Sustainable Urban Development : A Case Study On Goksu Delta

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Abstract

Goksu Delta exists in Silifke district of Mersin province in Mediterranean Region of Turkey. Delta has 260 km long Goksu River and a watershed that has a 10,069 km^2 area. Hence, it is one of the most important watersheds of Turkey. In comparison with the agricultural areas, urban settlement areas are smaller in size. However, settlements are concentrated around the Goksu River. This situation affects the sustainable urban development in a bad way. In addition to these, fishery in Akgol and Paradeniz Lagoons is another reason for the pollution. Rich flora and fauna species live in Delta. Unfortunately there is a great pollution potential in Delta due to the uncontrolled agriculture and unplanned constructions. Pollution threatens survival of living species. In order to prevent the increasing pollution in the region, Goksu Delta is accepted as a special protection area. In this study, pollution parameters will be analyzed in a statistical manner by using data obtained from published reports and current pollution status will be identified. Reasons of the environmental pollution will be investigated. Resources that are responsible of the pollution will be displayed. Against the current pollution, nature and watershed protection methods will be shown within the results.

Keywords: Goksu Delta, Sustainability, Urban development, Pollution, Water resources management

Introduction

Water is an essential component of the Earth's ecosystem; each freshwater body has an individual pattern of physical and chemical characteristics which are determined largely by the climatic, geomorphological and geochemical conditions prevailing in the drainage basin and the underlying aquifer. River is the body of running water, it has fresh water, parallel banks and a bottom slope in the direction of flow, and in a river the flood waves are primarily progressive. Rivers are located in watersheds. A watershed can be defined as a catchment or drainage basin. The chemical quality of the aquatic environment varies according to local geology, the climate, the amount of soil cover, etc. Freshwaters have been subjected to increasing pressures and suffered quality degradations in the past in many parts of the world (European Commission, 2003). High contents of nutrients in water such as nitrates and phosphorus are the major issues in terms of water quality, which are mostly focused on worldwide. Significantly, excess nitrate and phosphorus concentrations in surface waters such as lakes and coastal waters cause eutrophication. Excessive nutrients in the ecosystem are mainly caused by anthropogenic activities. Direct atmospheric deposition, landscape morphology, hydrological conditions, biogeochemical processes in soil, sediment and geological characteristics can be defined as additional sources but their contributions have less significance. Agricultural sources due to the increased use of manures and manufactured inorganic fertilizers in global agriculture are the single greatest causes of pollution degrading the quality of surface waters. European water policy has undergone an important reconstruction process especially through with the new Water Framework Directive which sets clear objectives of protecting European waters with certain deadlines and approaches. Water Framework Directive (European Commission, 2000) proposes the following goals:

- Expanding the scope of water protection to all waters, surface waters and groundwater
- Achieving "good status" for all waters by a set deadline
- Water management based on river basins
- "Combined approach" of emission limit values and quality standards
- Getting the prices right
- Getting the citizen involved more closely
- Streamlining legislation

The Goksu Delta is a wetland ecosystem located in Eastern Mediterranean shore of Turkey. That is located in Silifke District of the Mersin Province of Turkey (See **Figure 1**). The total population of the

Silifke District is 112,565, and 50,327 people are settled in town center. There is a rapid increase in Silifke population due to immigrations from underdeveloped cities. That is one of the five Turkish Wetlands under protection of Ramsar Convention (Ramsar-a 2004). The Ramsar Convention is an international agreement held in 1971 in the city Ramsar, Iran. Protection of ecological values of wetlands, especially to protect the biodiversity of flora and fauna, is the main purpose of the Convention (Ramsar-a 2004). Goksu Delta has been added to Ramsar list in 1994 (Ramsar-b 2004).It is being protected by the Ramsar Convention. The wetland is threatened by the anthropogenic and naturals factors such as agriculture, fishery, fluvial input by Göksu river, drainage channels and coastal currents. Soil texture of the region is 2.1% sand, 42.4% loam, 35.3% clayey loam and 20.2% clay. Hence land is suitable for agriculture in the region. Settlements are concentrated around the River. **Figure 2** shows the settlement around the Goksu River in the 50’s. At that period proportional to the town’s population, settlement around the Goksu River was limited. Today there is a mass settlement around the Goksu River and land use is being changed and it is highly urbanized due to the increase of the population of Silifke (**Figure 3**). There is a great pollution potential in watershed due to the uncontrolled agriculture and unplanned constructions. This leads to decrease in river water quality. This situation affects the sustainable urban development in a bad way. In addition to this, fishery in Lagoons and wetlands is another reason for the pollution. In Delta, the two major lakes are located west of the place where the Göksu River flows into the sea. One of them is called Paradeniz Lagoon which has 492 hectares (4.92 km^2) area, the second one, Akgol Lagoon is fresh water lake and it has an area of 1200 hectares (12 km^2). Both lagoons are quite shallow. Average water depth in Akgol is 1 meter, and 1.5 meters in Paradeniz. Brackish water of the paradeniz is due to a continuous link with the sea. Fishery is done in Paradeniz, and there is a connection channel between Akgol and Paradeniz Lagoons. This two-way channel is working when the water level is high in Akgol and water flows from Akgol to Paradeniz. Only one Wastewater treatment facility is available in the region. The wastewater treatment plant with capacity of 21,500 m^3/day was built in 2007 and that is active since the end of that year. This study aims to examine the success of the efforts in terms of water quality assessment. Trying to find an answer to this question, considering sustainable urban development, what can be done for upgrading the surface water quality?

