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INFLUENCE OF SUSTAINABLE CONSTRUCTION MATERIALS AND TECHNOLOGIES ON ENVIRONMENT: A CASE STUDY FROM MERSIN PROVINCE OF TURKEY

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Abstract

Mersin province is in Mediterranean Region of Turkey. Unfortunately the city harms its own water resources because of massive settlements. Due to immigrations for decades, surface water quality continues to decline. This is a handicap situation for the sustainable urban development. Main pollution sources in city are the uncontrolled agriculture and unplanned constructions. In this study, pollution parameters will be analyzed in a statistical manner. Current pollution status will be identified. Reasons of the environmental pollution and resources that are responsible of the pollution will be reviewed. The relationship between rainfall and surface water pollution will be revealed. A mathematical relation between rainfall and water quality parameters will be investigated. Factors affecting runoff and soil erosion will be displayed. Against the current pollution, landscape and urban management techniques will be discussed. As a sustainable construction technology, green roof application will be proposed for the research area in order to decrease surface runoff. Although green roof applications are widespread in Europe, Turkey is not very familiar with this system. Results of the study show that the green roof application will decrease the stormwater runoff significantly.

Keywords: Green roof, rainfall, surface water pollution, sustainability, urban management

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1 Introduction

Goksu Delta is a wetland ecosystem located in Silifke district of Mersin province in Mediterranean Region of Turkey (See Figure 1). 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 [1]. Goksu Delta has been added to Ramsar list in 1994 [2]. Goksu Delta is being protected by the Ramsar Convention.



Figure 1. Location of Goksu Delta

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.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 neighbour underdeveloped cities. This study aims to examine the success of green roof application in terms of water quality improvement. Also, water quality of the Goksu River will be assessed and possible sustainable urban development methodologies will be discussed within this study.

2 Methodology

2.1 Sustainable urban development

Sustainable development can be defined as a pattern of resource use that aims to meet human needs while preserving the environment [3]. These needs can be met not only in the present, but also for future generations. It is crucial to achieve sustainable resources for an eco-friendly development. There are three key dimensions of urban social sustainability, these are; equity, sense of community, and urbanity [4]. The developing countries are more vulnerable than developed countries to environmental hazards. Rapid urbanization and urban development in cities of many developing countries are causing environmental problems such as water, air, and noise pollution. Surface water is polluted as a result of the lack of sewerage system and sewage treatment plants [5]. Designing cities compatible with their ecological surroundings will have considerable impacts on the establishment of sustainable landscapes [6]. 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. 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 [7]. Appropriate sustainability indicators can be developed on the basis of shared perceptions; such as stewardship [8]. Increasingly, legislative requirements are being placed on councils and businesses to incorporate sustainability into their activities. The construction industry plays a key role putting the concept of sustainability into practice. Construction industry can be described as major consumer of natural resources and potential polluter of the environment. However, sustainability is not only the responsibility of government and the construction industry. Citizens also need to get involved and be aware of the impacts of their behavior and their use and misuse of resources. Contributions in

construction industry can be on the use of innovative materials for the renewal of building systems and structures and design for durability [9].

2.2 Surface water quality assessment

World has a very scarce freshwater resources and it is highly important to meet water quality standards. This can be achieved through the strong ecological management techniques [10]. Streams, lakes, estuaries, and seas are under the threat of wastewaters from industrial, agricultural, and domestic sources [11]. Settlements are usually located nearby the fresh water resources. Management of water resources complicated because of the upstream and downstream impacts of these settlements. In this research, some pollution parameters were inspected in order to determine the current pollution level of the Goksu River in the region. Samples were collected from the three designated points (See Figure 2 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 River Watershed. Goksu Delta is a small portion of the whole Goksu River Watershed. Because of the geographical, soil properties of the Basin (See Figures 3, 4) and restrictions of Ramsar Convension [1, 2], settlements are mainly located around the upper part of the Delta area. Goksu River is passing through the city and city is located between sampling points 1, 2 (See Figure 2).



