalya Basin [38]. In this study, diffuse source loads were estimated at 532 ton TN/y (14 kg TN/ha/y) and 148 ton TP/y (3.9 kg TP/ha/y) and the distribution of point TN and TP loads were estimated at 24% (171.3 ton/y) and 22% (41.9 ton/y), respectively, for Acisu Stream watershed. The total watershed area of Acisu Stream is 37,818 ha and the cropland (including non-irrigated and permanently irrigated arable land, fruit tree and berry plantations, complex cultivation patterns, agricultural land with natural vegetation) covers 70% (26,710 ha) of the whole watershed. Additionally, the excessive use of fertilizers creates an intense agricultural production in the watershed and consequently the areal loadings of TN and TP diffuse sources are comparatively high. Based on the threshold load levels for significant pressure of point sources (>10 ton TN/y and >1.5 ton TP/y) and diffuse sources (>5.85 kg TN/ha/y and >0.4 kg TP/ha/y) [39], Acisu Stream is assessed to have significant pressures in terms of both diffuse and point sources of TN and TP.

Estimation of diffuse pollution sources in river basins constitutes an essential part in the analysis of pressures and impacts and in the preparation of program of measures. However, monitoring at the sub-watershed level is not practical because it is time consuming, expensive and labor intensive. Therefore, use of simulation models is very common and consequently, the capabilities and suitability of different tools/models are compared with respect to diffuse pollution emission pathways, such as

Table 4
The measurements and analysis results of the selected water quality parameters for the upstream (Acisu-6) and the downstream (Acisu-0) monitoring stations

Parameter	Upstream station (Acısu-6)				Downstream station (Acısu-0)			
	Autumn	Winter	Spring	Summer	Autumn	Winter	Spring	Summer
pH	8.17	8.27	8.28	8.40	8.12	8.21	8.28	8.24
Color 436 nm (m^{-1})	0.020	0.012	0.029	0.028	0.001	0.050	0.031	0.026
Color 525 nm (m^{-1})	0.003	0.011	0.024	0.024	0.000	0.044	0.026	0.021
Color 620 nm (m^{-1})	0.000	0.011	0.023	0.024	0.000	0.040	0.023	0.018
EC (μS/cm)	485	612	538	435	20,958	5,283	8,577	6,647
DO (mg/L)	8.69	9.85	9.35	8.19	7.71	7.34	8.88	6.65
DO_{sat} (%)	92.50	96.40	98.55	93.10	97.50	74.20	100.00	85.40
COD (mg/L)	14.84	6.60	8.87	11.84	–	27.57	15.31	57.49
BOD_5 (mg/L)	8.26	2.38	7.23	5.61	9.32	5.81	5.78	7.74
TOC (mg/L)	1.87	2.17	2.04	1.86	15.91	4.69	7.78	30.47
NH_4–N (mg/L)	0.126	0.004	0.010	0.032	0.163	0.336	1.726	0.608
NO_3–N (mg/L)	0.714	5.171	2.519	0.516	1.667	3.090	1.266	1.326
TN (mg/L)	0.935	5.933	2.952	0.663	1.986	4.136	3.499	2.392
PO_4–P (mg/L)	0.0363	0.0050	0.0085	0.0071	0.3558	0.1935	0.1016	0.1965
TP (mg/L)	0.052	0.026	0.043	0.050	0.233	0.232	0.132	0.247
TSS (mg/L)	13.7	2.9	11.3	16.5	16.8	16.0	17.9	17.8
F^- (μg/L)	251.45	116.55	88.85	225.50	789.50	187.20	269.33	883.56
Cl^- (mg/L)	6.99	23.48	14.81	5.79	3,031.86	1,781.68	2,808.29	2,293.29
Br^- (μg/L)	114.0	59.2	26.3	6.8	10,696.3	4,956.2	6,839.4	6,221.9
Na^+ (mg/L)	11.49	22.18	16.67	8.11	947.91	486.17	718.82	735.16
NO_2^- (mg/L)	0.028	0.088	0.036	0.037	0.010	0.490	0.165	0.418
SO_4^{2-} (mg/L)	18.71	51.86	34.29	12.90	373.70	316.71	419.10	327.74
FC (cfu/100 mL)	92	170	767	240	31	2,222	120	273
FS (cfu/100 mL)	113	0	16	36	53	128	0	4
TC (cfu/100 mL)	1,061	3,460	760	1,760	2,195	16,444	787	1,480
E. coli (cfu/100 mL)	8	0	0	73	3	0	9	40

