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Research Article

Setting Measures for Tackling Agricultural Diffuse Pollution of Küçük Menderes Basin

Küçük Menderes Havzası'nda Tarımsal Kaynaklı Yayılı Kirlilikle Mücadele Tedbirlerinin Belirlenmesi

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Abstract

We explained the methodology used in setting the basic and supplementary measures for diffuse pollutants at Küçük Menderes Basin. As the majority of diffuse pollutants arise from livestock breeding and agricultural activities, we focused to propose measures regarded with tackling the pollution from agricultural activities. The types and distribution of diffuse loads were expressed by total nitrogen and phosphorous parameters. We used the results of a yearlong surface water quality monitoring involving physico-chemical, chemical and biological parameters with specific pollutants and priority substances, set in the European Union Water Framework Directive as the AquaTool input data. The AquaTool model was run for attaining the outcomes of a series of measures determined according to the ecological sensitivity of each water body. The removal efficiency of pollution loads provided by the best management practices in agricultural activities and livestock breeding were compiled from literature, and typical removal rates were further determined for the basin. We produced nine alternative scenarios at first cycle for determining compliance measures for mitigating point and diffuse sources of pollution

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in surface water bodies, and water quality improvements observed in the Model were reported. A number of exemptions were defined for some of the water bodies that could not achieve the environmental objectives at the end of first implementation cycle. 759 proposed measures for tackling diffuse pollution were 81% of the total measures considered. Additionally, the measures for mitigating diffuse agricultural pollution were almost equal to half of the diffuse pollutant measures, and 40% of the overall measures listed.

Keywords: *Diffuse pollutants, basic measures, total nitrogen, total phosphorus*

Öz

Türkiye'nin batısında yer alan Küçük Menderes Havzası'nda özellikle yayılı tarımsal kirleticiler için temel ve tamamlayıcı tedbirlerin belirlenmesinde kullanılan metodolojiyi açıkladık. Havzadaki yayılı kirleticilerin büyük kısmı hayvancılık ve tarımsal faaliyetlerden kaynaklandığından, makalede tarımsal faaliyetlerden kaynaklanan kirlilikle mücadele ile ilgili tedbirlere odaklanılmıştır. Yayılı yüklerin tipleri ve dağılımı toplam azot ve fosfor parametreleri ile ifade edilmiştir. AquaTool girdi verileri olarak Avrupa Birliği Su Çerçeve Direktifi'nde belirlenen spesifik kirleticiler ve öncelikli maddelerle birlikte fiziko-kimyasal, kimyasal ve biyolojik parametreleri içeren bir yıllık yüzeysel su kalitesi izleme sonuçları kullanılmıştır. AquaTool modeli, her bir su kütlesinin ekolojik duyarlılığına göre belirlenen bir dizi önlemin sonuçlarına ulaşmak için çalıştırılmıştır. Tarımsal faaliyetlerde ve hayvancılıkta en iyi yönetim uygulamaları kullanılarak belirlenen kirlilik yüklerinin giderim verimi literatürden derlenmiş ve havza için tipik giderme oranları ayrıca belirlenmiştir. Yüzey suyu kütlelerinde noktasal ve yayılı kirlilik kaynaklarının azaltılmasına yönelik uygun tedbirlerin belirlenmesi için ilk döngüde dokuz alternatif senaryo üretilmiş ve AquaTool modelinde gözlenen su kalitesindeki iyileşmeler raporlanmıştır. İlk döngünün sonunda çevresel hedefe ulaşamayan su kütleleri için muafiyetler tanımlanmıştır. Yayılı kirlilikle mücadele için 759 önlem önerilmiş ve bu miktar havzada belirlenen tüm önlemlerin %81'ini oluşturmuştur. Ek olarak, yayılı tarımsal kirliliğin azaltılmasına yönelik önlemler, yayılı kirleticilerin önlenmesi ile ilgili tüm önlemlerin neredeyse yarısına ve listelenen genel önlemlerin %40'ına eşittir.

Anahtar kelimeler: *Yayılı kirleticiler, temel tedbirler, toplam azot, toplam fosfor*

Introduction

In Article 11 of European Union Water Framework Directive (EU WFD) the Member States should establish programme of measures (PoMs) for each river basin (European Commission [EC], 2000; EC, 2012). With the assessment of pressure-impact-risk analyses coupled with water quality analyses conducted within the framework of preparing the River Basin Management Plans (RBMPs), it is intended to achieve environmental objectives by setting the necessary basic and supplementary measures for tackling water pollution. It is aimed to take measures based on the requirements of the legislation in force for effective, efficient and sustainable water usage as well as the protection of water quality, and prevention of point/non-point (diffuse) pollution.

The implementation of the relevant current laws for the protection of water resources is basic before determining other measures. Directives related with urban wastewater, nitrate, industrial emissions, drinking water, bathing water are among those directives that need to be fully applied. The best environmental implementation for controlling the diffuse pollutants are the licenses based on the binding rule or the records (EC, 2012). Supplementary measures can bring stricter limit values than the measures specified in the EU legislation, and stricter controls may be required particularly for agricultural activities involving crop production and animal raising. When selecting the combination of supplementary measures for a water body, the criteria of technical appropriateness of the measures and the achievement of the objective within the determined time should be taken into account. Additionally, it is also necessary to reveal how to implement the measures more cost effective and consistent. If the implementation of the measure within the specified period results in uneven costs or if it is not technically feasible, an exemption may be defined for extending the period to the next planning cycle as depicted in EU WFD.

Different mechanisms are available in the process of setting measures in various countries. These mechanisms can be economic instruments, negotiated agreements, and methods for increasing water efficiency, training programs and research, development and implementation projects as experienced especially by developed countries of the Member States who have already completed their first cycle in the implementation of the measures. Recent studies from Europe refer to the lessons-learnt from the experiences of the first cycle implementation; a few examples from Germany (Evers, 2016; Taha et al., 2019), Denmark (Baattrup-Pedersen et al., 2018), England (Giakoumis & Voulvoulis, 2019) and the Netherlands (den Haan et al., 2019) may be cited.

Turkey as a candidate country of EU, has been preparing river basin management plans for main 25 river basins of the country. Detailed and up-dated information on Turkey's water resources have been compiled in the recently published book (Harmancıoğlu & Altınbilek, 2020) in which a chapter was devoted to river basin management efforts (B. Selek & Z. Selek, 2020). Turkey, forming a bridge between the two continents; Europe and Asia, lies within a strategic geographical location, bears variable geographical, topographical, hydrological, geological and climatic properties representing different characteristics in its water basins. Rapid population increase, inefficient use of water resources, climate change effects and environmental degradation due to human-induced activities necessitate implementation of sustainable management strategies against further deterioration of the basins.