Figure 2. 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

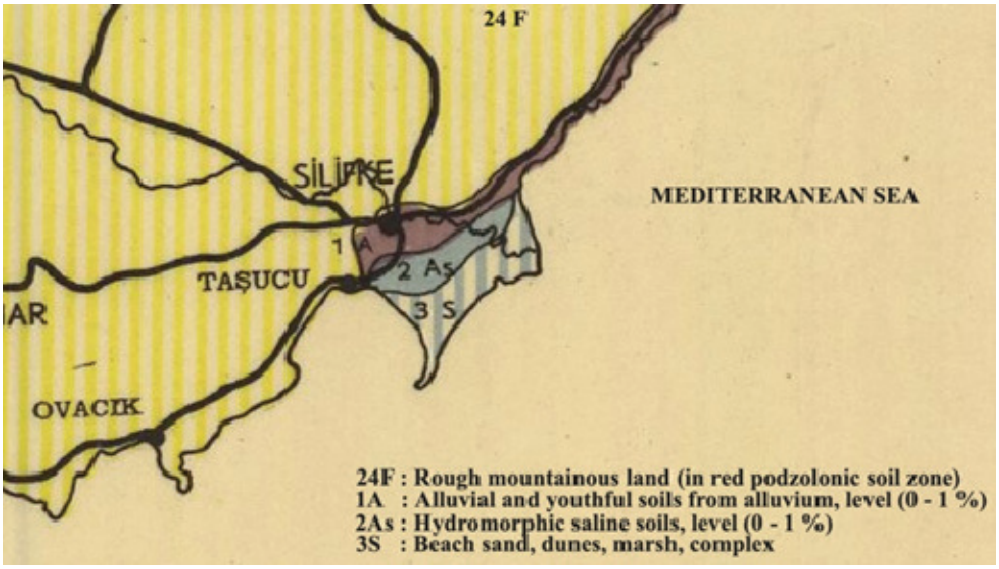


Figure 3. Soil classification of the Goksu River Watershed [12]

