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Agricultural Diffuse Pollution and Sustainability in Ergene Basin

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Abstract

Limited waters sources in the world are consumed rapidly, it has been seen that water sources should be examined with its basin holistically. When Ergene Basin is examined holistically, it seems to have agricultural area approximately 76% of the area and a significant production value (64% sunflower and 50% rice) in grain production in the country. When total consumption of chemical fertilizers and pesticides in agriculture are analyzed according to the years, an increase is observed. In this study, it is aimed to determine the long term nutrient (total nitrogen- TN and total phosphorus- TP) loads and consumption of pesticides in Ergene Basin by years. For this purpose, nutrient loads from agricultural diffuse sources have been estimated by using chemical fertilizer amounts and conversion factors, animal numbers and emission factors. The loads from chemical and natural (animal) fertilizers are 26960 tons/year TN and 3650 tons/year TP in the year 2015. Also in this study, monitoring stations have been proposed for the determination of nutrients and other pollutants loads considering sub-basins and pollution sources for the water sources, air and soil can be monitored simultaneously. When the effects of nutrient loads and pesticides at surface waters and soils in Ergene Basin are considered both ecologically and socio-economically, it has been identified that intended use of water sources was changed, agricultural and aquatic production was negatively affected by deteriorated ecological balance at surface water. Also, the diffuse pollution from agricultural sources causes soil contamination. Ecological and economic sustainability of Ergene Basin are considered to be under a certain threat.

Keywords

Agricultural diffuse pollution, nutrient load, pesticide, sustainability

1. INTRODUCTION

Surface waters are polluted by point and diffuse sources resulting from natural and anthropogenic effects. Nutrient loads coming from both sources have become one of the major ecological issues which also affect aquatic ecosystems. Furthermore, they lead to ecologic and economic losses. Nutrient loads vary by different parameters like precipitation and discharge, water temperature, biological activities in the water masses, conditions of other water quality parameters, natural and chemical fertilizer practice rates, life standards of the communities, wastewater collection systems and water treatment technologies, regulations on the control of nutrient emissions, non-phosphated detergent production, limitations on fertilizer usage, etc [1], [2], [3]. The accelerated eutrophication of freshwaters and to a lesser extent some coastal waters is primarily driven by phosphorus (P) inputs. While efforts to identify and limit point source inputs of P to surface waters have seen some success, diffuse sources remain difficult to identify, target, and remediate. As further improvements in wastewater treatment technologies becomes increasingly costly, attention has focused more on diffuse source. Phosphorus inputs to fresh waters can accelerate eutrophication. Although nitrogen (N) and carbon (C) are also essential to the growth of aquatic biota, most of the attention has focused on P because of the difficulty in controlling the exchange of N and C between the atmosphere and water, and fixation of N by some blue-green algae [4].

Diffuse source pollution from agricultural land use is a complex issue to mitigate due to their storm-dependent and diffuse nature for the management of freshwater worldwide, and improvements in the chemical and/or ecological quality of many waterbodies impacted by farming still need to be achieved. This may be because; controls over nutrient transfers from agricultural land are not yet strict enough, or have not been implemented for long enough or sufficiently widely; agricultural nutrient loads and/or their ecological relevance are overestimated relative to other sources; and other site and environmental factors are more important than nutrient status in determining ecological status [5].