In this study, the basic aim is to mention the methodology used to set the measures in handling diffuse pollution, especially diffuse agricultural pollution with a case study (Küçük Menderes Basin [KMB], located on the Aegean Sea coast) in main river basins of the country. RBMP of this basin has recently been prepared and approved by the Republic of Turkey, Ministry of Agriculture and Forestry (MAF) according to the requirements of the EU WFD (Küçük Menderes River Basin Management Plan [KMRBMP], 2020). Determination of the pollution sources that arise due to various land-use activities, evaluation of pressures/impacts/risks based on the ecological targets, review of existing evaluations of hot spots, investigating the suitability of the existing pollution control measures, reviewing the current regulations, policies and strategies have been addressed within this comprehensive study.

Method

Study Area

KMB locates in Western Turkey and drains off its water into Küçük Menderes River and other streams. The geographical location of the basin in Turkey and its surface water bodies are shown in Figure 1. It has a total area of 6963.25 km^2 and consists of 5 sub-basins with a total population of 3.5 million. The most important river of the basin is Küçük Menderes River. According to the Master Plan study of the basin (State Hydraulic Works [SHW], 2016), water potentials calculated by taking the weighted average-based values on the sub-basins are given in Table 1.

The Mediterranean climate, characterized by dry summers and mild, wet winters, dominates the majority of the KMB. Generally, drought is not experienced much in the basin. The total rainfall amount in the east and southeast of the basin presenting a sub-humid region is higher than the rainfall in the other parts of the region. The average basin temperature is calculated and determined as 16.8^{0}C. As seen from Table 1, the annual average precipitation has been determined as 693 mm; however, the average of the total evaporation values of the basin is calculated as 1.525 mm. According to CORINE 2018 land-use distribution data, almost half of the basin is covered by forests and semi-natural areas followed by agricultural areas occupying 40% of the total area. Residential and industrial areas constitute only 6% of the entire basin.

According to WFD, surface water resources should be divided into 3 groups such as natural, artificial and heavily modified according to their physical and morphological characteristics classified under 4 different categories of river, lake, coastal and transitional waters (EC, 2003). Based on this categorization, there are 38 rivers and 13 lakes in the basin. 19 of 38 river water bodies are classified as heavily modified because of their structural changes. Only two of the 13 lakes are classified as natural. The rest of the lakes consisting of dams and ponds are heavily modified. Five dams are operated for providing domestic water needs. As a result of in-depth investigation, it has been observed that the water bodies of KMB are highly contaminated physico-chemically and chemically as well as in terms of their biological quality elements. Detailed information on the characteristics of the basin can be found in KMRBMP (2020).

Figure 1

Geographical Location of the Basin and Its Surface Water Bodies

Table 1

Surface Water Potential of the Basin

Basin Hydraulic Properties	Unit	Values
Area	km^2	6963
Surface Water	hm^3/year	624
Current Water Consumption	hm^3/year	223
Current Water Potential	hm^3/year	401
Water Consumption with Source Development	hm^3/year	311
Annual Average Rainfall	mm	693
Average Flow Capacity	v_s/km^2	2.84
Average Flow/Rainfall Ratio	-	0.13

Monitoring and Modelling Studies

Current Pollution Profile of the Basin

According to the risk assessment profile of the surface water bodies in the RBMP, 29 water bodies are “at high risk” whereas 16 of the water bodies are “at moderate risk” in the basin. The current pollution regarding point and diffuse sources of pollutants are calculated and estimated, respectively. The distribution of these two major types of pollution is expressed by the two nutrient parameters of total nitrogen (TN) and total phosphorous (TP). The pollution loads and their distribution in the current situation are given in Table 2.

Table 2

Pollution Loads and Their Distribution in the Basin

Pollution Types	Total Point Pollutant Loads			Total Diffuse Pollutant Loads		
Parameter	COD	TN	TP	COD	TN	TP
Load (tons/year)	11548	1024	123	4474	7731	655
% Distribution	72	12	16	28	88	84

COD: Chemical Oxygen Demand; TN: total nitrogen; TP: total phosphorous

Evaluation of the data given in Table 2 clearly indicates that the basin suffers mainly from diffuse pollutants, as in the most of the watersheds of the country. Turkey is still an agricultural producing country even though it accelerates and deepens the industrialization efforts. Therefore, we emphasize to select the most suitable and efficient measures, either structural or non-structural, for meeting the environmental objectives. Accordingly, it is important to know the sources and the distribution of different types of diffuse loads in the whole basin. In Table 3 we show the distribution of diffuse loads based on the two significant parameters of TN and TP.

Agricultural activities due to fertile soil types of the Aegean Region coupled with favorable climatic conditions for intensive agriculture and livestock breeding make the basin a highly prioritized one regarding its high point and diffuse pollutant loads. In this basin, agro-industrial activities and mining operations are equally important economic activities due to high level of ease of moving goods and services, ease of access and connectivity. This transportation opportunity makes it very attractive region for economic activities. The major sources of diffuse loads arise from livestock breeding and agricultural activities in forestry, meadows, pastures, etc. The leading diffuse load generated by livestock breeding on the basis of two nutrient parameters (TN and TP) are 43% and 55%, respectively. This type of diffuse pollution is followed by agricultural activities where excess chemical fertilizer use constitutes the majority of diffuse loads. These ratios are 25% and 27% for TN and TP, respectively. This trend indicates the requirement of applying Best Management Practices (BMP) and Integrated Manure Management (IMM) in the PoM.

Table 3

Distribution of Diffuse Loads in the Basin

Land-use activities causing diffuse pollution	TN (% distribution)	TP (% distribution)
Fertilizer application	25	27
Livestock breeding	43	55
Meadows, pastures, forestry	24	14
Unsanitary Landfill	6	2
Septic Tanks	1	2
Atmospheric Deposition	1	-

Surface Water Quality Monitoring

Within the context of the RBMP of the basin, water quality monitoring studies have been lasted for 12 months (September 2017- September 2018). The results were used as input data in water quality modelling via AquaTool Model. 79 water quality monitoring points have been identified within its 56 surface water bodies, of which 38 are within rivers, 13 are on lakes/dams, 4 are on coast and 1 are within transitional water. The frequency of measurements is twice (spring and autumn) in this period for biological factors and from 1 to 12 times (every month) in this period for physic-chemical parameters and lastly from 1 to 4 times (each season) in this period for hydromorphological monitoring. Ecological status of the surface water bodies based on WFD is summarized in Table 4.

Table 4

Ecological Status of Its Surface Water Bodies

Status	River Water Body	Lake water body	Coastal water body	Total
Bad	20	1	0	21
Poor	3	1	1	5
Moderate	4	11	3	18
Dry	9	0	0	9
No Monitoring	2	0	0	2
Total	38	13	4	55

Modelling of Surface Water Bodies

AquaTool model is used for the development and analysis of decision support systems for the planning and management of the PoM. Modules that can be used within the Aquatool model program are listed below.