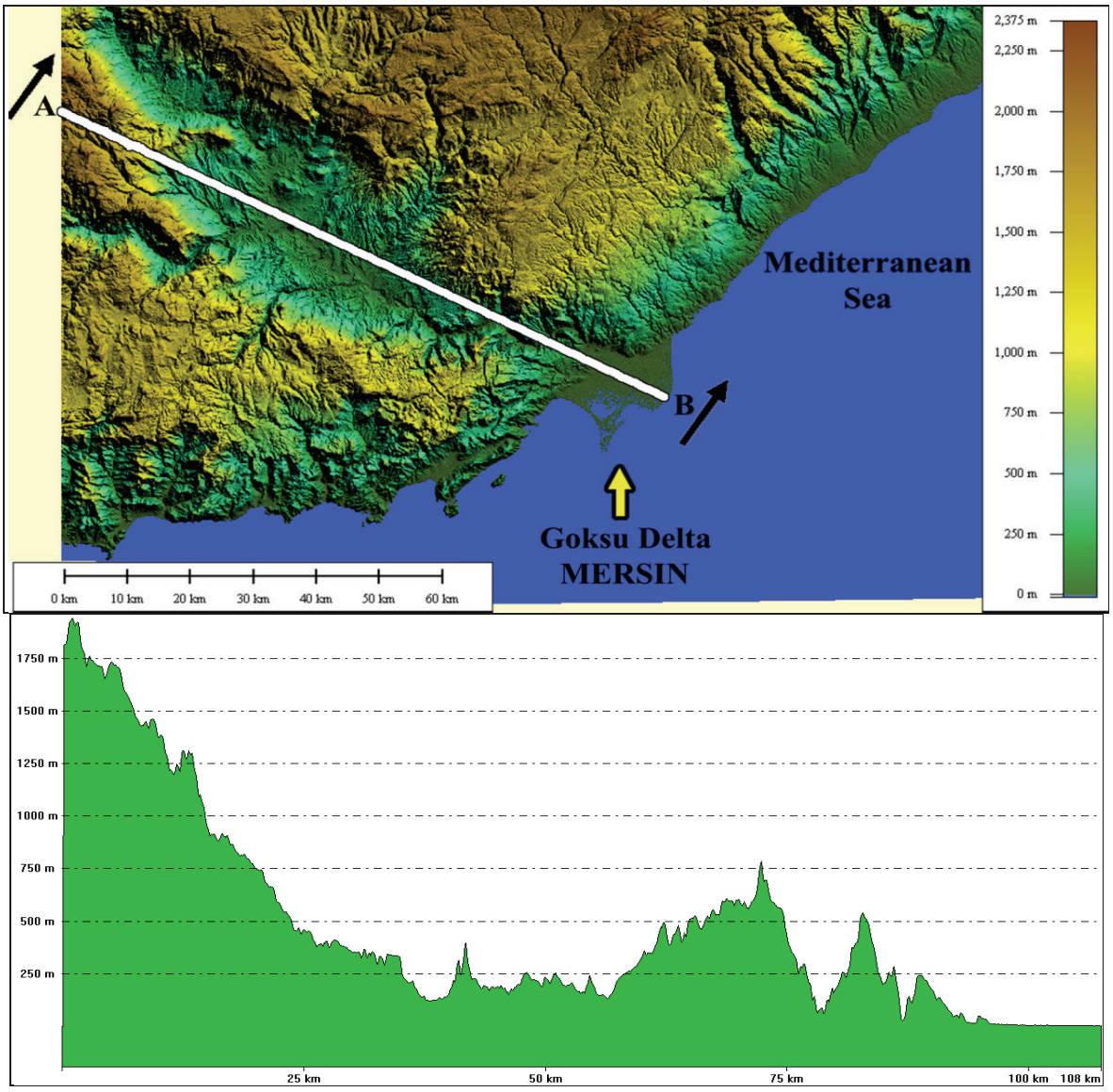


Figure 4. Digital elevation model, elevation distribution of Goksu Watershed (A-B cross section)

2.3 One sample T-Test

Yearly average concentrations of the measured water quality parameters and matched water quality classes are shown in results section of the study. Water quality classes (WQCs) are shown in paranthesis. This classification is done according to Turkish Water Pollution Control Regulation (See Table 2). Since the available NO_2-N data is continuous and also approximately normal, we can apply the One Sample T-Test [13].

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

2.4 Watershed management

A watershed is an entire drainage region with sources of water like rainfall, snowmelt drains into sea, river, lake, wetlands, estuaries, etc. Agricultural production is important for Goksu Delta, in terms of economic growth. Agricultural production, industrial and social development, construction industry 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 [14]. Watershed management is considered as the most appropriate approach to ensure the preservation, conservation and sustainability of all land based resources. It also helps for the improvement of the living people's living conditions. Water quality is dependent on healthy ecosystems and sustainable land use management in watersheds [15]. Best management practices are applied to conserve natural sources 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 and the promotion of organic agriculture [16]. This list can be extended with change in land use types, rehabilitation of arid lands, upgrading septic systems and municipal wastewater treatment facilities to reduce the total phosphorus concentrations.

2.5 Green roof application

Plant covered roof systems in any man made building, that are used to decrease runoff value, reduce heat island effects and insulate buildings are called as Green Roofs [17]. The main object in this study is to analyze the feasibility of green roof systems for Goksu River Watershed in Silifke District of Mersin Province - Turkey. Green roofs can be separated in to two main groups. These are; intensive and extensive. Intensive roofs are usually more than 20 cm deep which allows for the growth of larger plants such as trees. Since it has very large soil thickness and tall plants, above the roof, there is more structural loading imposed by an intensive roof. Extensive roofs on the other hand, contain smaller plants, such as; shrubs, sedums, and herbs. Parts of the typical extensive green roof system are shown in Figure 5. In Germany, many living roofs are still functioning beyond fifty years of installation [18] because the roof system protects the roofing deck from harmful ultra-violet radiation as well as from hail, wind, and other atmospheric antagonists. Extensive green roofs can be applied on most flat roofs as well as angled roofs where permitted slope is no more than 30-45% [19], also some manufacturers can produce vertical living walls [20]. It is clear that for the ease of green roof system implementation, local government involvement must be promoted [21].

