A study on dynamic modeling to examine the impact of reducing water pollution on market condition in the Turkish Black Sea Basin

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Abstract:

In this paper, we introduce a dynamic conceptual mathematical model clarifying the interaction between socioeconomic activities and contribution of pollutants into the Turkish Black Sea Basin ending to the sea, and future changes. With some simulation cases which are the reduction rate of pollutants as parameters of water pollution in order to analyze the impact of investment criterion for wastewater treatment systems on household and industrial sector's economic activities such as the impact of production, investment and other macroeconomic indicators into market flow system in the Turkish Black Sea Basin. Then we introduce some policy measures in formulating a balance between economic development and less harm to environment as water quality objectives

1. Introduction

The Black Sea is known as one of the semi-closed seas mainly deteriorated by human activities. According to Black Sea Environmental Program BSEP (1994), Global Environmental Facility GEF (1996), the Black Sea has suffered from catastrophic degradations of its natural resources. The entire ecosystem has started to collapse due to increasing loads of nutrients from agricultural activities, domestic and industrial sources located along the Black Sea coastal line, and/or contaminants transferred by rivers and streams to the sea. This problem coupled with an unmanaged irrational exploitation of fish stocks caused a sharp decline of fisheries resources GEF (1997).

The Black Sea Basin and its socioeconomic structures have been reviewed including hydrological and ecological properties from the point of view referring some researches in the previous paper Ulger and Higano (2002) shows that the Black Sea Basin has different ecosystem and economic characteristics since many countries located in the basin and coastal area of the sea. Therefore, we emphasize that each sub-basin in the Black Sea Basin should be studied in formulating its economic structure integrated with environmental media so as to find out the sources of pollutants, their contributions and interrelations

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between them. As a result, we have developed a mathematical model clarifies and integrates the current environment as a water pollution and economic activities in the Turkish Black Sea Basin. In this paper, we summarize sources of pollutants and their contributions with running the model as a basic case within the period from 1998 to 2008 and 2009. Furthermore, some cases are introduced and analyzed in order to find out optimum solution set. Finally, we also propose some policy instrument to improve the water quality in the Turkish Black Sea Basin.

2. The data

The data used into the model have been gathered by the Turkish governmental organizations mainly State Institute of Statistic (SIS), State Planning Organization (SPO), State Hydraulic Works (SHW) and Electrical Power Resources Survey Administration. According to the data available, we have developed the model describing the actual economic structure and indicators related to water pollution in zones in the Turkish Black Sea Basin.

3. The Model

Study area covers Turkish Black Sea Basin SHW (2001), SIS (2001) is classified and divided into sub basins (zones) according to watersheds, hydrology and geological structure. For more information, see the reference Ulger and Higano (2002).

We have formulated the model and integrated the ecosystem and economic system with water pollution related to macroeconomic indicators in the basin and zones, determined systematically as follows;

Total pollution is sum of the total pollution generated from the whole basin:

$TPB_p(t) = \sum_z TP_{zp}(t)$ …(1); where, $TPB_p(t)$ is total amount of pollutant p generated from the Turkish Black Sea Basin at time t., $TP_{zp}(t)$ is an amount of pollutant generated in each zone and p is BOD, COD, TSS, TN, TP., and z = zone1, 2, 3, 4, 5, 6.

<u>Pollution generate from each zone</u>

$TP_{zp}(t) = PH_{zp}(t) + PI_{zp}(t) + PL_{zp}(t)$ …(2); where, $PH_{zp}(t)$ is an amount of pollutant from domestic wastewater, $PI_{zp}(t)$ is pollutant from industrial wastewater and $PL_{zp}(t)$ is pollutant from land use

<u>Pollution from household:</u>

$PH_{zp}(t) = \sum_k e^h_{kp} PT_{zk}(t)$ … (3); where, e^h_{kp} : Amount of pollutant *p* per capita for each type of settlement *k*, which is classified into 5 categories; village has no treatment, city or town without sewerage, with sewerage, primary treatment and activated sludge. Here, first three categories have no treatment facility. However, amount of pollutant per capita is different because of the settlement systems. $PT_{zk}(t)$ is population with settlement type *k* in each zone *z* at time *t*. In Turkey, emission coefficient is estimated g/head/day. As an example, population connected sewerage system discharge 50-60g BOD, 80-90g COD, 70-90g TSS 10-12g TN and 3-4g TP head/day Province Bank (1990). Cost of treatment for each category is estimated using population data, investment and operational cost for sewerage system, pretreatment and biological treatment that government and/or municipalities have established so far in Turkey and in the basin ACWTP (2000), SPO (2000)

Population:

Since the treatment plants are recently established in some cities and towns, the capacity of these plants cover the increase of population for more than 20 years SPO (2000).The following equation shows the total population in each zone:

$$P_z(t) = \sum_k PT_{zk}(t)$$

$$P_z(t+1) = (1+\eta_z)\sum_k PT_{zk}(t) \pm \Delta P_{zk}(t) \ldots\ldots \quad (4)$$

η_z : Growth rate of each zone *z*, $P_z(t)$: Total population in each zone *z* at time *t*.