Agriculture clearly needs to remain a viable, productive and profitable industry and it is important to establish clear evidence of the eutrophication impacts of farming so that sustainable solutions that do not unreasonably affect farm profitability can be found. Measures to reduce nutrient emissions to water may be costly to implement, and so it is important to take account of factors that affect their potential effectiveness when implemented. As nutrient inputs to agricultural systems may increase in the future to grow more food and biofuels, and as hydrological patterns may become more extreme under climate change, it will also become increasingly important to identify where water quality and the provisioning of agricultural goods and services are incompatible. The success of diffuse source measures also relies heavily on farmer engagement and skill, and needs to be tailored to suit specific site requirements, which will vary from farm to farm. Soils, fresh application of fertilizers/manures and farmyards are all potential sources of nutrients that will deliver variable N and P loads depending on the type of farming system, soil type and site hydrology. Transfers of legacy nutrients will dilute the beneficial impacts of controls over current activities, and strategies to reduce legacy nutrient inputs will clearly not bring immediate benefits. Controlling nutrient loads from agriculture therefore depend not only on how much the inputs can be reduced, but how those inputs are managed on the farm and how cultivation and cropping practices can be adapted to reduce the mobilization and transport of legacy soil nutrients through runoff and erosion. Critical source areas and delivery pathways of P transfer on farms are numerous, dynamic and complex, and will clearly differ between landscapes with permeable and impermeable soils, crop factors, including soil P sorption capacity, crop type, P application type, method and rate, and land management, influence plant uptake of P and only their accurate identification will provide a sound basis for the implementation of effective options to mitigate P transport [4], [5].

Fertilization increases efficiency and obtains better quality of product recovery in agricultural activities. Chemical fertilizers mainly contain phosphate, nitrate, ammonium and potassium salts. But agro-chemical-based intensive agriculture has contributed substantially to the emission of the very powerful greenhouse gases CH4 and N2O, and the entry of pollutants (excessive nitrogen and phosphorus, pesticide and heavy metals) into water bodies and soils. These pollutants have adverse effects on environmental quality and public health, for example, eutrophication of lakes and streams, soil salinity, soil contamination by heavy metals, groundwater accumulation of nitrate and the accumulation of pesticide residues in food [6], [7].

Nitrogen in agricultural areas reach the water environment by three ways: Drainage, leaching and flow. Even in ideal conditions, plants use 50% of nitrogenous fertilizers applied to soil, 2-20% lost evaporation, 15-25% react organic compounds in the clay soil and the remaining 2-10% interfere surface and ground water [6]. Especially in spring and in the beginning of summer, mass fertilizer usage generally leads to an increase in the nutrient concentrations [3], [5]. Depending on the nutrient concentrations, sediments become the secondary nutrient pollution sources [8]. Continuous use of acid-forming nitrogen fertilizers causes a decrease in soil pH, liming, if not carried to prevent the declining efficiency of field crops [6]. Excessive N inputs are often one of the main reasons for the high incidence of pests and diseases in vegetable production, and in turn, this commonly leads to farms using even more pesticide, resulting in high-pesticide residues on vegetables and in the environment. The excessive and unbalanced inputs of chemical fertilizers can cause the damage to soil structure and soil quality. Unbalanced nutrient ratios in mixed chemical fertilizers can cause both biological and physicochemical damage to soils, leading to acidification, secondary salinization and reduction of microbial activity. This damage lowers crop yields and may lead to farmers applying even more fertilizers to try to compensate for the reduced soil productivity and thereby intensify NPS pollution and the cycle of environmental degradation [7].

Pesticides are one of the vital components of modern agriculture practices. Adoption of modern agricultural practices of highly intensive nature to feed the ever increasing population of the world resulted in the widespread pollution of synthetic pesticides in the environment. Thus the presence of these compounds is ubiquitous, often contaminating surface and ground waters as they migrate from their point of application. Pesticides can reach surface water through runoff from treated plants and soil. Contamination of water by pesticides is widespread. Heavy treatment of soil with pesticides can cause populations of beneficial soil microorganisms to decline [9]. Microorganisms are important inhabitants of aquatic ecosystems and soils, where they fulfill critical roles in primary productivity, nutrient cycling, and decomposition. Microorganisms are exposed directly to the pesticides because of the direct and indirect input of the pesticides. Though certain pesticides are known to elicit a variety of chronic and acute toxicity effects in microorganisms, some of them still have the ability to accumulate, detoxify, or metabolize pesticides to some extent. It is supposed that detrimental effects of pesticides on microbial species may have subsequent impacts on to higher trophic levels [10], [11].