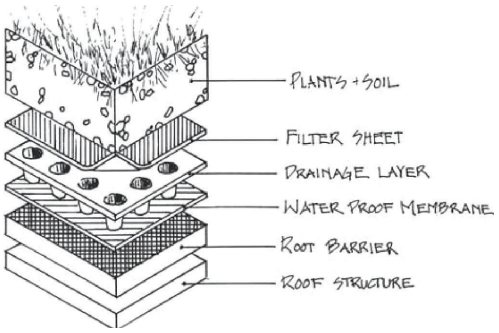


Figure 5. Green roof cross-section [22]

Vegetation medium should not be very thick for the extensive green roof systems. Root depth of 10 cm should be considered to minimize the soil medium depth. Between the soil medium and the drainage mat there is a permeable soil filter fabric that is known as geotextiles. It retains the soil and keeps the roots of the vegetation from penetrating the drainage layer and potentially clogging the drainage layer [23]. The drainage mat diverts any excess rain water that is not absorbed by the soil medium or vegetation to roof top drains. Geomembranes are impermeable layers that protect the roof deck from infiltration of water. Multiple sheets of geomembranes can be welded together to make one continuous impenetrable layer protecting the roof deck [23]. Sedums are commonly used for vegetation coverage because of their ability to store water in their leaves for extended periods of time.

2.5.1 Types of Green Roofs

According to Dinsdale et. al [23], there are three most common systems exist, these are: complete, modular and precultivated vegetative blankets, respectively (See Figure 6- a, b, c). Compared to complete systems, modular green roof and pre-cultivated blanket layer systems are very practical, and ease to apply systems.



Figure 6-a. Complete systems [24]



Figure 6-b. Modular green roof [25]



Figure 6-c. Pre-cultivated blanket layer [26]

2.5.2 LEED credit impacts

Leadership in Energy & Environmental Design (LEED) is a rating system that has been developed in the United States. Green roofs can facilitate a significant improvement in the LEED rating of a building, depending on design and level of integration with other building systems. The use of vegetation on roofs has origins dating as far back as the Hanging Gardens of Babylon. Although the oldest Green Roof in the United States was built in 1930 on top of the Rockefeller Center, interest in Green Roof technology has only occurred within the last 15 years. Currently, Chicago, Portland and New York are the leaders in implementing Green Roof technology in the United States. Approximately 30−40 % of global energy consumption as well as 20−30 % of greenhouse gas emissions can be traced back to the construction industry [27]. Hence, impact of construction projects on the environment originates from the construction materials, the nature of the design of the houses, the construction methods, the location and layout, as well as from energy consumption [27, 28]. This will have serious implications

for the construction sector, as the built environment is a substantial contributor to greenhouse gas emissions. The Kyoto Protocol requires a substantial reduction in greenhouse gas emissions and it is believed that green roof systems may help for the reduction of green house gasses such as CO_2, NO_x in cities. The realization of vegetated roofs finds more and more frequent application in the building sector, although still there is a hesitation among policy makers and designers [29]. The building of green roofs is becoming a good practice in a lot of countries in Europe, especially in Germany, Netherlands, as well as in the USA [30]. A range of different types of designs are now available and realized from very extensive till intensive roofs. There are seven main benefits to having a green roof. They include increased energy efficiency, an increase in air quality, a decrease in heat island effect, temperature regulation both on the roof and surrounding areas, stormwater retention, an increase in roof lifespan and a LEED point. Vegetation provides also nesting places for birds such as, blackbirds, song thrushes and house sparrows.