$\Delta P_{zk}(t)$: Change of population regarding treatment. It increases for biological-treated population and decreases for others except type *k1*. Here, with this equation it can be seen the number of people who have treatment in each year in the simulation period In Turkey, the government transfers annually a certain percentage of its revenue to support the budget of municipalities SIS (2000). Municipalities with government support establish investments for household treatment. According to available data, we assume the investment for household treatment in each zone is a part of total investment because of the difficulty in expressing the budget balance for each municipality mentioning that in the study area, there are more than 500 municipalities and each one has its own budget. Hence the capital accumulated for household treatment is:

$KT\_H_z(t+1) = (1-\sigma^T)KT\_H_z(t) + IT\_H_z(t)$... (5), where $KT\_H_z(t)$ is capital stock for abatement type *k* in zone *z*., $IT\_H_z(t)$ is annual investment for abatement. The treated population will increase if there is investment for it to reach the final target all population served with sewerage system with biological treatment. Therefore, the total treated population by abatement type *k* is dependant on the scale of investment as expressed in following equation:

$IT - H_z(t) = \sum_k \beta_k \Delta P_{zk}(t)$ ... (6)., where, β_k is the estimated cost per capita including maintenance cost for each type of treatment *k* in order to have biological treatment. This investment also assumed that is a part of total investment in each basin:

$IT - H_z(t) = \varepsilon_z^h I_z(t)$ ... (7) Where, ε_z^h is household-treatment investment coefficient, and $I_z(t)$ is total investment in each zone

Pollution from industry*:*

In Turkey, industrial activities are classified according to International Standard of Industrial Classification (ISIC) system SIS (1996). There are 97 sectors in IO table. Here, we reclassified those sectors into 27 sectors in each zone in the basin. Total pollutants generated from all industrial activities are determined with the following equation:

$PI_{zp}(t) = PMI_{zp}(t) + \sum_l e_{lp} A_{zl}(t) + e_p^f X_{z3}(t)$ ... (8) Where, $PMI_{zp}(t)$ is total amount of pollutant *p* generated from manufacturing industry in zone *z* at time *t*. Here assuming that livestock and fishery are part of industrial activities and manufacturing industry also include mining, construction, and service sectors combined into one sector in the model. e_p^f is an amount of pollutant *p* generate from one unite of production (*1billion Turkish lira*) of fishery, $X_{z3}(t)$ is production of fishery in zone *z*. e_{lp} is amount of pollutant *p* generated from livestock *l* per head, $A_{zl}(t)$ is number of livestock *l* in zone *z,* and. *l*= 1 is cattle•*l*=2 is poultry. We estimate the livestock export coefficient using number of dairy/beef cattle and poultry, concerning the studies on animal rising, production, and pollution DEFRA (2002), OECD (1998), Wit and Bendoricchio (2001). In the basin, animal rising is not intensive except poultry. In general, most farmers have a few numbers of cattle taken to harvested agricultural land, grassland, or posture for grazing every day except winter season and bad weather. Second, the manure that collected by the farmers use as fertilizer on the agricultural land so, pollution from cattle is a part of land use (agriculture) activity that we already assumed load factor for it. As a result, in the model, we assumed load factor for livestock considering poultry as a whole and only number of intensive dairy/beef cattle.

The data used as an initial year 1998 and applied for simulation period. There are five existing types of treatment plants for manufacturing sectors in each zone; these are no treatment, pretreatment, chemical, biological, and advanced treatment. Here we classified the production in each zone in terms of treatment facilities so as to estimate total pollution and treatment cost per unit of production using some assumptions WB (1996), WB (2000), WB (1994), WHO (1993) for each category as a value of 1998 price.

$PMI_{zp}(t) = \sum_{i=5}^{27} \sum_{T} e_{ip}^{T} X_{zi}^{T}(t) \cdots$ (9) Where, e_{ip}^{T} is an amount of pollutant p emitted by one unit of production (*1billion TL*) with treatment type T for each industry i, $X_{zi}^{T}(t)$ is the production with treatment T for each industry

According to recent environmental law, every factory has to establish a treatment plant as a part of its construction. New investments also have to establish their treatment plants according to Environmental Impact Assessment Regulation in Turkey. However, some factories already established and entered to the market have no treatment plant or treatment is not sufficient. The capital stock for those treatment facilities is expressed in this equation; $KT - I_{zT}(t) = \sum_{i=5}^{26} \gamma_T X_{zi}^{T}(t) \cdots$ (10) Where, γ_T is the cost of abatement type T per one unit of production, $KT - I_{zT}(t)$ is the capital stock of industrial treatment facilities of abatement T in zone z.

Capital accumulation for investment of treatments is expressed:

$KT - I_{ziT}(t+1) = (1-\sigma_i^T)KT - I_{ziT}(t) + IT - I_{ziT}(t)$ … (11) Where, σ_i^T is depreciation rate for treatment facilities, $IT - I_{ziT}(t)$ is investment for industrial treatment for industry i in zone z at time t. This investment is also a part of total investment in each manufacturing sector described as; $IT - I_{ziT}(t) = \varepsilon_z^i I_{zi}(t)$ … (12) where, ε_z^i is Industrial-treatment investment coefficient and $I_{zi}(t)$ is investment for industry i in zone z.

Pollution from land use*:*

We classified the land use into five categories in the model. Pollution from land use is as known non-point source of pollution that it is not easy to find out how much pollution release to the water resources Arheimer and Brandit (2000), Baginska et al., (1998), Baykal et al.,(1998). Furthermore, pollution export rate is also not known in Turkey and in the basin. Therefore, we search studies on agriculture and other land use activities that have similar characteristics with the study area carried by scientists like Ramos et al., (2002), Skop and Schou (1999), Wit and Bendoricchio (2001), international organizations such as WHO (1993), OECD (1998), WB (1994) and governmental organizations SPO (2000), SIS (1999), SIS (2001). We harmonized and estimated the export coefficient for each land use category. For example cropland export rate used in the basin is 5.1 kg /ha/y for BOD, 8.6 kg /ha/y for TN and 1.2 kg/ha/y for TP that reaches to water resources.