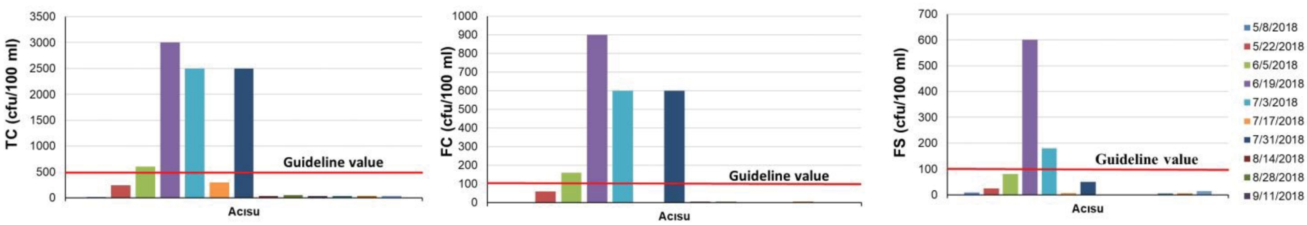


Fig. 5. Results of bacteriological analyses at the river mouth of Acisu Stream in 2018.

atmospheric deposition, overland flow, erosion, tile drainages, groundwater, different land uses and urban areas, in addition to emissions from point sources, such as municipal WWTPs and industrial discharges. MONERIS, being a relatively simple model [40] was extensively used to quantify nutrient losses in many European rivers such as the Weser river in Germany; Oder and Vistula catchments in Poland, Axios River in Greece, alpine catchments in Austria, rivers in Spain and Cyprus, and produced acceptable results in comparison to other models such as HSPF or SWAT which require input data sets with high temporal frequency and spatial resolution. Similarly, SLAM model combines multiple spatial datasets, such as land use and physical characteristics of the sub-catchments, to estimate nutrient emissions to surface water [41]. SLAM was used to predict annual nutrient emissions in 16 major river catchments in Ireland [42]. SWAT is a widely applied model in different parts of the world to identify and characterize critical source areas (CSAs) and predict diffuse pollution of nutrients and sediment. Alternatively, MapShed is an open-source model and it has also been used to identify CSAs and to simulate the effects of alternative best management practices to reduce diffuse sources of nutrients and sediment [43] and to evaluate different management

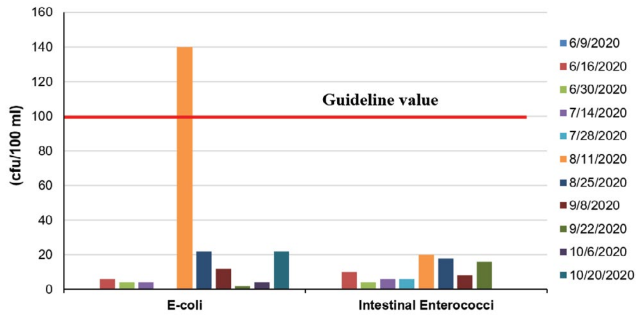


Fig. 6. Bacteriological water quality at the river mouth of Acisu Stream in 2020.

scenarios [44]. In this study, MapShed model was successfully applied to estimate diffuse pollution sources of TN and TP and the diffuse pollution loads were assessed with respect to different sources and pathways.