In basins, where pollutants are carried into the surface waters, nutrient control is possible with a good basin management. The concept of "Sustainable Basin Management" has gained great importance, and it is now necessary to understand socio-economic function of the region as well as its natural, physical, chemical and ecologic processes. Monitoring is critical to addressing the main objectives of diffuse sources management strategies, and present unique challenges to reliably represent site-specific variations in time and space. Monitoring programs are designed to identify nutrient losses and their sources areas, quantify the effects of mitigation measures, and document conservation program effectiveness. However, there is a cumulative uncertainty associated with water quality monitoring. This uncertainty is derived from stream flow measurement, water sample collection frequency, sample preservation and storage, and analysis. Water quality data must further be related to information on catchment characteristics (e.g., soil properties, drainage conditions, contribution from point sources) and on agricultural activities such as crops grown, fertilization regimes, and soil cultivation practices. Access to such data is crucial for the interpretation of water quality data. Thus, the inherent landscape and management characteristics of monitored catchments must be stated, so that they can be related to surrounding agricultural areas where less information on agricultural management and nutrient loads are available. This would improve the applicability of monitoring results for larger agricultural areas [12].

This study aims to determine the nutrient loads and consumption of pesticide coming from agricultural diffuse sources of Ergene Basin by years. For this purpose, nutrient loads were estimated depending on some assumptions. As a result of all obtained data and estimations, it is aimed to determine the effects of nutrient loads and consumption of pesticide on the ecosystem and socio-economic structure. Besides these, monitoring stations have been proposed for the determination of nutrients and other pollutants loads considering sub-basins. These stations are supposed to include water, air and soil monitoring simultaneously.

2. MATERIALS AND METHODS

Ergene Basin spreads throughout an area of 10733 km2 between Northern Marmara Basin, Meriç Basin and Bulgarian border; it is an inland basin surrounded by coasts of the Black Sea in the northeast, and Marmara and North Aegean Sea (Gulf of Saros) in the south as shown in Figure 1. The main river in Ergene Basin is the Ergene River with 282 km length and 28.73 m3/s average annual flow-rate. Average rainfall in the basin is 602.18 mm [3].

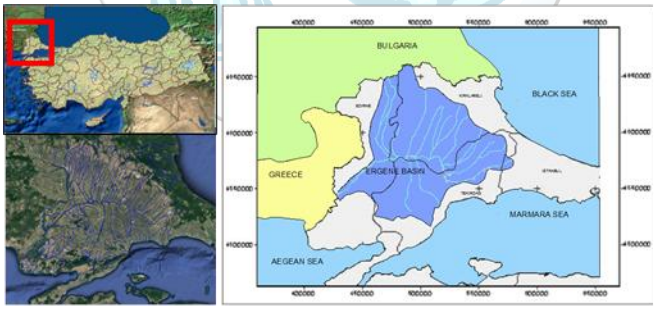

Figure 1. Geographical location of Ergene Basin (26o35'- 42o06')

The Thrace sub-region (Edirne, Kırklareli and Tekirdağ provinces), where Ergene Basin is located, constitutes one of the significant agricultural and livestock production centers. While the total cultivated area of the sub-region is 1.239.102 ha, only 65.1% of this area is used for agricultural purposes. Monoculture agriculture and burning stubble applied for many years remove organic matter in the soil and thus plant-available nitrogen is caused to decrease year by year. This is the region which uses the most fertilizer per unit area, with an average of 145 kg per hectare (2-fold that of Turkey average). Approximately 20% of the fertilizer especially nitrogen fertilizers consumed in Turkey is used in the region [3], [13]. There are 14 surface waters monitoring stations in the basin [14].

Point sources which result in surface water pollution in Ergene Basin are domestic and industrial pollutant sources. Diffuse sources are agriculture areas (chemical and natural fertilizers), meadow and forest areas, urban and rural settlements, vehicle emissions, and irregular solid waste landfills [2], [3], [15]. Between the nutrient loads coming from point and diffuse sources in Ergene Basin, diffuse sources have a considerable share (Table 1), and TP load is considerably low compared to that of TN [2].