$PL_{zp}(t) = \sum_{j} e_j L_{zj}(t)$ … (13) Where, e_j is Amount of pollutant *p* export rate per hectare for each type of land use pattern *j*, $L_{zj}(t)$ is area of land use *j* in each zone. *j*=1 is crops + area under fallow, *j*=2 is other agriculture (vegetable, vineyard, orchard, olive, tea), *j*=3 is posture, meadow and wetland, *j*=4 is forest, woodland, and *j*=5 is city area and other unused land

Land use pattern:

$L_{zj}(t+1) = L_{zj}(t) \mp \Delta L_{zj}(t)$ … (14),

$\Delta L_{z5}(t) = \theta_z \eta_z P_z(t) + \phi_i I_{zi}(t)$ … (15)

Where, $\Delta L_{zj}(t)$ is change of land use by time, $\Delta L_{z5}(t)$ is increase of city area in each zone *z,* θ_z is demand of residential area per capita in zone *z,* and ϕ_i is demand of investment lot per production unit for each industry *i*.

Land use category *5* might be changed for any purpose. However, The area used for agriculture and forest should not be decreased according to Turkish regulation except for fundamental investments, which may be used in converting any land if there is no other options. According to monitoring study carried by State Statistic Institute (SIS) in Turkey, land use change by the time is negligible. Therefore, we assumed that the area of land use is constant by the simulation period.

Relation between production and capital

$K_{zi}(t)=\alpha_i X_{zi}(t)\ldots$ (16) Where, $K_{zi}(t)$ is capital stock of industry *i* in zone *z* at time *t*, $X_{zi}(t)$ is total production of industry *i* in zone *z* at time *t* and α_i is capital required per production unit (capital output ratio for each industry).

Capital accumulation:

$K_{zi}(t+1)=(1-\sigma_i)K_{zi}(t)+I_{zi}(t)\ldots$ (17) Where, σ_i is depreciation rate, $I_{zi}(t)$ is investment calculated according to capital formation ratio for each sector: $I_{zi}(t)=B_{zi}I_z(t)\ldots$ (23) Where, B_{zi} is capital formation matrix for each sector.

Flow of the market:

$$X_z(t)=\sum_i X_{zi}(t)\cdots(18)$$

$$X_z(t)\geq A_{zi}\sum_i X_{zi}(t)+C_z(t)+I_z(t)+Ex_z(t)-Em_z(t)\cdots(19)$$

Where, A_{zi} is input coefficient matrix., $Ex_z(t)$ is exports, $C_z(t)$ is consumption and $Em_z(t)$ is Imports Here, consumption and investment are estimated including sum of private and government activities

$GRP_z(t)\leq\sum_i \mu_{zi}X_{zi}(t)\ldots$ (20) Where, $GRP_z(t)$ is gross regional product for Turkish Black Sea Basin, and μ_{zi} is Value added ratio

Objective function:

$MAX=\sum_t\left(\frac{1}{1+\rho}\right)^{t-1}\sum_z GRP_z(t)\ldots$ (21), subject to basic case equation (1) to (25), and case1, case2, case3, case4, for each pollutant

4 • Simulation

We run the model dynamically using Lingo Software Program LINGO (1995). The simulation results, analysis, and interpretations are as follows;

4.1. Total Pollution in the Basin (Basic Case) Total pollution generated from socio-economic activities is demonstrated in Figure 1. Here, it can be seen the total pollution and its behavior from the initial year to the end of simulation period states that pollutants are decreasing by the simulation period. From 1998 BOD 22.6%, COD 21.8%, TSS 21.3%, TN 4.2%, and TP 7.2% percent decrease at the end of the year 2009. It can be also conducted that reducing of TN and TP are very less amount comparing the others because, the treatment techniques mostly do not include nutrients removal systems. Distributions of pollutants and sectors` contributions are shown in Figure 2, 3 and 4.,

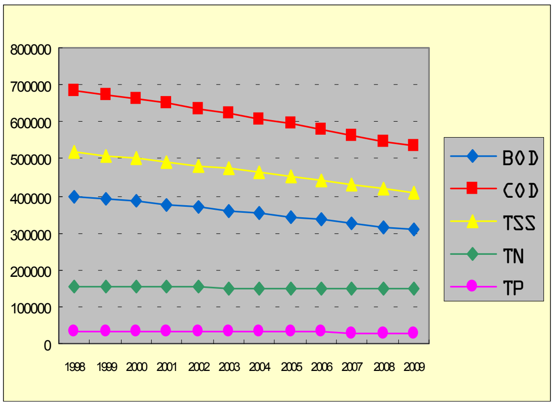

Figure1. Total pollution in the Basin (ton).

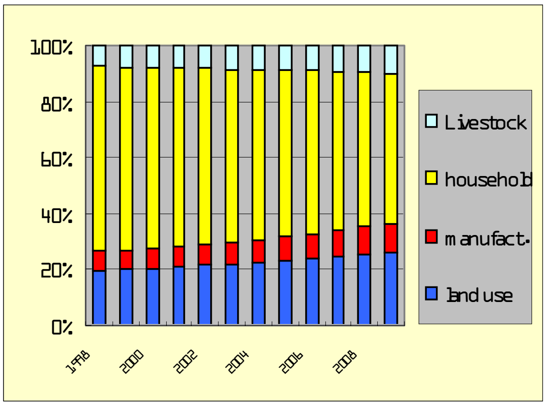

Figure.2. BOD Distribution in the Basin by sector

Household wastewater is the biggest contributor in terms of BOD, COD, TSS, and TP in each year. In case of TN, the biggest source of pollutant is land use, which contributes more than 50%. Both household and land use contribution is 80-85 % of total BOD and COD, 60-65% of TSS, and 85-90% of total TN and TP.