Integrated and sustainable management of water resources is a challenging issue and all countries face difficulties to achieve good water status in terms of quantity and quality. As an example, EU-WFD is implemented by the EU member countries since 2000 through the RBMPs where the first cycle of RBMPs covered the period 2010–2015. The second-cycle RBMPs were implemented late and covered the period 2018–2021 and finally the third cycle RBMPs are in progress that covers the period 2022–2027. The WFD was complemented by the Groundwater Directive in 2006, the Floods Directive in 2007 and the Environmental Quality Standards Directive in 2008. The EU-WFD was successful (i) to establish a governance framework for integrated water management for more than 110,000 water bodies in the EU, (ii) to initiate new and comparable ecological assessment and monitoring methods for effective restoration measures, (iii) to slow down the deterioration of water status and (iv) to reduce chemical pollution. Although the deadline for achieving the objectives of the WFD was 2015, the implementation is significantly delayed and currently less than half of the EU's water bodies are in good status. Furthermore, many countries are far from achieving the objective of good water status in all waters bodies by 2027 and recommendations are given to enhance monitoring and assessment systems, to improve and integrate program of measures with other sectoral policies, and to extend the WFD beyond the current deadline of 2027 as a long-term perspective [45]. Agriculture, energy and transport sectors were evaluated to have a high impact on water. Despite the improvements in protection of water bodies and flood risk management, the level of implementation by Member States is evaluated as insufficient. Climate change, loss of freshwater diversity, water scarcity and emergent pollutants are stated as the main challenges for the EU countries and the momentum of the European Green Deal is expected to improve the current conditions [46]. Similarly, the United States Environmental Protection Agency (US-EPA) has reported that about 17% of the river systems and 28% of reservoirs in the US are classified as nutrient impaired and immediate actions are required to improve water status [47]. Furthermore, 46% of the streams are reported to be in poor condition in the US with respect to biological and physical conditions and mainly due to accumulation of nutrients and sediment. In case of Turkey, being a EU candidate country, there are many completed and on-going studies, mainly in the last decade, to comply with the EU directives and especially the WFD. RBMPs are prepared for 25 river basins in Turkey according to the WFD to achieve good status in all water bodies by 2036 with the implementation of the required program of measures. Basin Protection Plans were previously prepared for all river basins in Turkey and currently these plans are transformed into RBMPs. However, the complex stream networks in Turkey, insufficient data bases on water quality and quantity, poor monitoring, insufficient enforcement and policies are among the main problems in integrated management of water resources [48].

4. Conclusion

Point and diffuse sources of pollution impose a high pressure on the quality of surface water resources. In this study, the impairment of water quality was presented for a small Mediterranean watershed which was very prone to point and diffuse sources of pollution. The municipal wastewater discharges were the main sources of point pollution causing organic and bacteriological pollution in addition to eutrophication. Moreover, the existence of intense agricultural activities caused use of various types of fertilizers (containing nitrogen and phosphorus) and pesticides to increase yield and income from the crops. However, both fertilizers and pesticides can be transported in different pathways and pollute the water resources. In this research study, all the analysis results of pesticides at the surface water monitoring stations were below the limit of quantification but it needs further investigation for assessment of groundwater. The amounts of pesticides used in agricultural activities is gradually increasing at the study area and there is a need for a risk assessment study to investigate the possible health risks (diseases such as cancer in humans) due to exposure to pesticides. Additionally, pesticide contamination in soil and water can adversely affect the flora and fauna of the natural environment and disrupt the existing ecosystem. In the study area of Acisu Stream, anthropogenic sources of pollution (wastewater discharges and agricultural activities) need to be controlled in a better way. The bacteriological analysis results at the river mouth of Acisu Stream showed that wastewater discharges from the existing three WWTPs may cause violation of Blue Flag water quality standards from time to time and cause significant local adverse effects on tourism. The monitoring study and the analysis of pressures and impacts on the water quality of Acisu Stream presented a systematic approach for integrated management of water quality. Sustainable management of water resources is an urgent issue to bring environmental, social and economic benefits to all societies.

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