• SIMGES Module (Water allocation module)
• SIMGES Module (Water quality module)
• EVALHID Module (Rainfall runoff model - Hydrological model)

At the initial stage of the modelling studies, hydrological modelling was carried out in four sub-basins (one of the sub-basins does not bear any water bodies) and the model was calibrated. Hydrological modelling studies were conducted between 2000 and 2018, and temperature, precipitation and potential evapotranspiration data were used as input data. Following the hydrological modelling, we studied intensively on water quality modelling. At this stage, water pollution from point and diffuse sources were taken into consideration. There is no monitoring studies on industrial discharges, because the values of these discharges are accepted in compliance with the legislation. The results of the monitoring studies carried out for a yearlong were utilized for the calibration of the AquaTool model.

AquaTool model was operated until the end of 2031 with the monthly average flow rates of the last five years. The efficiency (output) of the results of the proposed measure scenarios based on the parameters exceeding the environmental objectives has been evaluated via the model. It is need to fulfil the environmental objectives for the water bodies in the upstream of the Küçük Menderes sub-basin; they cannot be achieved in some parameters despite all the measures taken as the sub-basin that is the most polluted one among the others. This situation is still valid even some supplementary measures were also proposed to protect the basin. This is an indication that industrial activities are also highly active in addition to agricultural activities in water bodies approaching downstream in this sub-basin. Although advanced treatment technologies were proposed for the industry, the pollutants that discharge to the same water mass exceed the carrying capacity of the water. At this stage, no other measures were proposed in the first cycle concerning the parameters that do not meet the environmental objectives. However, monitoring these specific parameters in the first cycle can be continued and additional measures may be introduced if found necessary in the second cycle. Exemptions have been defined for the first cycle in the KMRBMP.

Measures Identified In the Basin

First, gap analysis (between measured concentration and environmental objectives for the pollutant) was conducted to achieve the environmental targets. Then, each of the basic measures were applied and further tested with the AquaTool model. The need for supplementary measures were then determined, and each of these additional measures were applied separately. Every time, model was run to obtain the results and this procedure continued until the environmental objectives are met. The list of measures identified as appropriate for the basin is given in Table 5.

Table 5

The List of Measures Identified As Appropriate for the Basin

1st Cycle	S1	AAT construction in direct discharges
		Rehabilitation of Irregular Solid Waste Landfill
		Controlled use of animal manure
	S2	S 1 + Management of nutrient and pesticide use
	S3	S2 + Terracing in Agricultural Lands
	S4	S3 + Measures for Olive Cultivation Enterprises
		S3 + Measures for Gas Stations
	S5	S4 + Advanced Treatment in Industrial Facilities
	S6	S5 + Nutrient Removal of all OSBs
		S5 + Nutrient Removal in Urban AATs
	S7	S6 + Vegetative Barrier
	S8	S7 + Crop Rotation
	S9	S8 + Green Belt (Through the stream)
2nd Cycle	S10	S9 + Environmental Flow Measure

Methodology of Selecting Measures for Diffuse Pollutants

Within the period of determining the measures for diffuse pollutants, we aimed to select in compliance with both the overall WFD approach and the related national legislation such as;

- Regulation on Surface Water Quality,
- Regulation on Good Agricultural Practices,
- Code on the Good Agricultural Practices for the Prevention of Nitrate Pollution (CGAP).

National regulation on the Protection of Waters against Nitrate Pollution from Agricultural Sources states that nitrate sensitive areas should be determined initially to fix the respective measures and their order of application. The necessary measures to improve the water quality in sensitive water bodies have been determined at first. Additionally, good agricultural practices have been taken as a basis for the prevention of agricultural pollution in nitrate sensitive areas according to the national regulation on the Determination of Sensitive Water Bodies and the Areas Affecting Them and the Improvement of Water Quality. The Regulation on the Control of Solid Wastes also provides a basis for the closure and rehabilitation of existing unsanitary solid waste depots in the basin and for the establishment of solid waste sanitary landfills.

As the majority sources of diffuse pollutants arise from livestock breeding and agricultural activities, the measures concerning these practices will be the focus of this article.

Code on the Good Agricultural Practices

National regulation on Good Agricultural Practices was published in 2010 to conduct rules and procedures for an agricultural production method allowing traceability, sustainability and food safety in agriculture without harming the human health, animal health and environment. Organic substances positively affect physical, chemical and biological properties of soil For instance, water retention and aeration properties of soil are improved, the penetration of plant roots in soil gets easy and the water penetration into soil increases. 92% of Turkey's soil is lack of sufficient organic matter; whereas, farmyard manure contains many nutrients for macro and micro plants like nitrogen, phosphorus, calcium and sulphur (Konca & Uzun, 2012).

The removal efficiency of TN and TP loads provided by the Best Management Practices (BMP) for agricultural activities are compiled from literature and displayed in Table 6. Typical removal rates were further selected for KMB during the selection of the PoMs.

The main measures proposed for agricultural production for KMB as mentioned in the Code of Good Agricultural Practices were as follows;

- The high slope (12-20%) and extremely high slope (>20%) areas for terrace farming in the basin
- Management of nutrient and pesticide uses
- Riparian forest buffers on lakes and river banks
- Vegetative barrier practices
- Crop rotation (alternation)

Table 6

Removal Efficiency of Nutrients in the Best Management Practices (BMPs) For Agricultural Land-Use Activities (Tavşan, 2008)

BMPs	Nutrient Removals (%)		Reference
	TN	TP	
Management of Nutrients	21	6	USEPA (2003)
Management of Nutrients	20-90		Novotny (2003)
Organic Agriculture	40-64	No data available for P removal	Scialabba and Hatam (2002)
Organic Agriculture	46 (clayed soil) 10 -35 (sandy soil)	No data available for P removal	Eila et al. (2005)
Terracing	56-92		Ritter and Shirmohammadi, (2001); Cestti et al. (2003)
Terracing	30-70		Novotny (2003)
Change in the Surface Flow Direction (diversions)	20-45		Novotny (2003)
Riparian Forest Buffers on Lake and River Sides	80-90	50-75	Novotny (2003)
Vegetative Filter Strips	50-80	50-80	Grismer et al. (2006)
Vegetative Filter Strips	35-90	5-50	Novotny (2003)
Vegetative barriers	70	70	Blanco-Canqui et al. (2004)
Conservation tillage	No data available for N removal	50	Fawecett (2005)
Conservation tillage	50-80	35-85	Novotny (2003)
Crop rotation (clover-potato)	No data available for N removal	12-33	Lauringson et al. (2004)
Crop rotation	50	30	Novotny (2003)
Strip cropping systems	No data available for N removal	50	Novotny (2003)
Crop Pattern	No data available for N removal	30-50	Novotny (2003)

Terracing.