Manufacturing and livestock activities are not considerable amount comparing the total land use and household contributions and it is less than 30% except TSS in the basin

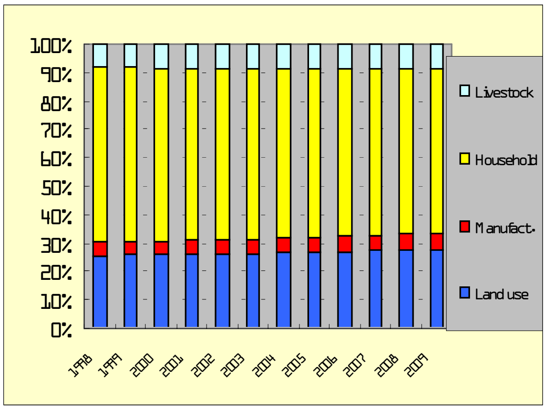

Figure 3. TP contribution by sectors in the basin

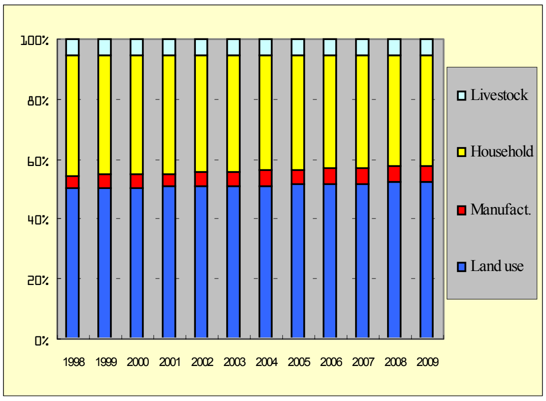

Figure 4. TN contribution by sectors in the basin

In order to figure out the whole basin structure, it is necessary to analyze in detail sector by sector in each zone and their characteristics on water pollution issues. Therefore, we also specify the model for each sector in each zone as follows;

4.1.1 Household Pollution

The total BOD, COD, and TSS are reduced about 37%, TN and TP are reduced 12.4% and 13% respectively at the end of 2009 in the basin. However, reductions of pollutants are not the same in each zone. For example in zone 1, BOD, and COD reduction is about 60%, TSS 55%, TN, and TP about 5%. This is because of the treatment system, distribution of population in each category and investment for treatment.

In the model, we also specified the relation between treated and untreated population. Treated population increases from approximately 3 million to 8.5 million at the end of the simulation period it means, have received biological treatment. At the same period, the other categories, the number of population decrease from 5 million to 3 million for without sewerage category, 3.4 million to 1 million for sewerage category and more than 1 million pretreatment categories reduced to zero in the basin. When the untreated population reaches to zero it means all population is treated and it is not necessary for investment just maintains applied for biological treatment. There is also no investment for village population category in the basin because there is no option for treatment. Therefore, according to increasing or decreasing of population by the year the pollution increases or decreases. Contribution of village pollution in zone 1, 2, 4, 5 and zone 6 are about 12-15 thousands ton of BOD, 20-25 thousands ton of COD, 11-14 thousands ton of TSS, 2.5-3.5 thousands ton TN, and 900-1200 ton TP. Zone 3 has the biggest number of village population. Therefore, the contribution is considerable amount such as 20 thousands ton BOD, 35 thousands ton COD, 18 thousands ton TSS, 4.8 thousands ton TN, and 1.5 thousand ton TP flow to water resources.

4.1.2. Land Use Pollution

Land use activities are the second biggest factor for all the zones. Contribution of land use pollution in terms of pollution parameters that the area used as a crop production has the biggest share of pollution in the basin. Crop production itself contributes more than 55% for all pollutants and it reaches 60% of BOD and COD, 70% TN, and almost 80% of TP with vegetable-vineyard- orchard category. These two categories are assumed agriculture activities. The others like forest, posture-meadow, city-unused land contribute about 10 % for BOD, COD and TN. TP contribution from those activities are about 5% except city area that reaches 11-12% of total contribution in the basin. In case of the zone 1, 2 and zone 4 show the similar characteristics as in the basin mentioned above. However, zone3, 5, and zone 6 have different characteristics of land use activities. Zone 3 has the largest agriculture area particularly cropland. Therefore, it contributes more than 85% for BOD, COD, and TN, and approximately 90% of total TP. Zone 5 contributes the biggest amount of pollutants from the vegetable-vineyard-orchard category. Zone 6, the city-unused land, and posture-meadow are the dominant contributor means; agriculture land here is not productive enough and not so big compares the other zones.

4.1.3. Livestock Pollution

Zone 3 is the biggest contributor of BOD and COD, In case of TN and TP, zone 2 is the main factor. Zone 2, 3 and 4 together contribute about 70% of total pollutants. Zone 6 is the smallest contributor in the basin. The number of livestock is not changed by the time as a considerable amount according to the data SIS (1999). Therefore, amount of pollution by the time is assumed constant and there is no policy measure to mitigate the pollution.

4.1.4 Industrial Source of Pollution

The fate of industrial pollution, almost all pollutants are increasing 50% at the end of the simulation year although some of industries have treatment plants. Industrial pollution mostly comes from manufacturing sector. Distributions of pollutants by sectors are not the same between zones. The contribution of COD by main sectors in zone 1 are paper industries contribute the biggest amount of COD followed food, textile, chemical, plastic and others. In case of zone 2, food sector is dominant for contribution of COD and the next are wood, paper, textile, metals, and others. By the time, in zone 2 wood sector's pollution increases dramatically. However, food and paper, pollution decrease a small amount in the period of simulation. In zone 4, food sector is the biggest polluter, next textile, chemical, plastic, and other sectors. COD from food sector increases almost two times. Another example for zone 5, food sector is again the biggest COD contributor although it is reduced 10% by the time. As a result, we can state that food, textile, paper, chemical, wood, plastic, and metal are the main sources of manufacturing pollution. However, TN and TP pollution are almost zero except particularly food, chemical, textile, non-metal, metal, and machinery respectively.