Table 1. Distribution of point and diffuse pollutant loads in the basin [2]

TN (24 000 tons/year)		TP (2700 tons/year)	
Loads from Diffuse Sources	Loads from Point Sources	Loads from Diffuse Sources	Loads from Point Sources
86 % (82% from *agriculture)*	14 %	83 % (92% from *agriculture*)	17 %

It is seen that diffuse sources' contribution to the nutrient load in the basin is 86% for TN and 83% for TP, which are both considerably high. Considering the load distribution of the diffuse sources in the basin, it is seen that the chemical and natural fertilizers constitute nearly the total load (83% TN, 93% TP).

Diffuse sources which lead to the pollution of the surface water sources in Ergene Basin are agricultural areas (chemical and natural fertilizers), meadow lands and forests, urban and rural settlements, industrial areas, vehicle emissions, and leachate of "wild dumping" areas [2], [3].

In order to determine the nutrient loads from agriculture and examine the change by years, the number of animals (cattle, small cattle, poultry) obtained from Turkish Statistical Institute, unit loads, type and amount of chemical fertilizers obtained from the Provincial Directorate of Food Agriculture and Livestock of Edirne, Tekirdağ and Kırklareli, and active nitrogen and active phosphorus conversion factors [16] were used. Since it is not accurately possible to determine the size of the diffuse loads, in an attempt to estimate the nutrient loads caused by the use of fertilizers, some assumptions were made during the practice of selected estimation methods (Table 3). Nutrient (N and P) loads of agricultural diffuse sources were estimated to be the total annual load based on the variety of transport mechanisms within the annual water cycle [17], [18]. Data on use of fertilizers were obtained on the basis of administrative boundaries (Edirne, Tekirdağ and Kırklareli). In the calculation of nutrient loads from agricultural areas, chemical and natural fertilizers and losses were taken into account. Nutrient loads of diffuse sources were deemed to expand homogenously throughout the basin, and not to change from its source to surface water.

Table 2 - Land-use in Ergene Basin [3]

Type of land-use	Area (ha)	Area (%)
Agricultural areas	819862	75.7
Forests	168778	15.6
Urban settlements	51669	4.8
Rural Settlements	25630	2.3
Meadows	11459	1.1
Industrial areas	5075	0.5

Table 3. The assumptions made in the calculation of TN and TP loads [2]

	TN	TP
Cattle Unit loads (kg/animal/year)	10	5
Small cattle Unit loads (kg/animal/year)	5	1
Poultry Unit loads (kg/animal/year)	0.2	0.05
Losses from soil to receiving environment	% 15	% 3

In order to examine the consumption of pesticide in the basin by years, pesticide sale amounts were obtained on the basis of administrative boundaries from the Provincial Directorate of Food Agriculture and Livestock of Edirne, Tekirdağ and Kırklareli.

3. RESULTS AND DISCUSSION

In Ergene Basin, we can see that agricultural areas have the highest usage share (rate of 75.7%) (Table 2). It is seen in Table 1 that nutrient loads from diffuse sources in the basin is 86% for TN and 83% for TP and the chemical and natural fertilizers constitute nearly the total load (83% TN, 93% TP). In other studies [19]-[21], it is stated that the agricultural activities have been historically, and the dominant nitrogen sources as well.

We can see the chemical fertilizer consumption in Ergene Basin from 1994 to 2015 in Figure 2.

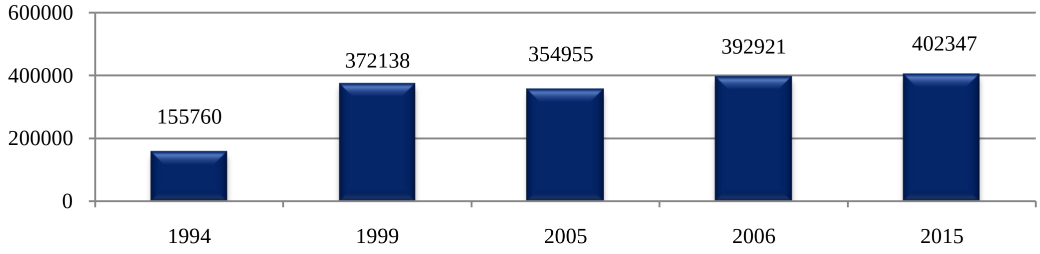

Figure 2. Chemical fertilizer consumption in Ergene Basin by years (tons)

When we examine the amount of chemical fertilizers used in the basin in the 20-year period (Figure 2) we can see an increase. In this case, N and P load is considered to be increased by years as we see in Figure 3.