3 Results

Water quality was assessed according to classification mentioned in Turkish Water Pollution Control Regulation [31] (See Table 3). 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 in terms of Turkish Water Pollution Control Regulation [31]. One-sample T-Test was applied for NO_2-N data because of the reasons mentioned in section 2.3. See Table 4 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 in Table 4. 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. Rainfall can be a significant source of variation in surface-water quality. Total rainfall greatly affects the dynamics of the environments, transports nutrients and allochthonous materials, and alters the water's visual, physical and chemical characteristics [32]. Rainfall is expected to have high correlations with nutrients. Locally green roofs can potentially alleviate overloading of municipal sewer systems by stabilizing water flow and reducing stormwater runoff from 70% to 90% annually [34, 35]. Monthly mean rainfall values for the region are shown in Figure 7 for years between 2005 and 2008. There is a great correlation between Green Roof systems and LEED certification (See Table 5). For the plant selection, in accordance with the LEED requirements, some local plants are suggested in this study. Osmunda Regalis and Sedum are local plants that are approached as green roof plant alternatives in this study in accordance with the Mersin climate (See Figure 8 – a, b). According to sample calculation, when a single building with a roof area of 900 m^2 is considered, there will be 77 % water retention by the usage of green roof systems within the subbasin 2 (Table 6). Preferred system may be either the usage of Modular systems or Pre-cultivated blanket layer application as an Extensive Type Green Roofs. These systems have less labor and material cost and very easy to apply, even for the old buildings. Green roofs have been credited with the ability to significantly improve the beauty of buildings and to appeal to the senses of people [23]. Watershed delineation and subbasin portions and areas are mention in Figures 9 and 10. Nitrogen and phosphorus are both nutrients. The effects of these nutrients on water are almost the same. 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. Considering monthly rainfall concentrations and water quality data, a nonlinear function was defined to show the total phosphorus (TP) concentrations as a function of rainfall value (See Figure 11). Observed and predicted values for monthly average TP concentrations in sampling point 2 at subbasin 2 are shown in Figure 11. It is revealed that 80 % of the subbasin 2 area is highly urbanized area, and at least 50 percent of this area is covered by roofs. For the calculations regarding the runoff retention, it is considered that 90 percent of the roof area is covered by extensive green roof systems. Predictions were done according to two cases; with or without green roof application for the buildings in subbasin 2 area.

Table 3. 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)
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)
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)
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)

Table 4. 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 ≤ Conc. < 0.01: WQC-II. 0.01 ≤ Conc. < 0.05: WQC-III. Conc. ≥ 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