Fishery means, freshwater fish farming is not a manufacturing sector, but we put into the same category because, we assume that the production is the function of pollution, although there is no option for abatement. Pollution from fish farming in terms of BOD, COD is not large amount. However, TN and TP contribution is highly considerable.

4.2. Market Flow and GRP

In Turkey, economic situation is not stable yet and fluctuating by the year. However, potential of economic development in industrial sector especially manufacturing is very high SPO (2000). In general, manufacturing sector uses its capacity of production less than 80% of total capacity. When the economic and social indicators show positive sign productions immediately increase SIS (2000). In the model, we assume that there is no negative sign which affects market flow and GRP in the basin so as to estimate future changes of economic development on the environment

GRP increases in each zone by the time shown in Figure 5 and 6. Zone 1 has the biggest amount of GRP, increases 77% at the end of 2009, and its contribution is 45% of total GRP in the basin. Zone 3 is the second zone that GRP increases 64% and contributes about 27% of total GRP in the basin. Zone 2 and zone 5 third and fourth biggest zones and

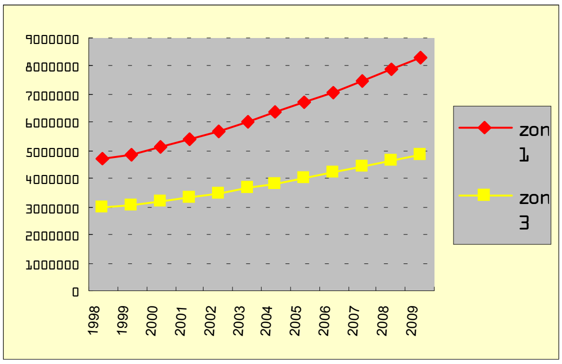

Figure 5 Total GRP in zones by time (billion TL)

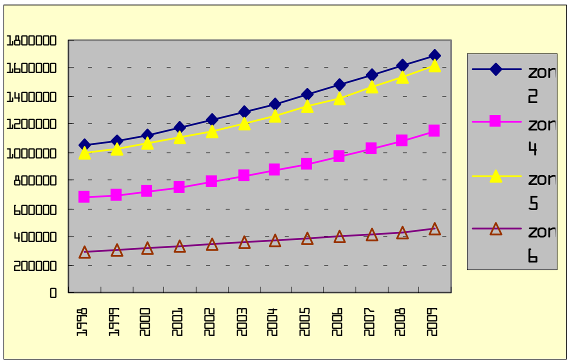

Figure 6 Total GRP in zones by time (billion TL)

GRP increase about 60% by the time and their contribution is similar around 10%. Zone 4 and zone 6 together contribute about 10%, their GRP increase 70% and 54% respectively by the simulation period. Zone 6 is the poorest and undeveloped basin comparing the others illustrated in Figure 7.

As another example, total production is also gives similar result as illustrated in Figure 8. Zone 1 and zone 3, again are the biggest zones, the next is zone 2, 5, 4 and zone 6. We can conduct that there is a linear relation between GRP, production, investment and consumption in the basin by simulation period

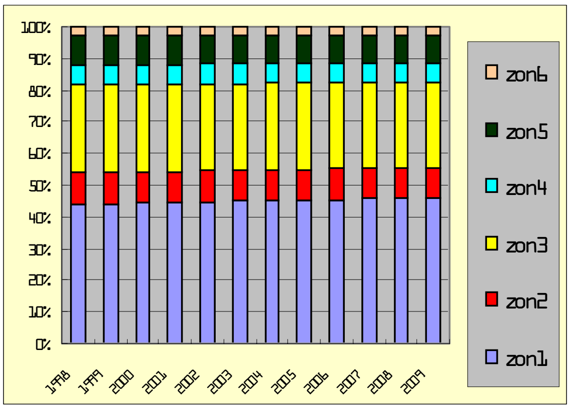

Figure 7 GRP contribution by the zone

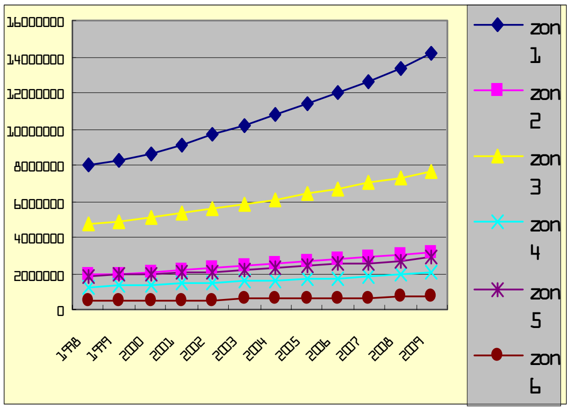

Figure 8.Total production in the basin

5. Cases

We introduce some cases into the model to find out optimal solution means significant reduction of pollutants by investments for treatment both household and industrial sectors with negligible impact on economic indicators such as investment for production and GRP in the basin. However, we assume that in the basin, land use and livestock activities are not considered as an important policy measures to reduce the pollutant by government and/or private sectors. Therefore, there are not any options for those sectors applied into the model.

First, we covert particularly both household and industrial investments for treatment categories as a free variable with ordering reduction rate of BOD, TN, and TP in the model. Then we run the model optimizing necessary investments to reach the reduction rate of pollutant at the same time maximizing GRP in the basin.

Case 1; is related to BOD reduction by 2.5% and 5% for each year from 1998 to 2008. We assume that COD and TSS reduction rate are also similar since treatment systems are the same. Total reduction and interrelated to investment, production and GRP are determined as follow; Figure 9 and 10 illustrate the number of people have without sewerage, with sewerage, pretreatment and biological treatment. Increase of number with biological treatment make decreasing of other categories. Reducing of BOD by 2.5% shows that at the end of the simulation period there are still more than 4 million have no treatment plant and around 100 thousands people have just sewerage systems. However, incase of 55 reduction shown in Figure 10, in 1998 all population receive biological treatment.