Terracing is a method of soil protection applied to prevent accumulation and erosion as a result of surface flow caused by precipitation on sloping land (Wheaton & Monke, 2001). Terraces change the land slope and reduce the surface flow rate (Novotny, 2003). Thus, it reduces the erosion rate in the upper layer of soil, the amount of sediment drifted by erosion and the amount of pollutants that may be related to them in surface flow (Cestti et al., 2003; Novotny, 2003). Terracing prevents 94-95% of soil loss, 56-92% of nutrient loss, and 73-88% of surface flow volume (Ritter & Shirmohammadi, 2001; Cestti et al., 2003). According to Novotny (2003), these rates can rise up to 95% for sediment and vary between 30-70% for nutrients. Terraces block the surface flow and store sediments and pollutants by holding them.

Terracing within the agricultural areas is determined as a basic measure to prevent the movement of priority substances, certain pollutants and nutrients towards water resources in KMB. For this purpose, firstly the slope categorization of the basin has been determined. In this categorization, agricultural production areas have been categorized based on this:

- Low slope (<6%),
- Medium slope (6% -12%),
- High slope (12% -20%) and
- Extremely high slope (> 20%).

For each agricultural land, terracing is considered at high and extremely high slope (including pastures, olive groves and continuously irrigated vegetable land). The reduction rates of TN and TP from the diffuse sources were differently foreseen according to the slope. Criteria to take measures for terracing were as follows:

1. In the water bodies there must be pollutants that cannot be associated with point sources,
2. The slope of agricultural areas (including pasture, olive grove and irrigated vegetable land) must be greater than 12%,
3. The ratio of total water bodies within the total agricultural land having the slope above 12% should be at least 5% or more.
4. If it is required, green belt should also be considered for these water bodies as a policy.

Nutrient Management.

If an excessive amount of nutrients is present in the soil, they will be moved from the soil to the water environment through erosion, surface flow, penetration and evaporation and become harmful (United States Environmental Protection Agency [USEPA], 2007). Nutrient management is one of the '*control at source*' practices that aim to optimize the crop productivity and quality, to reduce the manure costs and protect the water and soil quality (Hilliard & Reedky, 2000), and to reduce the formation of excess nutrients and their access to water resources (Natural Resources Conservation Services [NRCS], 2002; Cestti et al., 2003; Novotny, 2003; NRSC, 2007; USEPA, 2007).

Suitable time, quantity, and application methods should be used to minimize the environmental losses while maximizing crop productivity. Time and frequency of application are mainly determined by the climatic conditions that affect the growth of crops, nutrient requirement and transfer of nutrients (USEPA, 2007). Nutrient management and application are particularly effective in controlling dissolved forms of nutrients and provide 20-90% removal in N and P (Novotny, 2003).

Within the scope of nutrient management, the provincial directorate of the MAF allocates budget to inform and train farmers about the suitable time, quantity and frequency of nutrient application. In this way, it is expected to plan the manure use and decrease the N by 20% and P by 10%. In this context, training and awareness raising activities will be conducted throughout the basin.

Pesticide Management.

Pesticide management is a burden of practices that minimize the pollution caused by the chemicals used to control the creatures that give harm to the crops (Novotny, 2003). In this field, management is achieved in two ways; '*control at source*' and '*structural control*'.

<u>*Control at source:*</u> This management way involves (Novotny, 2003);

- Proper application ratios,
- Modern application equipment,
- Suitable timing and frequency,
- Selection of suitable pesticides (the least toxic and most easily biodegradable) for crops.

The selection of pesticides, prohibited or approved is determined by the legislations and they are updated regularly in parallel with other practices and experiments around the world. The General Directorate of Food and Control of the MAF have developed a database on the Plant Protection Products. In the related website, the information such as active substance types required for the harmful organism, application dose and the dates are existed (https://bku.tarim.gov.tr).

Structural Controls: Protective buffer zone applications (green belt, vegetative barriers, etc.) from "Good Agricultural Practices" are also used for pesticide and nutrient control. Thanks to the protective buffer zones, removal is achieved for different pesticide species at the ratios of 10 to 95% (United States Department of Agriculture [USDA], 2000). The pesticides exceeding Environmental Quality Standards (EQS) in each water body have been identified. The measures taken for the pesticide species detected in the water bodies were as follows:

1. Pesticide species detected in water bodies are compared with the "Prohibited Pesticides List" of MAF.
2. Some pesticides have been encountered in water resources of the basin in a large number and quantity. These non-prohibited species will be replaced with their substitutes.
3. Pesticide species that cannot be removed by items (1) and (2) will be captured by the measures such as terracing, vegetative barrier or green belt.

Vegetative Barriers.

Vegetative barriers are narrow parallel bands that consist of plants cultivated on a steep, hard and dense way in the areas close to the land border. Their difference from classical plant filter bands is that they are narrower (less than 1.5 m in width) and they have a steep and hard vegetation throughout the year. Their benefits are listed as follows (Los, 2001; USEPA, 2007);

- They control erosion, hold the sediments in surface flow, and prevent them from reaching the receiving water environment.
- They allow the sediments to accumulate in the upper slopes of the barriers, by slowing down the speed of the water coming in surface flow.
- They increase the efficiency of other protective applications.
- They reduce the total amount of water in surface flow by increasing the water filtration capacity.

It is recommended to apply vegetative barrier on the riverbanks of the agricultural areas to provide effective N and P removal of water bodies in KMB. The guidance of agricultural engineers is needed in the cultivation of plants that are dense, evergreen, less water consuming, specific to the region and taller than the plants in the cultivated agricultural land. In this way, not only nutrients, but also specific and priority pollutants will be held in these barriers. The removal efficiency will be 70% based on TN and TP parameters as suggested by Blanco-Canqui et al. (2004). It can be applied at a width of 1 m to the borders of agricultural land. Its application is easy and very little space is needed. Therefore, vegetation barriers are proposed for some water bodies where terracing is not sufficient.

Crop Rotation.

Crop rotation is the cultivation of different crops on the same land in an annual or periodically planned sequence. By this application, the quality of soil is improved while the natural degradation of weeds, insects and other residues reduces the need of manure. The inclusion of foliage (grass, green grass) or legumes in crop rotation will improve soil quality and reduce erosion (Cestti, 2003; Xie et al., 2015). Moreover, since legumes meet their own N needs and provide extra N to the soil by fixation, the manure usage in the cultivated crop will be quite low (Cestti, 2003). In Estonia, for example, it was observed that the P requirement in the soil decreased by 12-33% in a crop rotation by first planting alfalfa and then potatoes (Lauringson, 2004). According to Novotny (2003), TN and TP can be reduced by 50 % and 30%, respectively. One of the most important benefits of crop rotation is the control of the organisms that may give damage to the crops and soil without using pesticides (Xie et al., 2015) and improves surface water quality by reducing sediment loss, pesticide applications and dissolved or soil-bound particulate nutrients and pesticide losses (Cestti, 2003).