Figure 1. Location of Goksu Delta

Figure 2. Settlement around the Goksu River in the 50's

Figure 3. Settlement around the Goksu River of today

Methodology

Watershed management

A watershed is more than a single river and stream. It is an entire drainage region with sources of water like rainfall, snowmelt drains into sea, river, lake, wetlands, estuaries, etc. Forecasting the future status of pollution leads to decide on best management practices to conserve natural sources and in accordance with the sustainable development. Sustainable development is a pattern of resource use that aims to meet human needs while preserving the environment. Therefore these needs can be met not only in the present, but also for future generations. Agricultural production has become vital to Goksu River Basin, in terms of economic growth. It is well documented as an area under threat of severe natural resource depletion if it is not well managed with sustainability in mind. Agricultural production, other human-driven development and the survival of the local ecosystems compete for the water resources. The effects of nutrient enrichment in rivers are likely to occur when high concentrations of bioavailable nutrients are present during the periods of algal or plant growth (Bowes et al. 2005). Watershed management is considered as the most appropriate approach to ensure the preservation, conservation and sustainability of all land based resources and for improving the living conditions of the people. Water quality is completely dependent on healthy ecosystems and sustainable land use management in watersheds (Tezer 2007). Forecasting the future status of pollution leads to decide on best management practices to conserve natural sources and in accordance with the sustainable development. Best management practices (BMPs) could be stabilizing stream banks to reduce erosion, restricting livestock access to the creek, providing livestock with alternative water sources, reconstructing stream channels, creating in-stream habitat by building sequences of riffles and pools in the stream channel, creating forested wetlands in the floodplain area, and riparian area, restoring vegetated buffers (Novotny and Hill 2007), change in land use types, rehabilitation of arid lands, upgrading septic systems and municipal wastewater treatment facilities to reduce the total phosphorus concentrations. The conservation of riparian and aquatic habitats of watersheds has to be the primary task to balance natural and socio environmental interactions.

Sustainable urban development

Sustainable development is a pattern of resource use that aims to meet human needs while preserving the environment. Therefore these needs can be met not only in the present, but also for future generations. Achieving sustainable resources and environmental management regarding water, waste, climate change, air quality and/or land is highly important. It seems too common these days for people to aspire to the bare minimum of achievement. Government should encourage people at every opportunity to become better educated on environment protection. Three key dimensions of urban social sustainability are equity; sense of community; and urbanity (Bramley et al. 2010). Intergenerational justice or equity is the study of the rights and responsibilities that exist between earlier and later generations of a society. Intergenerational equity is also explored in environmental concerns, including sustainable development, global warming and climate change. An example is the forest-dwelling civilians in Antalya, who for generations have lived in a certain part of the forest and thus becomes their land. The adult population sells the trees to make money. Unfortunately forest region is under the supervision of government, and access of any forest dwellers is prohibited. Hence, this community is forced to be a resident in city center. If politicians do so, there will be no resources for the children or grandchildren of these forest dwellers in the future. They are making money by selling trees for centuries. Government should consider this historical fact before dismissing of this community from forests. People will not look forward to posterity, who never looks backward to their ancestors (Burke 1955). The government would better encourage the planting of trees instead of violating the intergenerational equity principle of sustainable development.

Over-consumption and inappropriate behaviour will prevent opportunities of future generations and quite probably their ability to enjoy the quality of life we have today. (Curwell et al. 2005). Sustainable Development stands for meeting the needs of present generations without jeopardizing the needs of futures generations. All developing regions have experienced substantial environmental degradation over the past decades, which could very well worsen as a result of long-term, man-made global climate change. The developing countries are more vulnerable than developed countries to environmental hazards and least able to cope with them when they occur. The developing countries are disproportionately affected by environmental degradation and lack of access to clean, affordable energy services. They also tend to be most dependent on the environment and direct use of natural resources, and are therefore most severely affected by environmental degradation and lack of access to natural resources.

Rapid urbanization and urban development in cities of many developing countries are causing environmental problems such as water, air, and noise pollution. The water in most of those cities is polluted (Novotny 2003) as a result of the lack of sewerage system and sewage treatment plants. This is in turn due to political instability, lack of sufficient funds, or corruption, which jeopardizes the public to health risks. In addition, the air is polluted because of high concentration of particles and gases generated by coal combustion, vehicles, power plants, and generators (Colls 2002), which cause respiratory diseases and even deaths. Rapid urban population growth accelerates urban environmental problems for the inhabitants of cities consume more food, water, fuel, and produce more wastes. According to Day et al. (2007) designing cities compatible with their ecological surroundings will have considerable impacts on the establishment of sustainable landscapes. This is because sustainable landscapes are responsive to human needs, fostering human understanding of natural and historical processes associated with a place and the protection of biodiversity and global sustainability.

Indicators are a way of measuring whether a city is moving towards a better ecological performance. If there is a problem, an indicator can help us determine what direction to take to address the issue. According to Harmon (2008) indicators should be “integrating” to make linkages among the economic, environmental, and social dimensions of sustainability, “forward looking” to assess impact on intergenerational equity, “distributional” to measure the degree of equity in social, economic and environmental conditions within a population or across geographic regions and finally, indicators should be developed with input from multiple stakeholders. Moreover, effective indicators should be relevant, easy to understand, reliable and based on accessible data. The identification of appropriate sustainability indicators is a major area of endeavor. They are rarely objectively measured with agreed units but are developed on the basis of shared perceptions; typically achieved via a community participation process such as stewardship (Downtown 2009). Stewardship is simply taking care of the environment or handling your uses of the system in a non-harmful way. This does not necessarily infer neutral stewardship, but rather that you are taking care of it well. Indicators created with input from a broad range of participants in the policy process tend to be the most influential, valid and reliable.