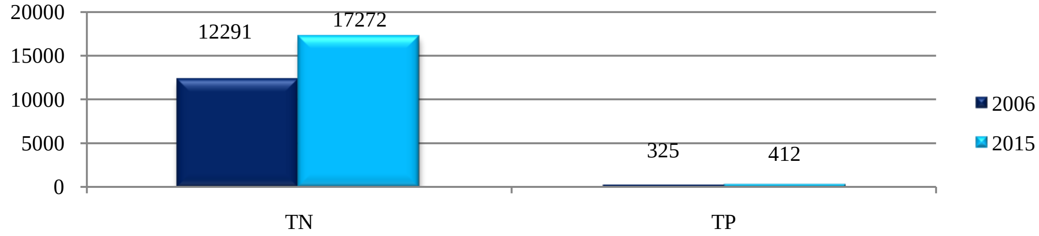

Figure 3. Nutrient loads from chemical fertilizers in Ergene Basin from 2006 to 2015 (tons/year)

When we examine the Figure 3 we can see an increase 41% of TN and 27% of TP. We can see the nutrient loads from natural fertilizers in Ergene Basin from 2001 to 2015 in Figure 4.

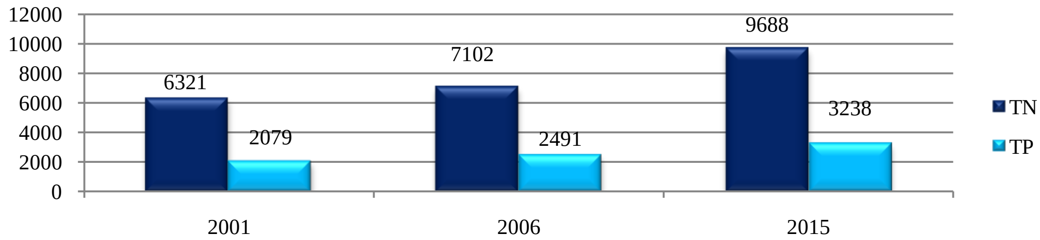

Figure 4. Nutrient loads from natural fertilizers in Ergene Basin by years (tons/year)

When we examine the nutrient loads from natural fertilizers in Ergene Basin by years (Figure 4), by almost 55% increase for both of TN and TP are seen in recent 15 years. We can see the total nutrient loads from diffuse sources in Ergene Basin from 2006 to 2015 in Figure 5.

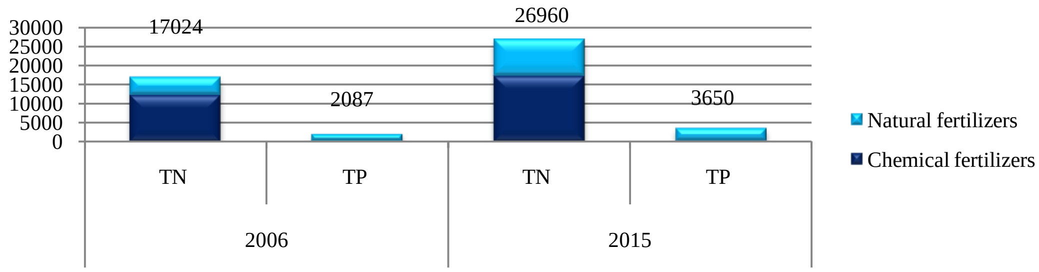

Figure 5. Total nutrient loads from agricultural sources in Ergene Basin from 2006 to 2015

When we examine the total nutrient loads from diffuse sources in Ergene Basin in the 10-year period (Figure 5) we can see an increase 58% of TN and 75% of TP.

Agricultural activities have decreased in the basin where the fertilization is 2-fold that of fertilizer consumption in Turkey [2], [13]. However, agriculture sector is still among the most important factors that shape socio-economic structure of the basin. Furthermore, it is estimated that fertilizer usage will continue at significant rates. When we consider the fact that the global climate change affects the hydrological cycle and nutrient transport, it seems that the fertilizer usage control is vital for agricultural production [2], [22], [23].

