Sectoral Impact Analysis Methodology within the Scope of Climate Change Adaptation

Maruf ARAS[1], Ayşegül TANIK[2], Ayşe Yıldırım COŞGUN[1],
Seda ABAT[2], Mehmet AŞKINER[1]

Abstract

The reality that climate change inevitably affects our world at present is taken into consideration and adaptation to climate change studies are becoming more pronounced at international scale. Although there are some studies related to the determination of adaptation measures in our country and in the world, there is still no common methodology for adaptation on a measurable basis. In this study, a new approach developed under the "Effects of Climate Change on Water Resources Project" was used to execute a sectorial vulnerability analysis. Sectorial vulnerability analyses have great importance in terms of determining the most vulnerable sector to climate change and of the related policy.

In this study, the methodology of sectorial vulnerability analysis is explained in water intended for human consumption sector for 2060s and at the scale of Büyük Menderes River Basin. The results showed that the impact level was expected as "medium" for the water intended for human consumption sector.

Key words: *climate change, sectorial impact, vulnerability analysis.*

1. Introduction

Turkey located at the Mediterranean Basin is a vulnerable region regarding adverse effects of climate change. Thus, adaptation to climate change is mandatory to minimize the corresponding negative effects. Climate change is an irreversible phenomenon and hence, adaptation measures should be developed and integrated to the related sectors. Water resources being largely and considerably exposed to negative effects of climate change and many sectors relying on water will indirectly be affected from the probable results. Because of that reason, climate change adaptation planning and execution in water management have a great importance and priority in Turkey (TUBITAK MAM, 2010).

Adaptation to climate change is the overall actions and measures taken by the societies and ecosystems to cope with the varying climatic conditions. In other words, adaptation to climate change is the process of strengthening, developing and executing the strategies to struggle with the effects of climate events (risks), and to manage them (UNFCC Publication, 2007).

[1]*T.R. Ministry of Forestry and Water Affairs, Directorate General for Water Management, Ankara*
[2]*Istanbul Technical University, Dean of Civil Engineering Faculty, Department of Environmental Engineering*
marufaras@ormansu.gov.tr, atanik@itu.edu.tr, aycosgun@ormansu.gov.tr,
seda.abat@iocevre.com, maskiner@ormansu.gov.tr

Within the scope of coping with the climate change, Project on 'The Effects of Climate Change on the Water Resources' has been executed by the General Directorate of Water Management under the Ministry of Forestry and Water Affairs. It started in December 2013 and lasted almost 3 years. The Project aimed to make projections regarding the expected conditions of the surface and groundwater resources of the all river basins in the country until 2100 by means of climate change projections, to determine surface and groundwater potential specific for the each river basin, and to estimate water budget changes in the basins that will suffer from the effects of climate change. Moreover, sectorial impact analysis for 4 essential sectors namely water intended for human consumption, agriculture, industry, and ecosystem have been executed in 3 pilot river basins in terms of the effects of climate change on water resources, and corresponding measures have been proposed as adaptation activities (SYGM 20016).

Climate change projections have been obtained with a resolution of 10 km with RegCM regional model by using the data sets of HadGEM2-ES, MPI-ESM-MR and CNRM-CM5 earth system models, and the findings were used to run the hydrologic and hydraulic models in all the 25 river basins of Turkey. It is seen that while temperatures exert a constant tendency to increase, precipitation anomalies were sometimes positive, but sometimes negative in the studies. In the projections executed for all basins of Turkey, a decrease was generally observed as expected. After obtaining the results, water potentials were determined for 25 river basins by running the hydrologic and hydraulic models with 3 models and 2 scenarios resulting in totally 6 conditions (SYGM 2016).

A vulnerability analysis methodology has been developed for the 4 main sectors (water intended for human consumption, agriculture, industry and ecosystem) in the 3 pilot river basins (Büyük Menderes, Meriç-Ergene and Ceyhan River Basins) to perform sectorial impact levels based on the outcomes of the project. The methodology in question has been specifically developed for the country in line with the general flow diagram of the impact analysis mentioned in the 4th and 5th Reports of the Intergovernmental Panel on Climate Change (IPCC AR4 and AR5). Similarly, the terminologies used in these reports are also kept on.

Sectorial Impact Analysis

Impact should be determined with respect to climate change adaptation. It is the indication of the impact level of a system from climate and adverse effects of climate change including extreme climatic conditions and that to what extent it has been affected and not been able to overcome.

Definitions used in the developed methodology

Intergovernmental Panel on Climate Change defines the climate change effect as a function of 3 main elements (IPCC AR5);

- The types and the magnitude of exposure to climate change,
- Vulnerability of the systems at any level,
- Resilience and adaptation capacity of the system.

These elements can be better explained below.

Impact (E) is the observation level of a system exposed to climate change and not be able to overcome its adverse effects, and it also includes the climate variability and the extreme weather conditions. Impact is a function of a system's exposure to climate change and its characteristics, magnitude and speed, vulnerability and adaptation capacity.

Exposure (M) indicates the changes in the examined elements of the system based on the climate variability or changing speed in average climatic conditions, including extreme weather events.