Measures to protect the Goksu River Basin can only be sustainable if governments promote economic development while at the same time raising the living standards of the region's people. Technology must play in establishing economic value for the services the forest provides, such as climate regulation, provision of water, biodiversity and soil conservation. The creation of new protected areas in watershed is a significant step for conservation. Preservation efforts in Goksu River Basin ecosystem are particularly important because of its great biological diversity.

Surface water quality assessment

Freshwater resources are highly important and valuable and it requires strong ecological management to meet water quality standards (Karakoc et al. 2003). Through the decades, streams, lakes, estuaries, and seas have been exposed to wastewaters from industrial, agricultural, and domestic sources (Li et al. 2007). Hence, the quality of surface water has been deteriorated in many regions. Upstream and downstream impacts make the management of water resources complicated. Historical data is needed in order to foresee the possible future pollution status of the watershed. If trend of the pollution is investigated, necessary management techniques for decrease of the pollution can be specified. Some pollution parameters were inspected in order to determine the current pollution level of the lakes and creeks in the region. Samples were collected from the eight designated points (See **Figure 4 and Table 1**) and some water quality parameters were measured. These parameters are dissolved oxygen, ammonium nitrogen, nitrite nitrogen, nitrate nitrogen, total nitrogen, total dissolved solid, total phosphorus, five-day biochemical oxygen demand, chemical oxygen demand, total coliform, and they were obtained from Special Environment Protection (OCK, unpublished report). This paper is of interest to environmental scientists and engineers who would like to have an overview of the pollution problem in Goksu Delta.

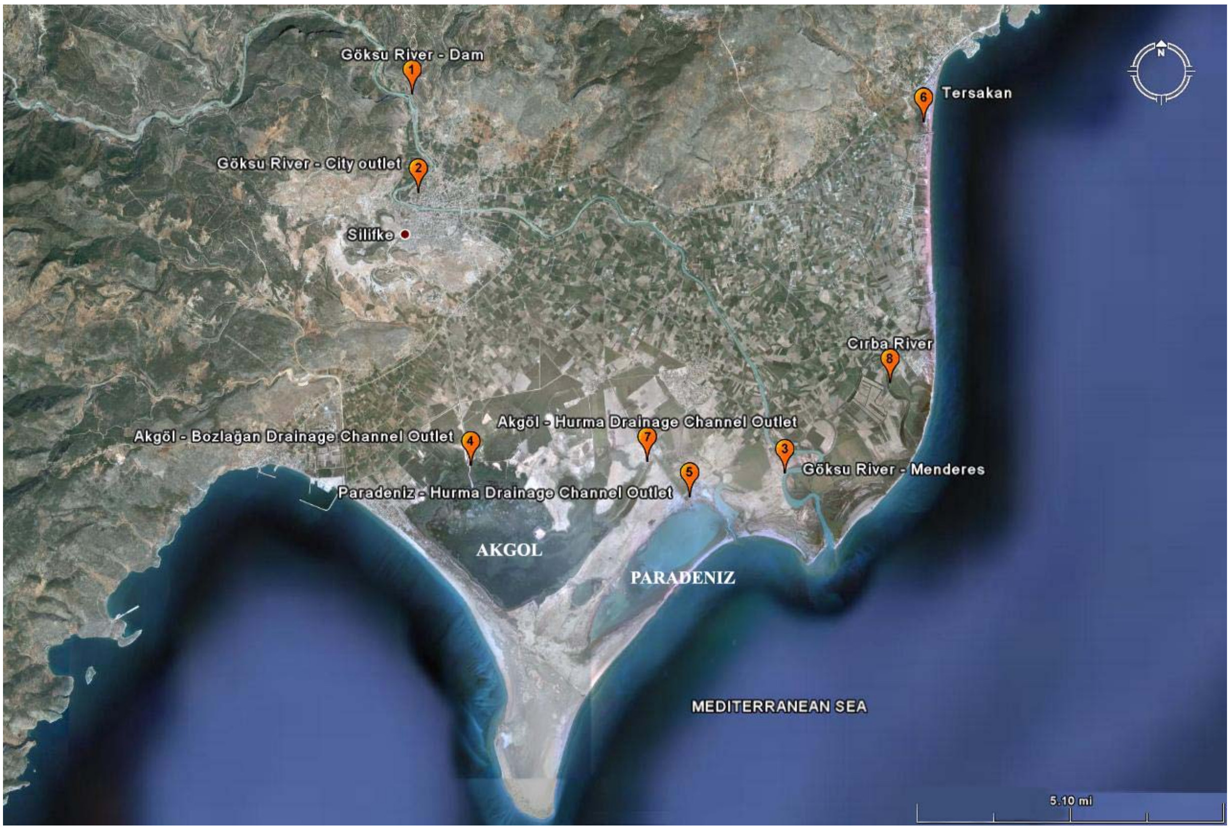

Figure 4. Water quality monitoring stations in Goksu Delta

Table 1. Sampling locations and coordinates

Point	East	North	Sampling Location
1	33° 55' 23"	36° 24' 24"	Goksu River - Dam
2	33° 59' 4"	36° 22' 55"	Goksu River - City outlet
3	34° 2' 3"	36° 18' 56"	Goksu River - Menderes
4	33° 56' 26"	36° 19' 3"	Akgol - Bozlagan Drainage Channel Outlet
5	34° 0' 21"	36° 18' 36"	Paradeniz - Hurma Drainage Channel Outlet
6	34° 4' 33"	36° 23' 59"	Tersakan
7	33° 59' 35"	36° 19' 7"	Akgol - Hurma Drainage Channel Outlet
8	34° 3' 56"	36° 20' 14"	Cirba River

Water quality assessment

This study evaluates the pollution of the waterbody in Goksu Delta region by using historical DO concentration data sampled from the designated streams and channels (See **Table 1**). Oxygen levels are significant for underwater habitats. DO concentrations are mostly affected by anthropogenic factors. Additionally, one-sample T-Test was applied as a statistical test in order to judge on the exact water quality class of the waterbody in aforementioned rivers and channels. A one-sample T-Test of whether the mean of a normally distributed population has a value specified in a null hypothesis. There is no need for a statistical test to decide on the water quality number of water quality parameters except Nitrite Nitrogen (NO_2-N). Because except NO_2-N concentrations, all parameters are clearly laid within the water quality class limits. However NO_2-N concentrations seem critical. Statistical analysis was applied in order to categorize river water quality in terms of Turkish Water Pollution Control Regulation (MEF 2004). Water quality classes mentioned in Turkish Water Pollution Control Regulation is shown in **Table 2**.