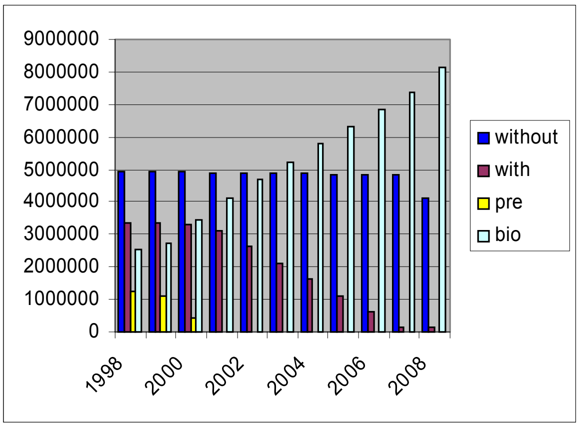

Figure 9 Number of people related to treatment (2.5%)

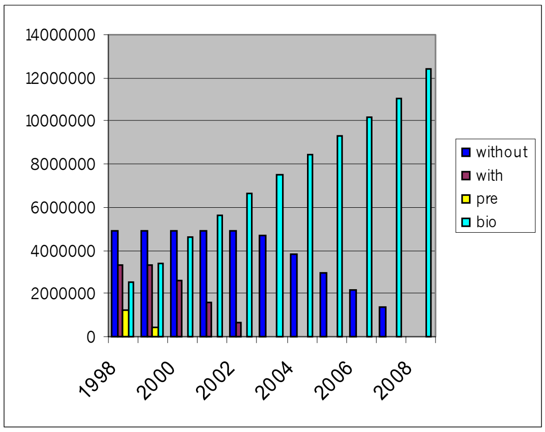

Figure 10 Number of people related to treatment (5%)

Total BOD pollution with 2.5% reduction rate decreases almost the same amount such as basic case mentioned previous section. However, with 5% reduction, total BOD reduce 40%, 32%, 43%, 45%, 55% and 31% in zone 1, 2, 3, 4, 5 and zone 6 respectively shown in Figure 11. Furthermore, household pollution reduces significantly by the simulation period is illustrated in Figure 12. In fact, except village population all the other categories have

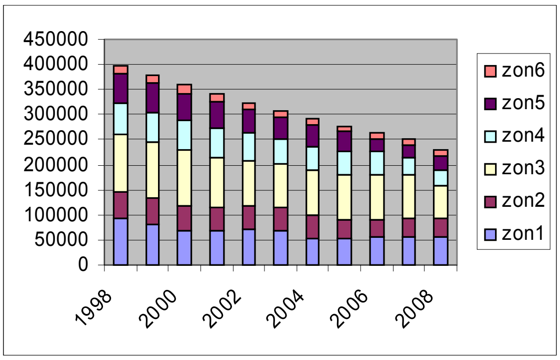

Figure 11 Fate of total BOD pollution (5%)

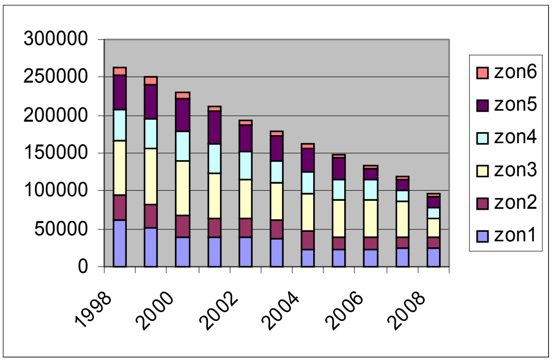

Figure 12 Fate of household pollution (BOD 5%)

treatment facility which reduce pollutant such as BOD, COD is around 90%. Pollution from villages and remain of 10% can be seen the last column of Figure 12 that is the total pollution generates from domestic sources in the basin and zones.

Industrial source of pollution give different indicators in each zone by reducing 2.5%. As an example in zone 1, 2 and zone 3 total pollution increase 25%, 15% and 5% respectively in the simulation period from 1998 to 2007. However, in zone 4, 5, and zone 5, total pollution as parameter of BOD reduce 21%, 60%, and 7%. As a basin, total BOD increases 1% in the years of simulation. In case of 5% reduction, total pollution in the basin reduces around 10%.

GRP reduction is about 110000 billion TL in total (1$=270000 TL in 1998 price) in case of increasing the reduction of BOD from 2.5% to 5% in ten years. This amount of money is very small amount comparing the total GRP in the basin. In case of total investment, 152207 billion TL value of total investment reduces from 1998 to 2008. Investment for household treatment, 117626 billion TL (approximately 440000000 million $) is necessary to construct and maintenance the treatment plants that all population will be treated at end of simulation period. Industrial investments for treatment of BOD are quite different by sectors. Investments are doubled in case of increasing reduction of BOD by 5% in almost all manufacturing sectors. Some sectors, in terms of basic case simulation have no any treatment because there is no option that investments are fixed. However, case 2.5% and 5% many sectors receive treatment systems because the optimization of investment that reduce 2.5 and or 5% reduction of pollutant.

Case 2; is reduction of TN by 0.5% and 0.8% in each year of simulation.