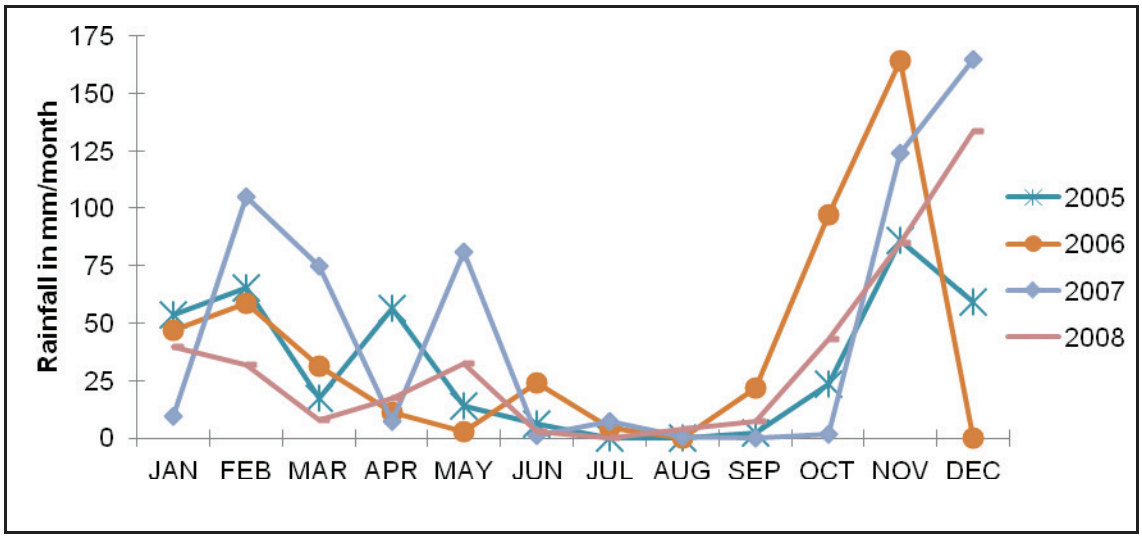


Figure 7. Monthly rainfall values for Goksu Watershed, Silifke – Mersin [36]

Table 5. LEED Credit Impacts

Primary Credit Impacts			
Credits	**Categories**	**Requirements**	**Points**
5.1	Sustainable Sites	Protect or Restore Open Space	1
6.1, 6.2	Sustainable Sites	Stormwater Management Rate, Quantity, and Treatment	2
7.2	Sustainable Sites	Design to Reduce Heat Islands (Roof)	1
1.1	Water Efficiency	Water-Efficient Landscaping	1
1.0	Innovation and Design	Innovation in Design	1
Secondary Credit Impacts			
Credits	**Categories**	**Requirements**	**Points**
1.0	Energy and Atmosphere	Optimizing Energy Performance	2
4	Energy and Atmosphere	Ozone Depletion	1
4.1, 4.2	Materials and Resources	Recycled Content (roof system components)	2
5.1, 5.2	Materials and Resources	Local/Regional Materials (roof components, plants)	2
2	Water Efficiency	Innovative Wastewater Technologies	1
3.1, 3.2	Water Efficiency	Water Use Reduction (20%, 30%)	2
TOTAL DERIVED POSSIBLE LEED POINTS : 6 + 10 =			**16**





Figure 8-a. Sedum plant **Figure 8-b.** Osmunda Regalis

Table 6. Potential rain water retention by a green roof of a sample building at Silifke –Mersin

Roof	
Green roof surface area (m^2)	900
Rain Fall	
Regional 10 year storm (cm of rainfall)	15
Growth Media	
Growth media depth (cm)	20
Dry Weight (kg/m^3)	0.64
Saturated Weight (kg/m^3)	1
Moisture Retention Fabric	
Moisture retention fabric dry weight (kg/m^2)	7.3
Moisture ret. fabric saturated weight (kg/m^2)	8.8
Drainage Core	
Top diameter of cups (cm)	0.65
Bottom diameter of cups (cm)	0.65
Cup height (cm)	1.30
Number of cups per m^2	872
Water retained (lt/m^2)	1.67
Volume of retained water (lt)	1502.90
Total tons retained	1.50
Run off coefficient	0.23