Table 2. Water quality classes according to Turkish Water Pollution Control Regulation

	Water Quality Class			
Parameter	**1**	**2**	**3**	**4**
Dissolved Oxygen (mg/l)	> 8	> 6	> 3	< 3
Ammonium Nitrogen (mg/l)	< 0.2	< 1	< 2	> 2
Nitrite Nitrogen (mg/l)	< 0.002	< 0.01	< 0.05	> 0.05
Nitrate Nitrogen (mg/l)	< 5	< 10	< 20	> 20
Total Dissolved Solid (mg/l)	< 500	< 1500	< 5000	> 5000
Total Phosphorus (mg/l)	< 0.02	< 0.16	< 0.65	> 0.65
BOD_5 (mg/l)	< 4	< 8	< 20	> 20
COD (mg/l)	< 25	< 50	< 70	> 70
Total Coliform (EMS/100 ml)	< 100	< 20000	< 100000	> 100000

Phosphorus (P) and nitrogen (N) cycles are disrupted primarily by our breadth of agriculture. N and P fertilizer pollution is present in all countries where agriculture uses fertilizers and in case of over application, fertilizers are released into the environment. Both N and P of course cause eutrophication of fresh water, and can cause algal blooms in fresh and salt water. The eutrophication potential of the Akgol and Paradeniz Lagoons was ascertained according to the Vollenweider model, using the historical water quality data. Also, Eutrophication potential of the aforementioned lagoons was determined according to eutrophication control limit values for lakes are specified by Turkish Water Pollution Control Regulation (MEF 2004) (See **Table 3**). Akgol Lagoon can be considered as a natural conservation area and Paradeniz Lagoon is naturally salty and bitter due to sea water intrusion.

Table 3. Eutrophication control limit values for lakes

Desired Water Quality Parameters	Usage	
	Natural conservation area and recreation	For various uses (naturally salty, bitter and soda lakes included)
pH	6.5-8.5	6-10.5
COD (mg/l)	3	8
DO (mg/l)	7.5	5
Suspended Solid (mg/l)	5	15
Total coliform (EMS)/100 ml	1000	1000
Total nitrogen (mg/l)	0.1	1
Total phosphorus (mg/l)	0.005	0.1

Results

Dissolved oxygen levels

Box plots were prepared in order to understand the temporal evolution of water pollution of the region in terms of DO concentration (See **Figure 5**). Outliers are distinguished in **Figure 5**. A minor outlier (denoted by a “o”) is an observation 1.5 x IQR outside the central box, where IQR is the interquartile range. As seen in **Figure 5**, Goksu River – Menderes and Akgol – Hurma Drainage Outlet have the lowest values of DO concentration in recent years. This is mostly due to the agricultural practices and recent increase in the number of settlements close to these two channels. Additionally, Goksu Rivers – Menderes is the last point of the Goksu River before it drains into the Mediterranean Sea. Also, Akgol - Hurma Drainage Outlet is the last point of the channel before it drains into the Akgol Lagoon.