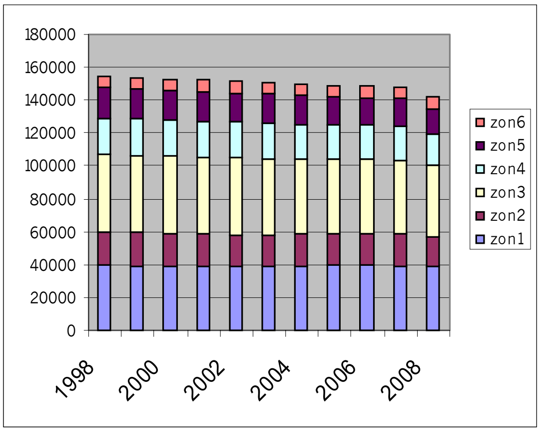

Figure 13 total pollution(TN 0.5%)

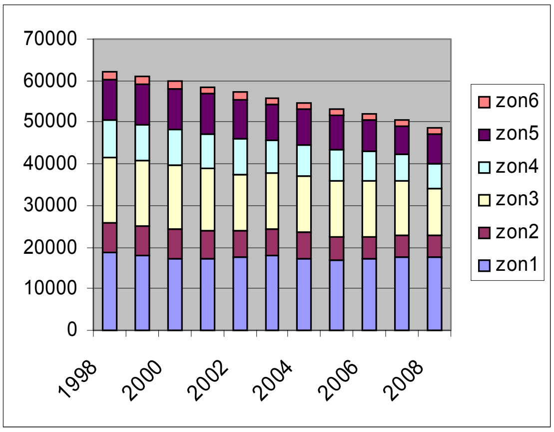

Figure 14 total household pollution(TN0.8%)

Total pollution in terms of TN reduces approximately 2%, 3%, 8% 13% 15% and 3% in zone 1, 2, 3, 4, and zone 6. In the basin, TN reduces 8.2% as a total shown in Figure 13. TN from household reduces 5%, 29%, 29%, 32%, 29%, and 14% in zone 1, 2, 3, 4, and zone 6.

In the basin, TN reduces 22% as a total shown in Figure 14.

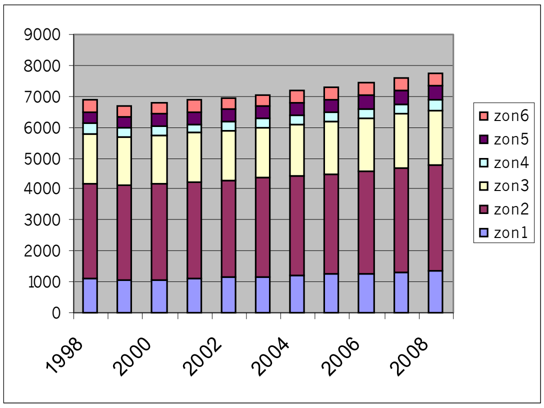

Figure 15 total industrial pollution (TN 0.5%)

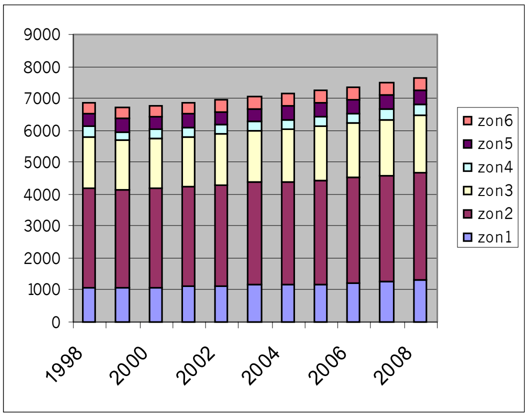

Figure 16 total industrial pollution (TN 0.8%)

Pollution from manufacturing industry is illustrated in Figure 15 and 16. It is clear from the figures that total pollution increase by the time. More reduction rate has been introduced. However, we could not find optimum solution because of the treatment techniques. With two cases 0.5 and 0.8% reduction rate, total pollution still increase 26%, 9%, 12%, 4%, 11% and 16% in zone 1, 2, 3, 4, 5, and zone 6. There is only 1-2% difference between two cases.

Case 3; is reduction of TP by 1% and 1.4%. We have found out that the result of case 3 simulation give similar result as case 2. Here, reduction rate is a little bigger than case 2 in terms of total reduction, household and industrial sector. Both case 3 and case 4 show also similar results in case of investment for production, treatment and GRP as we mentioned in case 1 .

6. Conclusion

We can conclude that the modeling of the ecosystem and economic structure based on available data and some assumptions is an appropriate way in providing valuable information related pollution, sectors` contributions and relation with economic indicators such as production, investment etc. in the basin system. Considering whole basin the summary of result, we figure out as follows:

1- Domestic sources of pollution is the main factor in the zones and in the basin although it is reduced 37% for BOD, COD, TSS and about 13% TN and TP. It contributes about 50% BOD, COD, around 55% of TP and 40% of TN at the end of the simulation period. 2- Land use activities are the second biggest contributors in the basin and in zones particularly agriculture activities which contribute 60% BOD, COD, 70% TN and 80% TP of the total land use origin of pollutants. Land use itself contributes around 25% of BOD, COD, and TP, and more than 50% of TN in the basin as a whole. 3- Livestock in the basin contribute about 10% of BOD, COD and TP, 5% of TN and about 30% of TSS. TSS seems high. In fact, land use activities may also contribute considerable amount of TSS but in this model land use activities is not included for TSS. 4- Industrial sector, particularly manufacturing is the source of pollution. Contribution from manufacturing is about 15% of BOD, 20% of COD, 10% of TSS and about 5% of TN and TP at the end of the simulation period. Here, the main problem is pollution from manufacturing sectors increase about 50% for all the pollutants from 1998 to 2009. Second, distribution of sectors and their contributions in each zone are quite different. In general, food, textile, paper and chemical, industries are the main polluting industries in the basin. 5- According to simulation result GRP increase considerable amount due to increase of production, investment etc. Actually, this is rational considering current dynamic economic state in Turkey and in the basin. 7- With the simulation cases, we would emphasize that domestic and industrial pollution may reduce sufficiently in terms of BOD and COD without any significant impact on economic development in the basin. However, in case of TN an TP, using the existing treatment system is not sufficient to reduce considerable amount by the time.