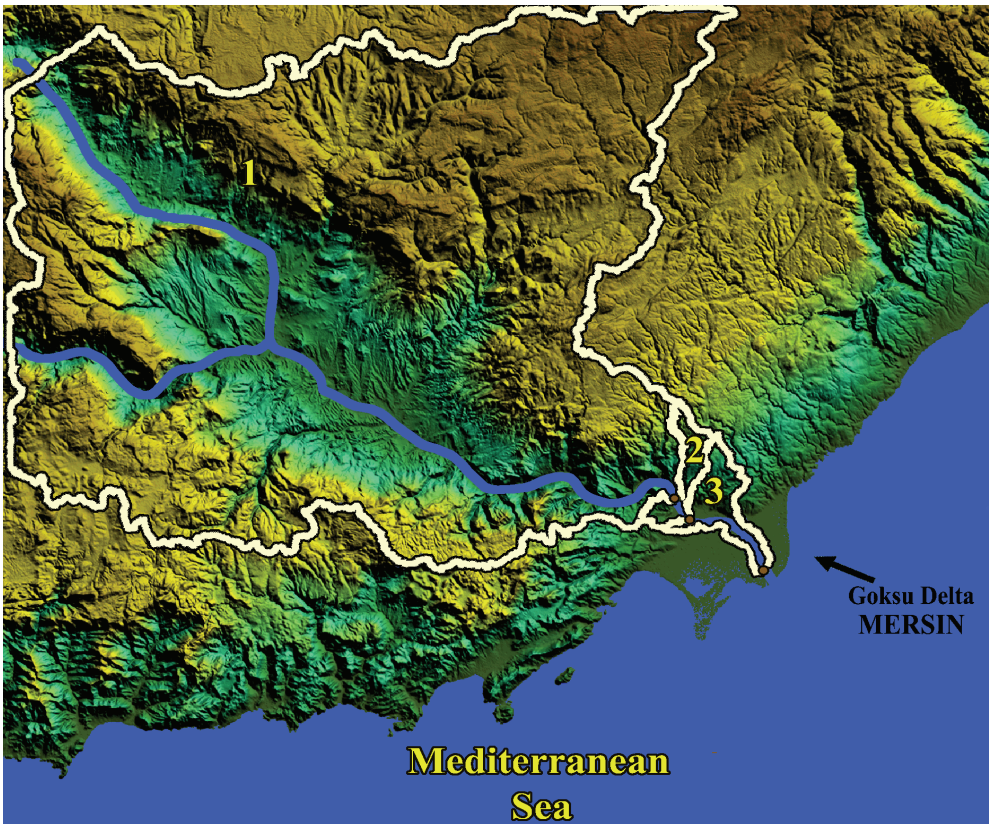


Figure 9. Delineated Subbasins of Goksu River Watershed

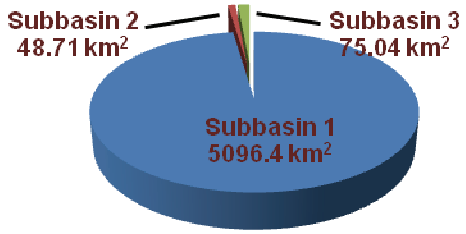


Figure 10. Areas occupied by subbasins

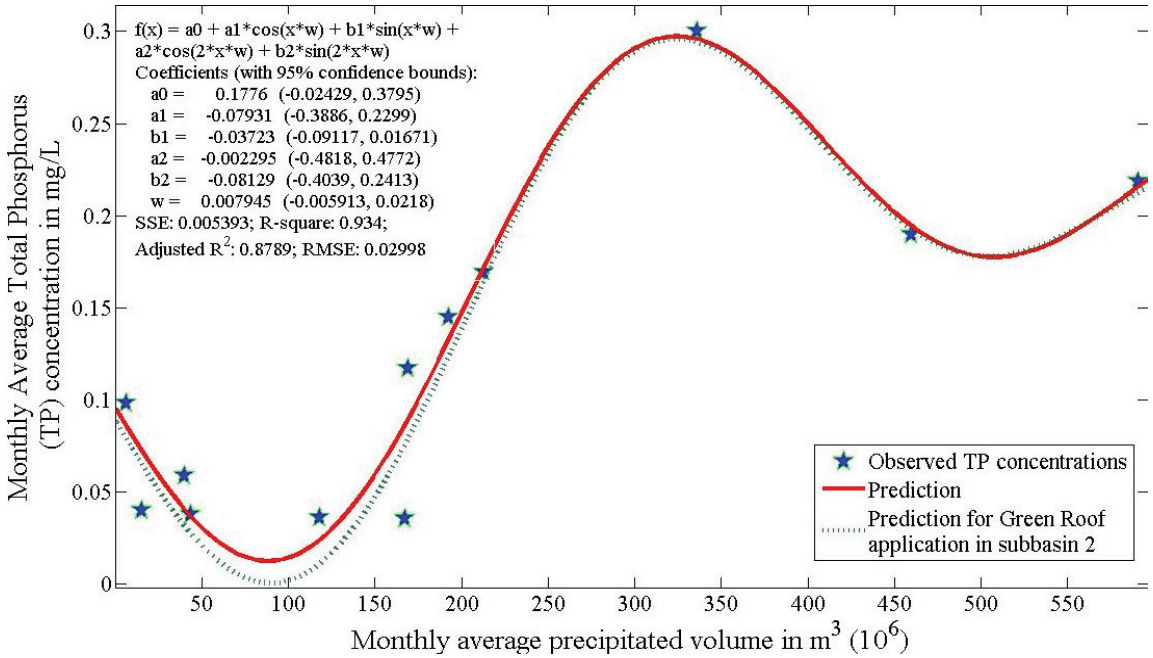


Figure 11. Observed and predicted values for monthly average TP concentrations in sampling point 2 at subbasin 2, with or without green roof application.

4 Conclusion

Measures to protect the Goksu River Watershed can only be sustainable if governments promote economic development while at the same time raising the living standards of the region's people. Sustainable development is a pattern of resource use that aims to meet human needs while preserving the environment [3]. These needs should be met not only in the present, but also for future generations. Government should encourage people at every opportunity to become better educated on environment protection. All developing regions have experienced substantial environmental degradation over the past decades. The creation of new protected areas, especially in subbasin 2 of whole watershed, could be a significant step for conservation. Preservation efforts in Goksu River Watershed ecosystem are particularly important because of its great biological diversity. Sustainable construction should not be viewed separately from sustainable urbanization and development. Sustainable construction means that the principles of sustainable development are applied to the comprehensive construction cycle from the extraction and beneficiation of raw materials, through the planning, design and construction of buildings and infrastructure. It is necessary to restore and maintain consistency between the natural and built environments, while creating settlements. 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 the reduction of the pollution can be specified. For this purpose a non-linear mathematical model as a function of rainfall was defined to show TP concentrations for the region. Additionally possible reduction in TP concentrations in case of the green roof application in subbasin 2 was calculated. Defining the trend of the pollution leads to decide on best management practices to conserve natural sources and in accordance with the