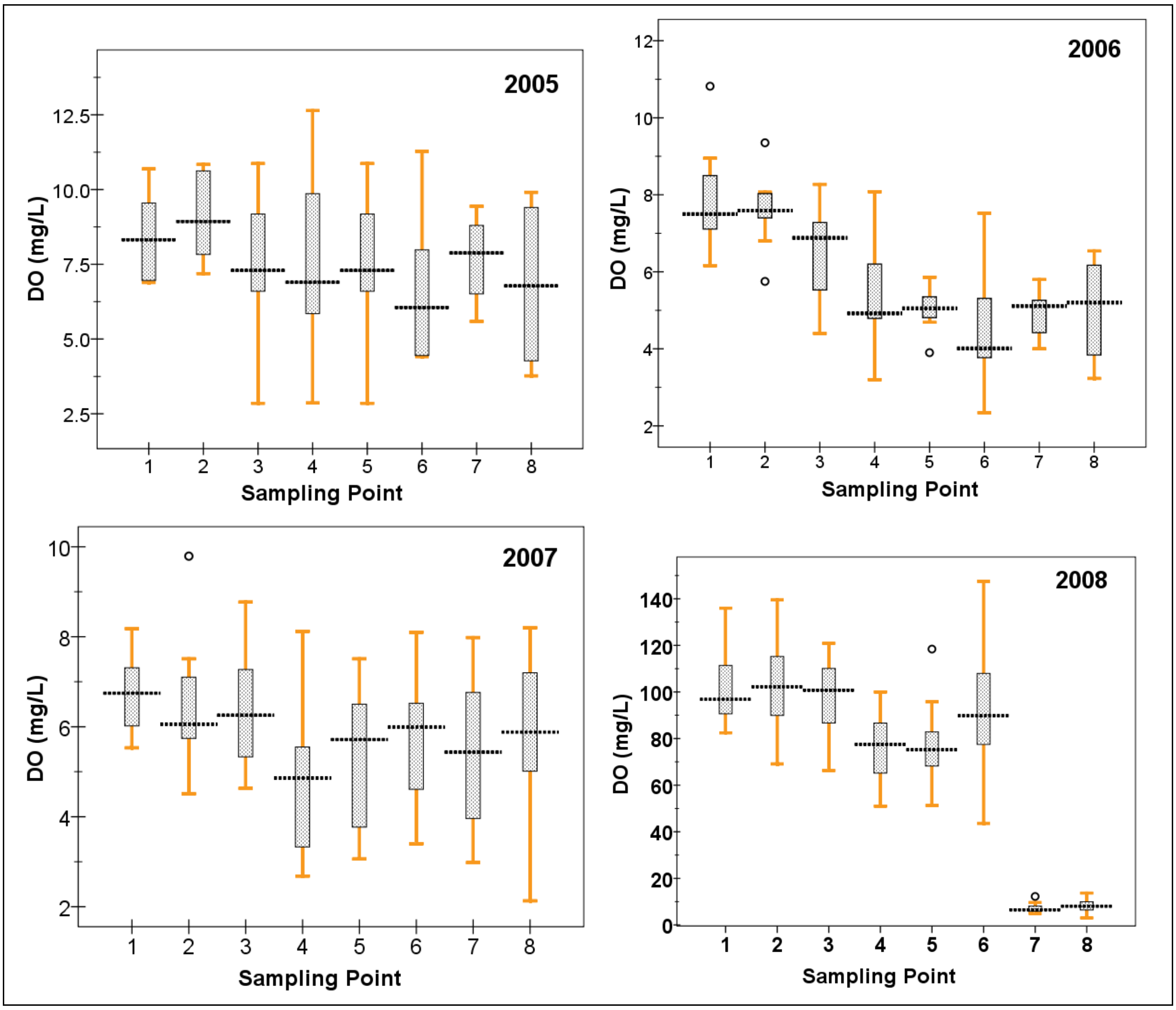

Figure 5. DO concentration levels in the 8 sampling points

One sample T-Test

Yearly average concentrations of the measured water quality parameters and matched water quality classes are shown in **Table 4**. WQCs are mentioned in paranthesis. Since the available NO_2-N data is continuous and also approximately normal, we can apply the One Sample T-Test (Sheskin 2003).

Nitrite Nitrogen data is available for this study and the average concentration for first, fourth and eighth sampling points is 0.01 mg/L, second, third, fifth and seveth sampling points is 0.02 mg/L and 0.04 mg/L for the sixth one. This means that in terms of NO_2-N concentrations, water quality of the eight points can be classified as WQC number 2, 3, 3, 2, 3, 3, 3, and 2, respectively. This classification is done according to Turkish Water Pollution Control Regulation.

Prescribed limits for Nitrite Nitrogen mentioned in Turkish Water Pollution Control Regulation are 0.002 mg/L, 0.01 mg/L, 0.05 mg/L, and more than 0.05 mg/L, respectively for four WQC. See **Table 5** for the One Sample T-Test results. The mean of the sample and confidence interval are shown. The confidence interval is the range in which the true population mean is likely to lie with the given probability. The t-statistic and hypothesis test are shown. The p-value is the probability of rejecting the null hypothesis, that the sample mean is the greater or equals to the hypothesized mean, when it is in fact true. A significant p-value implies that the sample mean is different from the hypothesized mean.