Crop rotation in KMB is recommended when the basic measures in the basin are insufficient to achieve the EQS. In addition to this, the criteria of selection of crops are directly related with the water availability in the provinces and districts in KMB and also the crops in rotation should be selected taking into consideration the Agricultural Basin Production and Support Model of Turkey, started in 2017.

Lake and River Bank Forest Buffer Zones (Green Belt-Buffer Zones).

Lake and riverside forest buffers are afforestation areas close to the riversides, and forms a transition between water and soil. The most effective type of the riverside buffers (riparian buffers) is forests. They contribute to the improvement of water quality while being a habitat for wild animals and fishes. Tree roots absorb the nutrients and other pollutants carried by surface flow. In this way, tree roots grow the fastest and the holding water capacity of roots increases (Campbell et al., 2004). According to Novotny (2003), riverside buffers remove 80-90% of sediments, 50-75% of TP and 80-90% of TN.

In some water bodies in the basin, green belt has been proposed as a basic measure within the scope of "Good Agricultural Practices". This measure has been carried out in the limited amount of areas considering some criteria listed below because of two main problems: Its high cost and high compensation paid to property owners for land expropriation.

1. If the water body is a lake used for supplying drinking water, a 10 m wide forest buffer surrounding the lake is proposed.
2. If the water body is a river and if terracing cannot be done due to slope and if vegetation barrier measure cannot be applied as it passes through the agricultural land, a 5 m wide forest buffer at each site along the part of stream passing the agricultural land is proposed.
3. If the water body is also a river and if it is passing through an active mining site, a 5 m wide forest buffer is proposed at each site along the part of the river passing the mining site.

On the other hand, the green belt measure was not proposed for those water bodies, which have been already surrounded by green belts as a result of deciding with analysing the satellite images. Upon an in-depth review of the nutrient removal rates to be attained via various BMPs, Table 7, including the removal rates selected for the KMB, was prepared. In Figure 2, a map of basic control measures for reducing the agricultural diffuse in the basin was shown (except for animal manure control).

Animal Manure Control.

For the reason that increase in the impairment effects of chemical fertilizers used in agricultural activities on the human health, ecological agricultural practices, based on the animal manure use that has the same functions with the chemical ones have been developed at the second half of the last century. The fertility of agricultural areas cannot be sustained, especially with the use of chemical fertilizers. Using poultry manure, for example, positively affects the structure of soil, and provides the necessary nutrients for growing the plants (Soyergin, 2003).

If the necessary attention and care are not paid after the removal of the cow manure and if the required precautions are not taken, the loss of liquid faeces containing 50% of the plant nutrients before moving to the field becomes an important problem. If not enough bearing is used, it may leak from the cowshed floor and can be significantly lost under the manure pile. Moreover, if the manure taken from the cowshed is left in open air and in loose piles, the loss may reach a significant size (Soyergin, 2003).

The amount of use of commercial (synthetic) fertilizers in agricultural areas in Turkey varies by the amount and types of the planted crops, climatic conditions, and soil features. Data on the amount of synthetic fertilizers used in 2016 has been obtained from the 4. Regional Directorate of MAF. On the other hand, the amount of manure generated in the basin that shows an important potential in terms of the use of organic manure in agricultural applications is obtained again from the same directorate. The number of cows and cattle, sheep and goats, and poultry based on a village is used to determine the natural nitrogen manure that can be used in sustainable agricultural practices.

Figure 2

Map of the Control Measures for Reducing Agricultural Diffuse in the Basin (Except For Animal Manure Control)

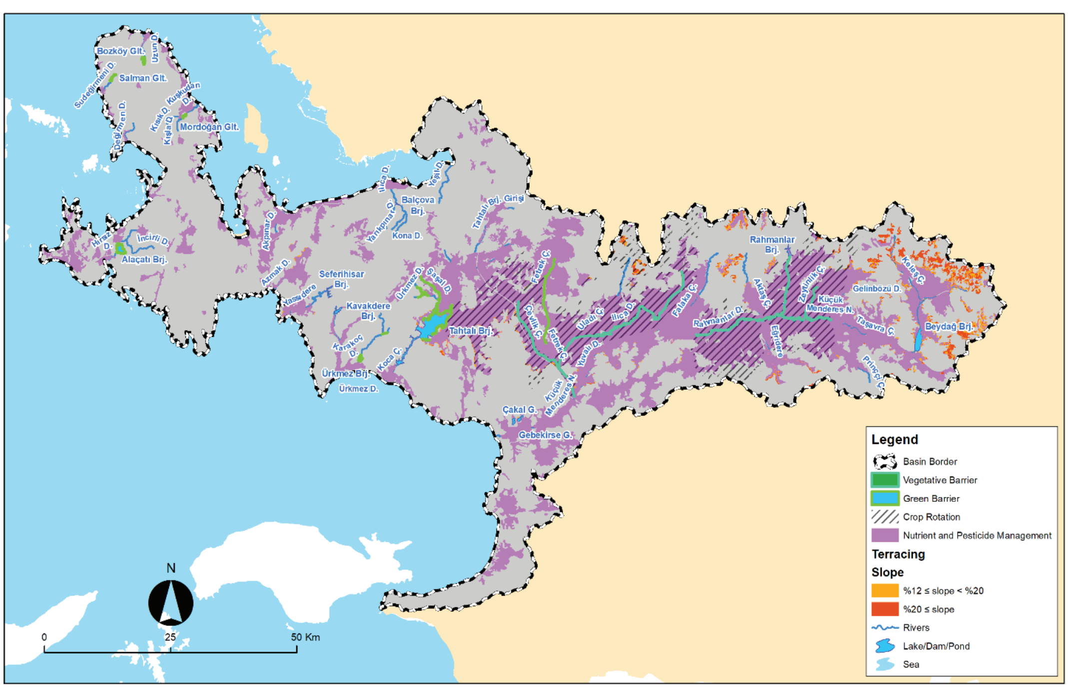


Table 7

Selected Removal Rates for BMPs

	Range of TN removal (%)	Selected TN removal (%)	Range of TP removal (%)	Selected TP removal (%)
Nutrient Management	20-90	30	20-90	20
Crop Rotation	50	50	30	30
Green Barrier	80–90	70	50–75	70
Vegetative Barrier	70	70	70	70
Terracing	30–70	70*	30–70	70*

**The ratio of agricultural land to be terraced/total agricultural land is considered.*

Within the scope of good agricultural practices, manure management planning should be established in nitrate sensitive regions that produce 1600 kg N/year and more, and in non-nitrate sensitive regions that produce 3500 kg N/year and more. The unit N loads given in Table 8 are used the calculation of the N amount produced by the livestock breeding.