In order to decrease nutrient loads from natural and chemical fertilizers in agricultural areas, farmers should be informed; good agriculture practices and organic agriculture should become widespread, incentives for the recycling of organic manure should be improved; fertilizer management system should be used to prevent excessive fertilizing for plants and tighten the regulations and national standards on organic waste disposal and pesticides use [4], [7], [24], [25]. To protect the water and soil we can enhance plant nutrition through balanced measures that include crop rotations with N-fixing crops, judicious use of organic and inorganic fertilizers. Besides lime can be used to regulate high soil acidity; a protective organic cover on the soil surface must be enhanced and maintained by using cover crops and crop residues [26]. Being an important environmental problem in the basin and increasing the transportation of nutrient materials, erosion should be decreased by means of afforestation, meadow development, tillage and crop residue management, buffer strips, riparian zones, terracing, contour tillage, cover crops, impoundments, wetlands and suitable agricultural methods. These practices tend to reduce rainfall impact on the soil surface, reduce runoff volume and velocity, and increase soil resistance to erosion. The response to management change can range from months to centuries and differ along the soil (5 to 15 years), river (1 to 5 years), and lake (10 to 30 years) watershed continuum [4], [12].

We can see the pesticide consumption in Ergene Basin from 2001 to 2015 in Figure 6.

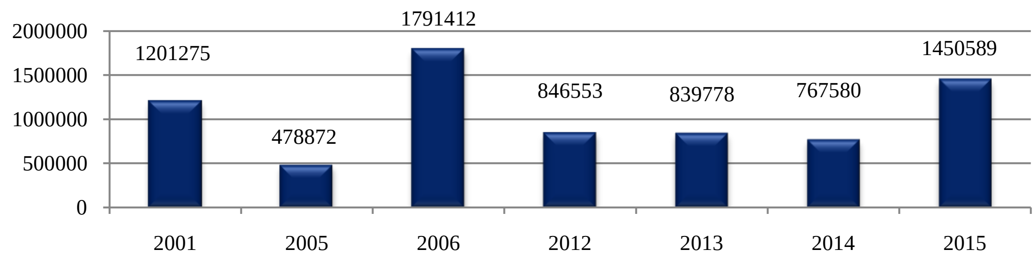

Figure 6. Pesticide consumption in Ergene Basin (kg-lt)

When we examine Figure 6, an increase from 2001 to 2006 and a decrease from 2006 to 2014 are seen. This decrease may be due to the trainings and regional studies of the Ministry of Food, Agriculture and Livestock. But off the record fertilizer and pesticide use in the region is also known. But a significant increase (89%) is observed the last 1-year period. However, because of the incorrect and intended land use the agricultural fields have been decrease and amount of fertilizers and pesticides used per area have been increase. Pesticides are often considered a quick, easy, and inexpensive solution for controlling pests. However, pesticide use causes a significant cost. The economic impact of pesticides in non-target species (including humans) has been estimated at approximately $8 billion annually in developing countries. Pesticides have contaminated almost every part of our environment. Pesticide residues are found in soil, air, in surface and ground water across the countries. Pesticide contamination poses significant risks to the environment and non-target organisms ranging from beneficial soil microorganisms, to insects, plants, fish, and birds. What required is to weigh all the risks against the benefits to ensure a maximum margin of safety. All activities concerning pesticides should be based on scientific judgement and not on commercial considerations. The best way to reduce pesticide contamination (and the harm it causes) in our environment is for all of us to do our's part to use safer, non-chemical pest control (including weed control) methods [9].

Long-term monitoring is essential; which should include baseline, extreme, and representative sites. Also, it was suggested that a few selected sites should be intensively monitored in conjunction with a larger number of less intensively monitored sites. Adequate long-term (10 years) monitoring of catchments is essential to reliable model calibration; however, there is often a limited amount of long-term water quality data that would be sufficient to estimate nutrient and sediment loads in streams (representative of storm and base flow). A well-distributed network of monitoring stations across all land uses, topographic conditions, and sub-catchments of the larger catchment would assist in model evaluation and verification when estimating at smaller scales. Legislation to ensure the continuity of long-term monitoring, cross-media monitoring at different scales such as field, farm catchment, sub-basin and basin and detailed information on soil and farm management are needed [2], [3], [12].