Table 4. Measured water quality parameters and matched water quality classes

YEAR	Point	Dissolved Oxygen (mg/l)	Ammonium Nitrogen (mg/l)	Nitrite Nitrogen (mg/l)	Nitrate Nitrogen (mg/l)	Total Nitrogen (mg/l)	Total Dissolved Solid (mg/l)	Total Phosp. (mg/l)	BOD_5 (mg/l)	COD (mg/l)	Total Coliform (EMS/100 ml)
2005	1	8.46 (1)	-	0.01 (2)	0.64 (1)	-	327.98 (1)	0.14 (2)	-	5.00 (1)	950.00 (2)
2005	2	9.06 (1)	-	0.01 (2)	0.81 (1)	-	335.13 (1)	0.17 (3)	-	5.22 (1)	1666.67 (2)
2005	3	7.35 (2)	-	0.01 (2)	0.42 (1)	-	2216.00 (3)	0.26 (3)	-	7.56 (1)	1383.33 (2)
2005	4	7.50 (2)	-	0.01 (2)	0.48 (1)	-	-	0.11 (2)	-	5.90 (1)	950.00 (2)
2005	5	7.35 (2)	-	0.01 (2)	0.42 (1)	-	2216.00 (3)	0.21 (3)	-	7.56 (1)	1383.33 (2)
2005	6	6.71 (2)	-	0.04 (3)	0.39 (1)	-	592.50 (2)	0.06 (2)	-	13.10 (1)	833.33 (2)
2005	7	7.68 (2)	-	-	-	-	-	0.09 (2)	-	27.38 (2)	1216.67 (2)
2005	8	6.82 (2)	-	0.09 (4)	0.73 (1)	-	2524.98 (3)	0.62 (3)	-	13.78 (1)	1283.33 (2)
2006	1	7.88 (2)	0.05 (1)	0.03 (3)	0.73 (1)	-	179.73 (1)	0.04 (2)	4.00 (1)	5.67 (1)	1444.44 (2)
2006	2	7.59 (2)	0.13 (1)	0.04 (3)	0.72 (1)	-	199.98 (1)	0.06 (2)	4.33 (2)	7.93 (1)	1766.67 (2)
2006	3	6.55 (2)	0.13 (1)	0.04 (3)	0.49 (1)	-	967.67 (2)	0.08 (2)	4.00 (1)	6.69 (1)	1677.78 (2)
2006	4	5.26 (3)	0.06 (1)	0.03 (3)	0.36 (1)	-	315.38 (1)	0.04 (2)	4.00 (1)	9.04 (1)	1511.11 (2)
2006	5	5.07 (3)	0.08 (1)	0.04 (3)	0.40 (1)	-	423.44 (1)	0.05 (2)	4.00 (1)	7.36 (1)	1533.33 (2)
2006	6	4.57 (3)	0.25 (2)	0.04 (3)	0.80 (1)	-	1823.78 (3)	0.18 (3)	4.00 (1)	12.88 (1)	1666.67 (2)
2006	7	4.90 (3)	-	-	-	0.89 (1)	-	0.04 (2)	-	11.65 (1)	1700.00 (2)
2006	8	4.94 (3)	-	-	-	0.73 (1)	-	0.08 (2)	-	15.43 (1)	1700.00 (2)
2007	1	6.76 (2)	0.06 (1)	0.02 (3)	0.54 (1)	-	-	0.12 (2)	4.00 (1)	5.00 (1)	1870.00 (2)
2007	2	6.47 (2)	0.07 (1)	0.02 (3)	0.57 (1)	-	-	0.12 (2)	64.8 (4)	104.5 (4)	2490.00 (2)
2007	3	6.39 (2)	0.07 (1)	0.03 (3)	0.60 (1)	-	-	0.14 (2)	4.00 (1)	5.00 (1)	2360.00 (2)
2007	4	4.91 (3)	0.05 (1)	0.02 (3)	0.38 (1)	-	-	0.11 (2)	4.00 (1)	5.00 (1)	2185.00 (2)
2007	5	5.38 (3)	0.05 (1)	0.03 (3)	0.37 (1)	-	-	0.11 (2)	4.00 (1)	5.20 (1)	2340.00 (2)
2007	6	5.65 (3)	0.11 (1)	0.05 (3)	0.34 (1)	-	-	0.23 (3)	4.00 (1)	13.52 (1)	2165.00 (2)
2007	7	5.38 (3)	-	-	-	1.17 (1)	-	0.09 (2)	-	5.12 (1)	2100.00 (2)
2007	8	5.75 (3)	-	-	-	0.64 (1)	-	0.20 (3)	-	16.56 (1)	1820.00 (2)
2008	1	102.40 (1)	0.05 (1)	0.01 (2)	-	1.29 (1)	-	0.03 (2)	-	-	1458.33 (2)
2008	2	103.04 (1)	0.08 (1)	0.02 (3)	-	1.45 (1)	-	0.07 (2)	-	-	1825.00 (2)
2008	3	97.51 (1)	0.07 (1)	0.02 (3)	-	1.18 (1)	-	0.05 (2)	-	-	1254.17 (2)
2008	4	76.13 (1)	0.06 (1)	0.01 (2)	-	1.18 (1)	-	0.03 (2)	-	-	1516.67 (2)
2008	5	77.66 (1)	0.06 (1)	0.02 (3)	-	0.99 (1)	-	0.03 (2)	-	-	1683.33 (2)
2008	6	94.06 (1)	0.12 (1)	0.04 (3)	-	2.41 (1)	-	0.10 (2)	-	-	2062.50 (2)
2008	7	7.22 (2)	0.08 (1)	0.02 (3)	-	1.78 (1)	-	0.03 (2)	-	5.55 (1)	2116.67 (2)
2008	8	8.35 (1)	0.04 (1)	0.01 (2)	-	0.63 (1)	-	0.04 (2)	-	27.13 (2)	1975.00 (2)

Table 5. One Sample T-Test results

One Sample T-Test about whether or not NO_2-N is above the prescribed limits mentioned in Turkish Water Pollution Control Regulation (Concentrations are in mg/l)										
Point	Mean Value of Concentration (Conc.)	Standard Deviation	Degree of Freedom	Test Value	Prescribed Limits in terms of Four Water Quality Classes (WQC).	p-value (level of significance)	Coefficient of Determination, R^2 (observed value vs. Expected normal value)	Hypothesis check: ($\mu_0 \geq$ Test Value or $\mu_a <$ Test Value). 95% Confidence Interval (CI)	Decision (According to T-Test)	Decision (According to Mean Value of Conc.)
1	0.01	0.0078	11	0.01	Conc. < 0.002: WQC-I. 0.002 $\leq$ Conc. < 0.01: WQC-II. 0.01 $\leq$ Conc. < 0.05: WQC-III. Conc. $\geq$ 0.05: WQC-IV.	0.157	0.997	95% CI includes null value, accept null hypothesis.	Water Quality Class Number 3	Water Quality Class Number 2
2	0.02	0.0182	11	0.05	Same as above	0.001	0.888	95% CI excludes null value, reject null hypothesis.	WQC Number 3	WQC Number 3
3	0.02	0.0119	11	0.05	Same as above	0.000	0.916	95% CI excludes null value, reject null hypothesis.	WQC Number 3	WQC Number 3
4	0.01	0.0060	11	0.01	Same as above	0.290	0.981	95% CI includes null value, accept null hypothesis.	WQC Number 3	WQC Number 2
5	0.02	0.0121	11	0.05	Same as above	0.000	0.831	95% CI excludes null value, reject null hypothesis.	WQC Number 3	WQC Number 3
6	0.04	0.0464	11	0.05	Same as above	0.419	0.784	95% CI includes null value, accept null hypothesis.	WQC Number 4	WQC Number 3
7	0.02	0.0103	11	0.05	Same as above	0.000	0.965	95% CI excludes null value, reject null hypothesis.	WQC Number 3	WQC Number 3
8	0.01	0.0041	11	0.01	Same as above	0.054	0.984	95% CI includes null value, accept null hypothesis.	WQC Number 3	WQC Number 2