Table 8

Unit N Load Arising From Livestock Activities (MoEF, 2010)

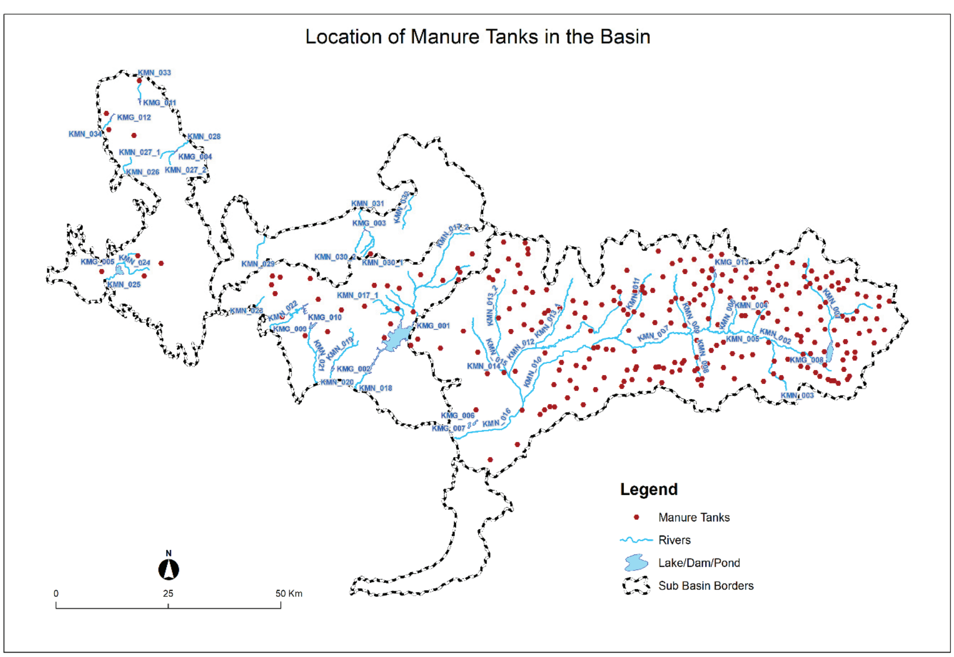
Animal Category	Nitrogen (kg/ton animal/day)
Cattle and cows	0.3
Sheep and goat	0.42
Poultry	0.52

Nitrogen unit (kg/day) is calculated based upon cows and cattles, taken as 500 kg, sheep and goats as 45 kg and poultry as 2 kg (MoEF, 2010). The total amount of organic N in manure is calculated annually based upon the unit loads of the settlements/villages and the number of animals. If sufficient measures are not taken during or after animal manure collected from barns, some of its value will be lost prior to carrying it to agricultural fields, and this amount is determined as 15% in the calculations. In addition to that, the organic substance of the manure, which has to be kept for a while in the sealed tank before starting an application, will be lost over time and this amount is accepted as 35%. Considering these losses, the amount of natural manure that can be safely applied has been determined based upon each water body. It is foreseen that the losses will decrease in the following years with the awareness raising activities, developments in application techniques and the measures to be taken during its transportation.

The settlements where animal manure will be correctly applied, are marked on Figure 3. Even if the animal manure is applied on agricultural areas, the use of chemical manure is still need to meet the N requirement of soil. The amount of chemical fertilizer after the application of animal manure has decreased compared with the chemical fertilizer amount used at present. The total amount of N from animal manure and chemical fertilizer based upon water bodies is given in Table 9. The amount of natural manure to be generated from animal breeding activities in the basin has the potential to significantly reduce the use of chemical fertilizers when it is used within the context of good agricultural practices. Fertilizer need of some water bodies can be met only with animal manure, but in the first cycle, the farmers' tendency to continue using chemical fertilizer is taken into consideration and the assessment is made based on the entire basin. Accordingly, the average use of animal manure throughout the basin was calculated as approximately 52%.

Figure 3

Settlements Where It is Recommended to Place Manure Tanks



Results and Discussion

In this study, initially gap analysis was conducted to achieve Environmental Quality Standards (EQSs). Then, each applied measure was tested by the AquaTool model. At the stage of the determination of measures, basic measure scenarios were entered into the model and the need for supplementary measures was determined by evaluating the results obtained. In the second stage, complementary measures were entered respectively, and lastly the program for measures was created.

The total number of the measures including point and diffuse sources of pollutants together with hydromorphological and geothermal measures, and measures on coastal bodies, on mining areas was 932. Out of this huge number of measures, diffuse pollutant measures recommended were 759 constituting 81% of the total measures considered. Within this profile, agricultural measures were 373 that are almost equal to half of the diffuse pollutant measures, and 40% of the overall measures listed. The list of measures regarding with agricultural diffuse pollution is given in Table 10.

The majority of diffuse pollutant measures were structural measures (except nutrient and pesticide measurement); therefore, the related ones are either basic or supplementary depending on the sensitivity of the water body. As the river basin management plans are the initial trials of the country, their implementation and results will be observed and evaluated within the first cycle.

Agricultural diffuse pollution mitigation poses a significant policy challenge across Europe and particularly in the UK. Prevailing legislation and volunteer studies in the UK are not enough to get necessary environmental outcomes due to several reasons (Collins et al., 2016). Thus, it is important to identify specific measures for on-farm towards whose farmers express positive attitudes for higher nutrient uptake rates. Accordingly, an attitudinal survey was carried out among farmers in England on those measures. The results suggest that mitigation measures that farmers are motivated to implement in the future to improve the environmental performance of agriculture in England and Wales are those that cost lowest per hectare of arable land. This outcome of the survey conducted in England actually holds true all over the world, no matter the development level of the country. In that sense, understanding farmer receptiveness and attitudes towards on-farm diffuse pollution mitigation options is critical in developing a comprehensive approach to control negative impacts of farming on environmental quality as underlined by Blackstock et al. (2010) and Buckley (2012).