sustainable development. The conservation of riparian and aquatic habitats of watersheds has to be the primary task to balance natural and socio environmental interactions. According to Curwell et al. [33] over-consumption will prevent opportunities of future generations. Considering the future generations, natural resources must be conserved. Green roofs can be applied for this aim. The retained water can be used as flushing water for the building. Results of this study show that, green roof application can be used as a sustainable construction material for the buildings.

This system has a great influence on runoff reduction and the improvement of the surface water quality. Goksu River Watershed was delineated into three subbasins. Subbasin 1 is the largest portion of the watershed, and that is located at the very beginning part of the Goksu River Watershed. There is no settlement at this subbasin since the area is roughly mountainous and it is not suitable for the settlements. Subbasin 2 is located at the beginning part of the Goksu Delta and it has the smallest area compared to other 2 subbasins. Silifke district is located here and there is a mass settelement at this subbasin. Subbasin 3 is the last subbasin of the whole watershed and it is located around the outlet of the Goksu River. Construction of the buildings is prohibited at this location in accordance with the Ramsar Convention. Only agricultural fields are available in this subbasin. Hence, the only settled area in the watershed is subbasin 2. In other words, green roof systems are only applicable in subbasin 2. Goksu River flows through subbasin 1, 2 and 3, respectively. Even subbasin 2 has a limited area over the whole watershed, it is revealed that application of green roof systems helped the reduction of TP concentration of river water significantly, especially when the rainfall value is low. Silifke district of Mersin Province – Turkey, is a typical underdeveloped city with a moderate population. It is clear that if this system is used in more developed, large and crowded cities, more remarkable results in terms of runoff retention and pollution prevention can be achieved.

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