Nutrient pollution and eutrophic status

Phosphorus loading from streams is a key factor in raising the risk of eutrophication in Akgol Lagoon and Paradeniz Lagoon. Eutrophication affects the dissolved oxygen (DO) concentration in lakes. If **Figure 6** and **Figure 7** are inspected, decrease in phosphorus loading is observed for year 2008. This is because of the waste water treatment efforts started with the constructed waste water treatment plant in 2007. The eutrophication potential of the lake was ascertained according to the Vollenweider model, using the historical water quality data (See **Table 6**). Eutrophication control limit values for lakes are specified by Turkish Water Pollution Control Regulation (MEF 2004) (See **Table 3**). Annual average concentrations of Water quality parameters show that they are above the prescribed limits defined by Turkish Water Pollution Control Regulation. Another technique for the reveal of eutrophication status of the Lagoons is to use the Vollenweider diagram or Vollenweider model. The Vollenweider diagram shows the trophic level of the lake using empirical formulas developed by notable limnologist Richard A. Vollenweider. The Vollenweider model has been developed with data from several hundred lakes worldwide, and a generalized regression of the data collected from 750 lakes has also been developed (Domagalski et al. 2007). The diagram and formulas are the consequences of the above cited research on lakes. Permissible and excessive loadings are calculated by empirical formulas (Havens et al. 2005; Vollenweider 1975). The average surface area (A) of Akgol and Paradeniz Lagoons are $12*10^6$ m^2 and $4.92*10^6$ m^2. According to Vollenweider (1975), permissible loading ($L_P(P)$) and excessive loading ($L_e(P)$) are given as:

$$L_P(P) = 100 + 10\ (Z/R_w) \quad (1)$$

$$L_e(P) = 200 + 20\ (Z/R_w) \quad (2)$$

Where R_w represents the hydraulic residence time.

Volume (V) of Akgol and Paradeniz Lagoons are $12*10^6$ m^3 and $7.38*10^6$ m^3 and their mean depths (Z) are 1 m and 1.5 m, respectively. Hydraulic residence time is represented as:

$$R_w = V / Q \quad (3)$$

Where R_w (T) is residence time, V is residence volume (lake volume), and Q is reservoir inflow.

The normalized phosphorus loading can be understood as the average concentration of phosphorus in the reservoir as a whole, based on the annual loading (Xiao et al. 2007). The phosphorus loads were calculated using the measured Total Phosphorus concentrations of the Akgol and Paradeniz Lagoons. Finally, discharges (Qs) dumped into lagoons by the three channel outlets were calculated. The calculated phosphorus loads for each year are represented on a Vollenweider diagram (See **Figure 6 and Figure 7**). Results indicate that in recent years, the risk of eutrophication for lagoons has been decreasing. However, suspended solid concentration of the Akgol and Paradeniz Lagoon are much higher than prescribed limits mentioned in **Table 3**. High amount of fluvial sediment transported by feeding channels causes an eutrophication threat for the lagoons.

Table 6. Historical annual average water quality data of Akgol and Paradeniz Lagoons

Lagoon	Year	pH	DO (mg/l)	Suspended Solid (mg/l)	Temp. (^oC)	COD (mg/l)	BOD_5 (mg/l)	SO_4^{2-} (mg/l)	Cl^- (mg/l)	Total Nitrogen (mg/l)	Total Phosphorus (mg/l)
Akgol	2005	7.5	3.6	95	-	-	-	-	-	0.43	0.28
	2006	-	-	148	22.75	36	15.75	325.68	891.8	5.38	0.11
	2007	-	-	215	21.25	29	12.5	135	2065	11.86	0.063
	2008	-	-	267	21.75	33	13.85	240	4119	6.17	0.089
Paradeniz	2005	7.7	3.02	239	-	-	-	-	-	6.8	0.23
	2006	-	-	255	23.75	59	14	1414.8	14155	6.04	0.13
	2007	-	-	292.5	22.5	67	27	982.44	11468	21.32	0.55
	2008	-	-	384.5	23	48	26.5	1262.6	14907	19.22	0.11