As a result, we would emphasize that the existing policy is not sufficient to reduce the pollutants in the future. It is clear that some policy measures should be applied on the basin that gives less harm to environment. As further stages of this paper, number of policy measures will be introduced. In general, we could propose some policy instruments that would be used in the model as follows:

Regarding household wastewater, the types of treatment facility will be chosen considering some factors such as scale of settlement, availability, and characteristic of land, cost and efficiency in reducing TN and TP. Industrial activities since we have detailed classification of sectors, it is easy to introduce a specific treatment technique for each specified sector. For instance, under the textile sector there are three sectors, which are wearing-dressing, dying, and leather. Textile for just cotton production or wearing-dressing biological treatment is sufficient. However, for dying and leather sector chemical treatment is also necessary. Although land use activities and livestock are the most difficult issue to control first, we would introduce in the model production of agriculture and livestock related pollution in order to find out change of production impact on pollution. Then it would be applied some practices like land use conversion, adequate cultivation, irrigation and fertilization techniques, crop rotation and planting systems etc. We would introduce budget balance for the government and municipality in the model to analyze the tax and subsidy systems and study possibility of optimal utilization of existing tax and subsidy. Furthermore, user charge, quotas or other economic instruments might be introduced to make a balance between economic growth and environmental media..

References

Arheimer, B., Brandit, M., "Watershed Modeling of Non-point Nitrogen Losses from Arable Land to the Swedish coast in 1984 and 1994" *Ecological Engineering,* Vol. 14 pp. 389-404, 2000

Baginska, B., et al., "Nutrient Export from rural in the Hawkesbury-Nepean Catchment" *Proceeding of 9.th Australian Agronomy conference,* Wagga wagga, 1998,

Black Sea Environmental Program (BSEP), "Saving the Black Sea", *Official Newsletter of the GEF, Issue 1,* 1994.

Baykal, B et. al., "Effect and Control of Pollution in Catchment Area of Lake Sapanca, Turkey" *Environmental Management,* Vol. 22, No. 3 pp. 407-414, 1998

DEFRA, Department for Environment Food & Rural Affairs. "Agriculture and Water: a Diffuse Pollution Review" *Report* 2002, England

GEF, BSEP, "Black Sea Transboundary Diagnostic Analysis*",* United Nations Publications, No E.97.III.B.15. Black Sea Environmental Program, Istanbul, 1997.

GEF Global Environmental Facility, Program Coordination Unit, *Black Sea Environmental Program*, Istanbul, 1996

LINGO systems Inc., "Lingo User Guide", 1415, north Dayton Street. Chicago, Illions 60622

Municipality of Ankara, "Ankara Central Wastewater Treatment Plant; Cost, Treatment Capacity and Properties" *Report*, 2000. General Directorate of Wastewater and Sewerage Systems, Ankara (In Turkish)

OECD, "Environmental Indicators Towards Sustainable Development" OECD Publication 2. p. 127, 1998 France

Province Bank, "Wastewater treatment system process regulation" 1990, Turkey.

Ramos, C., Agut, A., Lidon, A.L., Nitrate leaching in important crops of the Valencian Community Region (Spain) *Environmental Pollution,* Vol. 118, pp. 215-223, 2002

Skop, E., Schou, J. S., "Modeling the Effect of Agricultural Production. An Integrated Economic and

Environmental Analysis Using Farm Account Statistics and GIS". *Ecological Economics,* Vol.29, pp, 427-442. 1999

State Hydraulic Works, Research Planning and Coordination Department, *Statistic Bulletin with Maps-1999*, No. 991, Ankara, 2001

State Planning Organizations, "Industrial Politics", Special Commission Report, *Eighth. Five year Development Plan,* DPT, 2529 OIK, 545, 2000 Turkey (In Turkish)

State Planning Organizations, "Drinking and Wastewater Treatments Systems and Solid Waste Control" Special Commission Report, *Eighth. Five year Development Plan,* DPT, 2503, OIK, 545, 2000 Turkey (In Turkish)

State Institute of Statistic, "Input-Output Structure of Turkish Economy", SIS pub. 1996, Turkey

State Institute of Statistic, "River Basin Statistics", 19*96*, No. 2488, SIS press, 2001, Ankara. (In Turkish and English)

State Institute of Statistic, "Economic and Social Indicators" Ankara, Turkey. SIS press, 2000 (In Turkish, English)

State Institute of Statistic, "Agricultural structure (price, production, value)" No 2457, 1999, Turkey

Ulger, S., Higano, Y., "A Preliminary Study to Improve the Water Quality in the Black Sea: Turkish Black Sea Basin", *Studies in Regional Science*, The Japan Section of the RSAI Vol. 32, No. 1, 2002, pp. 353-367.

Vanni, M. J., et. al., "Dissolved and Particulate Nutrient Flux from three Adjacent Agricultural Watersheds: A five year Study" *Biogeochemistry,* Vol. 54, PP. 85-114, 2001

World Bank, "Water Pollution Abatement by Chinese industry Cost Estimates and Policy Implications" *Policy Research Working Paper,* WPS 1630, 1996.

World Bank," Pollution Charge Community Pressure and Abatement Cost: an Analysis of Chinese Industries". *Development Research Group*, January 2000.

World Bank, "Industrial Pollution Projection System (IPPS)" *Policy Research Working Paper,* 1431 Part 1, 1994

WHO, World Health Organization, "Assessment of Sources of Air, Water, and Land Pollution", Part I, Geneva, 1993.

Wit, M., Bendoricchio, G., "Nutrient Fluxes in the Po Basin" *The Science of Total Environment,* Vol. 273, pp. 147-161, 2001