Table 9

Animal Manure and Chemical Fertilizer Uses Based Upon Good Agricultural Practices in Water Bodies

Water body	Total chemical fertilizer usage in present condition (ton/year)	Total amount of natural manure (ton/year) **	Total amount of applicable natural manure (ton/year)	Required chemical fertilizer amount after the application of animal manure (ton)	Use of animal manure (%)
KMN_011	675	227	227	448	34
KMN_013_1	940	180	180	760	19
KMN_012	2,023	875	875	1,149	43
KMN_010	1,268	1,119	1,119	148	88
KMN_002*	1,154	1,014	1,014	140	88
KMG_008*	120	238	120.3	-	100
KMN_017_2	652	135	135	517	21
KMN_033	0.9	6	0.9	-	100
KMN_026	4.5	26	4.5	-	100
KMN_013_2	1,110	90	90	1,021	8
KMN_001	1,374	2,871	1,374	-	100
KMN_015	2,010	229	229	1,781	11
KMG_001	472	36	36	436	8
KMN_021	106	58	58	48	55
KMN_017_1	372	40.6	40.6	331	11
KMG_010	27	26.7	26.7	0.3	99
KMN_023	53	107.5	52.7	-	100
KMN_022	30	4.6	4.6	25	15
KMN_016	1,207	352.1	352.1	855.2	29
KMG_006	40.8	2.9	2.9	37.8	7
KMN_007	2,153	3,240	2,153	-	100
KMN_008	633	286	286	347	45
KMN_024	5.9	14.8	5.9	-	100
KMN_003*	466	287	287	179	62
KMN_006	597	265	265	331	44
KMG_013	407	76	76	331	19
KMN_004	381	463	381	-	100
KMN_009	698	230	230	468	33
KMN_005*	400	579	400	-	100
Total	19,379	13,080	10,027	9,353	52

*Sensitive Water Body

**The losses foreseen for the 1st cycle are not taken into consideration

Table 10

Number of Agricultural Measures for Non-Point (Diffuse) Pollutants

Agricultural measures for non-Point (Diffuse) Pollutant	Number of Measures	Unit	Basic (B)/ Supplementary (S)
Application of animal manure in a controlled way to agricultural land	279	settlement	B/S
Terracing	17	water body	B/S
Nutrient and pesticide management	57	water body	B/S
Setting vegetative barrier	5	water body	B/S
Conducting crop rotation	6	water body	B/S
Setting green belt	9	water body	B/S
Total	373		

Nowadays, social science linked watershed management recognized the need for voluntary action by farmers in the context of environmental regulation and government subsidies to reduce agricultural diffuse pollutants as proved by Collins et al. (2016) who have conducted a detailed survey among a group of farmers. Therefore, coping with agricultural diffuse pollutants seems to be a long-lasting issue especially in developing countries that face economic constraints in implementing the measures.

Within the context of measures program, basic measures to be followed in all the water bodies and supplementary measures in the required ones were proposed. It is expected that the strict implementation of these measures in the first cycle of the river basin management plan will improve or tend to improve the quality of surface water bodies. Measures for reducing point and non-point pollutants in surface water bodies at the first cycle covering the years 2020-2025 and at the second cycle covering the years 2026-2031, were proposed and improvements observed in water quality via the AquaTool model were reported. By applying the so-called measures in the first and second implementation cycles, the model has given the final ecological and chemical status of the water bodies as shown in Table 11. As can be seen from the table, a total number of 27 water bodies still "*do not meet the good status*".

Table 11

Ecological and Chemical Status of the Water Bodies after Implementing the Measures in Two Cycles (2020-2025 and 2026-2031)

Ecological Status			Chemical Status		
Status	Monitoring results	Modelling Results (after implementing the measures)	Status	Monitoring results	Modelling Results (after implementing the measures)
Bad	21	15	Failed	38	27
Poor	5	2			
Moderate	14	10	Passed	6	10
Good	4	10			
Dry	9	9	Dry	9	9
No Monitoring	2	2	No Monitoring	2	2
No modelling		7	No modelling	-	7
Total	55	55	Total	55	55

Conclusion

The ultimate goal in national and international legislation is to achieve '*good water*' status in all water bodies. As stated in all relevant regulations, guidance documents and practices some strategies need to be developed in order to prevent and control the pollution of water bodies. In this context, the measures program was prepared by taking into consideration the results of the monitoring program conducted from September 2017 to August 2018 for surface water bodies. Within the scope of the preparation of KMRBMP, surface water bodies were studied in a holistic manner. The measures to be taken to improve the surface water bodies interacting with each other in the basin were evaluated.

Both basic and supplementary measures were proposed and tested via the AquaTool model for the first and second implementation cycles covering the years 2020-2025 and 2026-2031. Despite the so-called measures taken within these two cycles, 27 water bodies out of 55 failed in satisfying the '*good ecological and chemical status*'. This situation implies that even though a series of basic and supplementary measures were considered, a considerable number of water bodies do not meet the requirements. Therefore, it is important to apply and realize all the referred measures in time to reach a better environmental condition in the basin in future.

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Extended Turkish Abstract
(Genişletilmiş Türkçe Özet)

Küçük Menderes Havzası'nda Tarımsal Kaynaklı Yayılı Kirlilik Tedbirlerinin Belirlenmesi

Küçük Menderes Havzası, Türkiye'nin batısında Gediz ve Büyük Menderes Havzaları arasında, sularını Küçük Menderes Nehri ve diğer akarsularla Ege Denizi'ne boşaltan alanı kapsamaktadır. Toplam alanı 6963.25 km^2 ve toplam nüfusu 3,5 milyonun üzerinde olan 5 alt havzadan oluşmaktadır. Havzanın en önemli nehri Küçük Menderes Nehri'dir. Havza toplam alanının %40'ı tarım alanları ile kaplıdır. Yerleşim ve sanayi alanları tüm havzanın %6'sını oluşturmaktadır. Avrupa Birliği Su Çerçeve Direktifi (AB SÇD)'nin sınıflandırmasına göre, havzada 38 nehir ve 13 göl bulunmaktadır. 38 nehir suyu kütlesinden 19'u büyük ölçüde değiştirilmiş su kütlesi sınıfına dahildir. 13 göl suyu kütlesinden sadece ikisi doğal göl sınıfındadır. Göllerin geri kalanı büyük ölçüde değiştirilmiş, baraj veya gölet inşa edilmiştir. Havzada evsel su ihtiyacının karşılanması için 5 baraj işletilmektedir. Havza için hazırlanan nehir havza yönetim planında: İnsan faaliyetlerinden kaynaklı kirlilik yükleri, ekolojik hedeflerle ilgili baskı ve etkiler, mevcut sıcak noktalar, mevcut kirlilikle kontrol yöntemleri ve önlemler, mevcut yasal düzenlemeler, politikalar ve stratejiler gözden geçirilmiştir. Havza yönetim planı sonuçlarına göre Küçük Menderes Havzası su kütlelerinin fiziko-kimyasal ve kimyasal olarak ve de biyolojik kalite unsurları açısından oldukça kirlenmiş oldukları görülmüştür. Havzada 9 nitrata hassas alan ile 16 kentsel hassas alan bulunmaktadır. Bu çalışmada, Küçük Menderes Havzası'ndaki su kütleleri ile ilgili özellikle yayılı kaynak kirliliğinin önlenmesi için gereken temel ve tamamlayıcı tedbirlerin belirlenmesi için kullanılan metodoloji anlatılmıştır.