Despite 14 surface waters monitoring stations exist in the basin [14], there is no long-term, systematic water quality monitoring data. Similar studies [2] and [12] highlight the importance of the need for systematic monitoring in order to determine the trends and achieve reliable results. Not only the water quality data but also the other media (soil, air) should be monitored simultaneously in the basin by environmental information systems. Determination of surface water quality is not capable alone. Therefore; the necessary data for future studies in Ergene Basin must define the land use, all water resources in the basin of the river sub-basin scale, quality, quantity and usage patterns in a systematic way by using geographic information systems. In order to obtain the water quality data systematically, water quality monitoring stations should be established at intervals to show the characteristics of the basin; water and sediment quality and hydrology parameters of the river and its tributaries should be measured regularly. At the same time water quality monitoring stations should be in the same zone with stream gagging station [24], [27]. Water quality data must further be related to the information on both catchment characteristics (e.g., soil properties, drainage conditions, contribution from point sources) and agricultural activities such as crops grown, fertilization regimes, and soil cultivation practices. Access to such data is crucial for the interpretation of water quality data. Thus, the inherent landscape and management characteristics of monitored catchments must be stated, so that they can be related to surrounding agricultural areas where less information on agricultural management and nutrient loads are available. This would improve the applicability of monitoring results for larger agricultural areas [12].

4. CONCLUSION

In this study, it is aimed to determine the nutrient loads from agricultural diffuse sources of Ergene Basin by years; it is found that the data of annual TN and TP loads increased. In order to decrease total annual loads, first of all, land-uses should be proper and suitable for the usage purposes; this is only possible by means of a sustainable basin management. Proper land usage ways should be determined by urban and local planners, and local decision-making mechanisms in accordance with national plans and regulations. In addition, there should be important sanctions for auditing the performance of these plan stipulations. In order to prevent the environmental pollution, development policies should be improved and basin management must be operated based upon those policies. In Turkey, basin management is a new concept and it is not implemented nationwide. Integrity of the Ergene River ecosystem has long been under pressure for the last three decades of the all pollutant sources from the basin and, in fact, the river ecosystem has suffered a collapse in the downstream region. The change in Ergene River does not only affect its own ecosystem, it also ruins three different ecosystems as well. Nutrients, organic substances, suspended solids and specific pollutants are carried by Ergene River through the Meric River, Lower Meric Delta and Aegean Sea (Gulf of Saros) ecosystems [28]. Lower Meric Delta is one of the important bird areas and any changes in the area based on the nutrients will affect the aquatic life, food chain will be destroyed, and biological diversity will be adversely affected. A decrease in the biological diversity will result in the extinction of predators and the decrease of performance in the natural and cultural production; thus, the use of chemicals in the agricultural production will increase.

Sustainable agriculture outcomes can be positive for food productivity, reduced pesticide use and carbon balances. Also it will minimize specific soil threats such as soil erosion by wind, water, and tillage, and soil compaction and physical deterioration and the loss of biodiversity from the soil. Significant challenges, however, remain to develop national and international policies to support the wider emergence of more sustainable forms of agricultural production [29].

Spatial and temporal distribution of pollutant sources should be determined within sub-basins through periodic monitoring, and water quality model studies should be conducted on Ergene River and its reaches. In this way, the changes by biochemical processes from the source of total loads to the receiving environment will be taken into account, and the detected process schemata will be a useful tool for basin management. It is believed that the non-ecologic basis of the land-use and consideration of administrative boundaries rather than sub-basins in basin management, lead to management failures in determination, management and audit of pollutant sources.

It is assumed that it will be a great step in the basin management to estimate the total ecological costs (agricultural, economic and social) caused directly or indirectly by the nutrients and other pollutant loads in Ergene Basin; and to place these values into national and regional development plans.

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