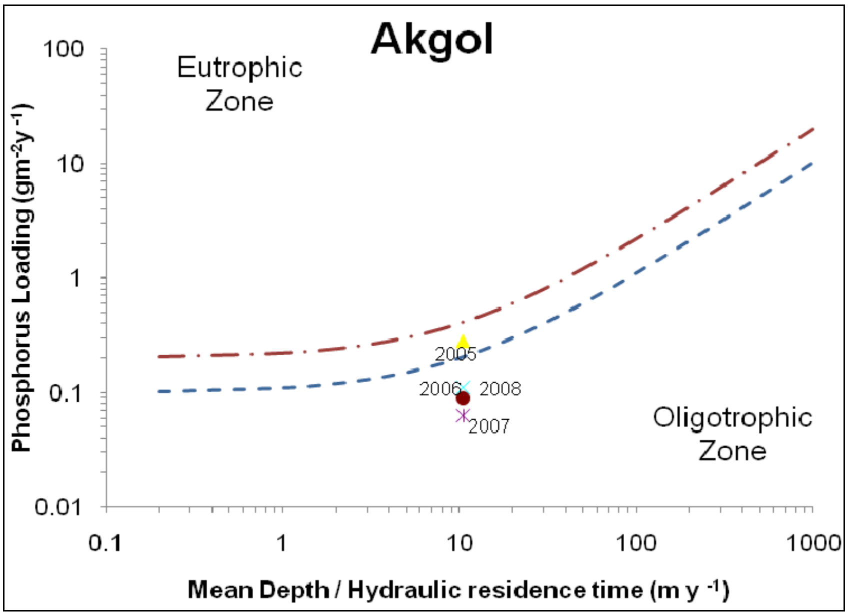

Figure 6. Phosphorus loads in Akgol Lagoon for each year

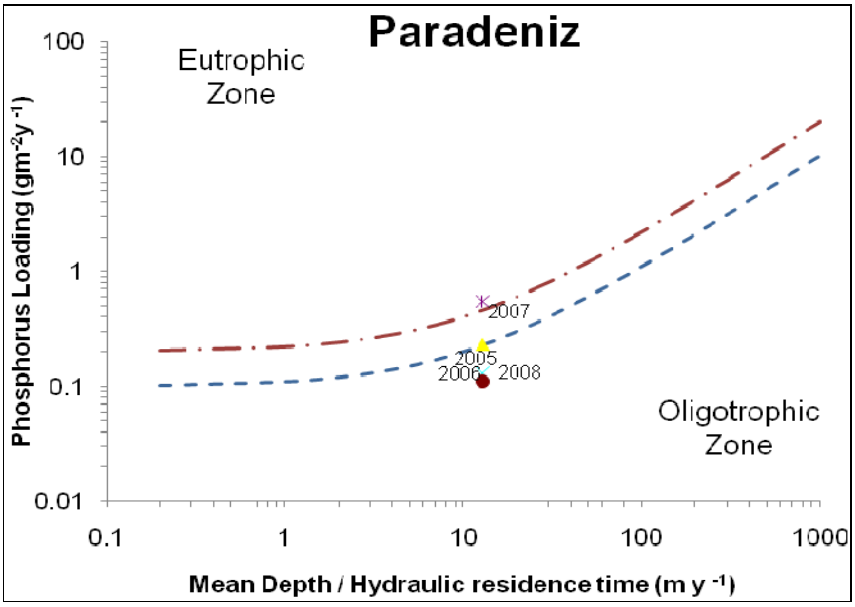

Figure 7. Phosphorus loads in Paradeniz Lagoon for each year

Conclusion

The management of water resources becomes highly complicated as a result of upstream and downstream impacts. In order to foresee these impacts, historical data should be analyzed and necessary measurements have to be taken. This study evaluates the pollution of the waterbody in Goksu Delta region by using historical water quality parameters measured in designated streams and channels. First the impact of pollution load was investigated on the dissolved oxygen (DO). Additionally, water quality was assessed according to classification mentioned in Turkish Water Pollution Control Regulation (MEF 2004). Moreover, one-sample T-Test was applied as a statistical test in order to reveal the exact water quality class of the waterbody in aforementioned rivers and channels in terms of Turkish Water Pollution Control Regulation (MEF 2004).

Finally, total phosphorus loads for each year were calculated and represented on a Vollenweider diagram, which shows the trophic level of the lake. Eutrophication potential of Akgol and Paradeniz Lagoons were also assessed according to eutrophication control limit values for lakes that are specified by Turkish Water Pollution Control Regulation. Results show that there has been a considerable risk of eutrophication for Akgol and Paradeniz Lagoons in recent years. The most frequent pollution problem, eutrophication, is caused by the fluvial transport of excess amounts of nutrient loading. A considerable amount of nutrient loading comes from residences settled around the aforementioned channels that flow into Akgol and Paradeniz Lagoons. Suspended sediment concentrations of these two lagoons are much higher than the prescribed limits. Demographic change is a significant external factor against the conservation of environment. Residential development has caused an increase in the number of settlements that has aggravated the problem of pollution. These results reveal the importance of waste management around the Goksu Rivers and of the water quality of the channels that drain into Akgol and Paradeniz Lagoons. Emission reduction of total nutrients can be achieved using management actions such as reforestation, buffer strips, and erosion control. Nutrient emissions from erosion are common due to agricultural practices, and these have a significant effect on surface water nutrient concentrations. Therefore, practices of prevention and control of erosion are crucial to improve water quality. Improved management actions should be applied as soon as possible to reduce the eutrophication risk of Akgol and Paradeniz Lagoons. Treatment practices in the Goksu River Basin must be improved as soon as possible. Urbanization of the Goksu River Basin have resulted in the degradation of the water quality. There is no significant measure regarding the improvement of rivers' water quality. Thus, introducing a proper waste management system around rivers has to be a priority for governors.

Sustainable development is a pattern of resource use that aims to meet human needs while preserving the environment. Therefore these needs can be met not only in the present, but also for future generations. Achieving sustainable resources and environmental management regarding water, waste, climate change, air quality and/or land is highly important in Goksu Delta region. Measures to protect the Goksu River Basin can only be sustainable if governments promote economic development while at the same time raising the living standards of the region's people. The creation of new protected areas in watershed is a significant step for conservation. Preservation efforts in Goksu River Basin ecosystem are particularly important because of its great biological diversity. The necessary investigations have to be done by the authorities and they should apply the required adjustments. As a recommendation, water quality protection efforts should be applied considering The European Water Framework Directive. Water quality protection practices can be the modernization and construction of infrastructure, improvement of municipal and industrial waste handling, constructing additional waste water treatment plants, reduction of emissions wastes, and dangerous materials in agriculture and so on. After the construction of treatment plant in Silifke, considerable increase in water quality has been observed in the region. There is a tremendous increase in the population of Silifke district due to the high immigration rate. Hence, single treatment plant will not be adequate in the future for growing population. Biomanipulation could be an effective method for controlling eutrophication in Akgol and Paradeniz Lagoons. Following biomanipulation significant reduction in chlorophyll would occur. The best management technique could be the rearrangement of settlement in the region. Buffer zone implementations around the rivers and the coastal zone would help decrease the pollution loads carried to Goksu River. Another best management technique could be to constrain the use of pesticides in agriculture and to support the success of organic agriculture in the Goksu Delta area.

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