Çalışmada yayılı kirlilik kaynaklarına yönelik tedbirlerin belirlenmesinde, tedbirlerin AB SÇD ile uyumlu olması gözetilmiş, Yerüstü Su Kalitesi Yönetmeliği, İyi Tarım Uygulamaları Hakkında Yönetmelik ve Sularda Tarımsal Faaliyetlerden Kaynaklanan Nitrat Kirliliğinin Önlenmesine Yönelik İyi Tarım Uygulamaları Kodu Tebliği temel alınmıştır. Su kütlelerinde yayılı azot ve fosfor yüklerine karşı alınacak tedbirler ile belirlenen nitrata hassas bölgeler için tedbirler ortaya konmuştur.

Havza yönetim planında öncelikle mevcut kirlilik profili ortaya konmuştur. Risk değerlendirme çalışmasının sonuçlarına göre toplam 29 su kütlesi "yüksek risk altında" ve 16 su kütlesi "orta risk altında" olarak bulunmuştur. Risk değerlendirmede noktasal ve yayılı kaynaktan gelen yükler değerlendirilmiştir. Yayılı kaynak kirliliğine neden olan en önemli iki kirletici parametre, toplam azot (TN) ve toplam fosfor (TP)'dur. Havzadaki veriler değerlendirildiğinde, havzanın özellikle yayılı kaynak kirliğine bağlı TN ve TP açısından oldukça kirlenmiş olduğu görülmüştür. TN ve TP açısından kirlenmenin dağılımı sırasıyla %88 ve %84 olarak belirlenmiştir. TN ve TP açısından kirlilik kaynakları başta hayvancılık, aşırı ve kontrolsüz gübre kullanımı olmak üzere arazi kullanım şekli, fosseptikler ve katı atık sahaları olduğu tespit edilmiştir.

Havza yönetim planında izleme çalışmaları Eylül 2017-Eylül 2018 arasında 12 ay boyunca yapılmıştır. İzleme sonuçlarına göre havzada 21 kötü, 6 zayıf, 18 orta, 9 kuru durumda olan ve 2 adet izlenemeyen su kaynağı bulunmaktadır. Çalışmada su kaynaklarının yönetim alternatiflerinin belirlenmesi ve gerekli verilerin düzenlenmesi için AQUATOOL programı kullanılmıştır.

Mevcut durum dikkate alınarak havzada noktasal ve yayılı kaynakların kontrolü için tedbirler belirlenmiştir. Öncelikle boşluk analizi yapılmıştır; yani ölçülen konsantrasyonlar ile çevresel hedefler arasındaki farklar belirlenmiştir. Böylece alıcı ortamın istenen su kalitesine ulaşmak için gerekli olan

ayrı uygulanmıştır. Her seferinde tedbirlerin sonuçlarını elde etmek için model yeniden çalıştırılmış ve bu prosedür çevresel hedeflere ulaşılıncaya kadar devam etmiştir. Havzada 1. ve 2. döngü için farklı kombinasyonlardaki tedbirler toplam 10 başlık altında değerlendirilmiştir.

Yayılı kirletici kaynakların büyük çoğunluğu hayvancılık ve tarımsal faaliyetlerden kaynaklandığından çalışmada, bu uygulamalara ilişkin tedbirler üzerinde durulmuştur. Küçük Menderes Havzası için tarımsal üretim için önerilen temel tedbirler şunlardır:

- Yüksek eğimli ve çok yüksek eğimli tarımsal üretim alanlarında teraslama
- Besi maddesi ve pestisit yönetimi,
- Göl ve nehir kıyısına tampon bölgeler,
- Bitkisel bariyer uygulamaları,
- Ürün rotasyonu.

Tüm bu tedbirler eğim, besi maddesi ve pestisit kullanım miktar ve davranışları, ürün bilgileri, su kütlesi özellikleri vb. dikkate alınarak havzada her bir su kütlesi için ayrı ayrı belirlenmiştir.

Hayvan gübresinin kontrollü kullanımı önemli tedbirlerdendir. Havza bazında ortalama hayvan gübresi kullanımı yaklaşık %52'dir. Yapılan hesaplamalarda havzadaki hayvancılık faaliyetlerinden üretilecek doğal gübre miktarı, iyi tarım uygulamaları kapsamında kullanıldığında kimyasal gübre kullanımını önemli ölçüde azaltma potansiyeline sahip olduğu görülmüştür.

Sonuç olarak havzada önerilen toplam tedbir sayısı (noktasal ve yayılı kaynaklar ile birlikte hidromorfolojik ve jeotermal önlemler ile madencilik ve kıyı alanlarındaki önlemler de dahil) 932'dir. Tavsiye edilen yayılı kaynak tedbirlerinin sayısı, toplam tedbirlerin %81'ini oluşturan 759'dur. Bu profilde tarımsal tedbirler, yayılı kaynak kirliliği için önerilen tedbirlerin neredeyse yarısına eşit olup 373’tür ve yayılı kaynak tedbirlerinin %40'ıdır. Yayılı kirletici tedbirlerinin çoğu yapısal tedbirlerdir; bu nedenle, su kütlesinin özelinde belirlenen tedbirler hassasiyetine bağlı olarak temel veya tamamlayıcıdır. Yönetim planlarının bu şekilde hazırlanması ülkenin ilk denemeleri olduğundan, bunların uygulanması ile ortaya çıkan faydalar ilk döngüde gözlemlenecek ve değerlendirilecektir.

Tedbirler programı dahilinde tüm su kütlelerinde uygulanması gereken temel ve tamamlayıcı tedbirler belirlenmiştir. Nehir havzası yönetim planının ilk döngüsünde bu önlemlerin sıkı bir şekilde uygulanmasının yerüstü suyu kütlelerinin kalitesini iyileştirmesi veya iyileştirme eğiliminde olması beklenmektedir. 2020-2025 yıllarını kapsayan birinci döngü ve 2026-2031 yıllarını kapsayan ikinci döngü sonunda yerüstü kütlelerinde noktasal ve noktasal olmayan kirleticiler için belirlenen tedbirlerin uygulanması sonucunda ulaşılacak bu sonuçlar AquaTool ile modellenmiştir. Elde dilen sonuçlara göre tüm havzada tedbirler sonunda hedefe yani “iyi durum” a ulaşamayan 27 su kütlesinin bulunacağı belirlenmiştir. Bu sonuçlar havzada önerilen tüm zorunlu ve tamamlayıcı tedbirlerin zamanında uygulanmasının önemini göstermektedir. Böylelikle havza ilk iki döngü sonrasında günümüzdeki durumdan daha iyi koşullara kavuşmuş olacaktır.