Sensitivity (D) is positive or negative impact level of a system caused by climate variability or change. This impact may be direct (such as mean temperature, a change in a crop yield caused by temperature changes) or indirect (such as damages caused by floods due to sea level rise on the coasts).

Adaptation Capacity (UK) means the ability of a system to climate change, variability and possible extreme and average damage levels, that of having the opportunities or resilience. The overall methodology of the sectorial impact analysis is indicated in Figure 1.1.

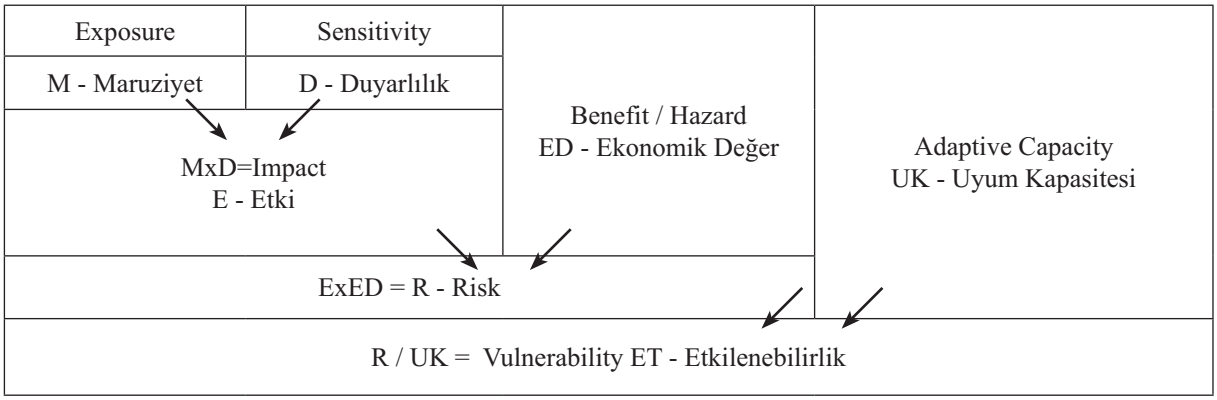

Figure 1.1. Sectorial Impact Methodology

The terms used in the methodology are explained below.

• Exposure (M): It is the only variable in the system and is calculated according to the model results, which are obtained from "the Climate Change Impacts on Water Resources Project executed by the Ministry of Forestry and Water Affairs", indicating the 50% possibility in every 10-year-period. That value is calculated for RCP 4.5 and RCP 8.5 scenarios, respectively.

• Sensitivity (D): It is calculated for every sector (water intended for human consumption, agriculture, tourism and ecosystem) in a way to indicate the current situation. The data of year 2014 is used.

• Impact (E): Exposure (M) x Sensitivity (D)

• Economic Value (ED): It is calculated for every sector (water intended for human consumption, agriculture, tourism and ecosystem) in a way to indicate the current situation. The data of year 2014 is used.

• Risk (R): Impact (E) x Economic Value (ED)

• Adaptation Capacity (UK): It is calculated for every sector (water intended for human consumption, agriculture, tourism and ecosystem) in a way to indicate the current situation. The data of year 2014 is used.

• Vulnerability (ET): Risk (R) / Adaptation Capacity (UK)

After calculation the elements above mentioned based on expert judgements, indices were determined from 1 to 4 in order to simplify the vulnerability projections, which are defined under the "Method".

2. Method

The methodology used for analysing vulnerability at each sectorial basis comprise calculation of the corresponding sensitivity, economic value and adaptation capacity indexes. This calculation is explained below for the example of water intended for human consumption sector in the Büyük Menderes River Basin.

A 5th sector is included to the analysis in each pilot river basins with the contemplation of evaluating one more sensitive sector based on the expert judgements and interviews between the stakeholders, and this last sector varied according to the basins. In Büyük Menderes Basin, the 5th sector is tourism. An assessment systematic has been constituted in order to quantify the impact level of 5 sectors (water intended for human consumption, agriculture, tourism and ecosystem) to be analysed. This systematic gives result in a way to evaluate the impact level of every sector in 4 categories as shown in Table 2.1.

Table 2.1.
Sectorial Impact Degree

Impact Level	Impact Score
Low	1
Medium	2
High	3
Very High	4

Sensitivity, impact, economic value, risks and adaptation capacity values are calculated according to the current situation of the river basins. All studies are carried out on the basis of indexes formed by taking into account the related sectors. This study was executed for all 5 sectors. However, in this paper only the water intended for human consumption will be referred as an example to show the outlines of the methodology developed. The sectorial based impact levels of the basin at the end of the studies are given in Table 2.2.

As it is shown in the Figure 1.1, the numeralisation started with the exposure and sensitivity levels according to the expert judgement. Those two values were multiplied to reach the

value of Impact. Then, impact were multiplied with Benefit/Hazard value to have the risk level. After dividing the risk level by Adaptive Capacity, which was also determined by the expert judgement, Vulnerability was found. Those numbers were classified to get impact scores shown in Table 2.2 to ease the evaluation impact analysis.

Table 2.2.
Sectorial Impact Levels of the River Basins

Vulnerability Range	Impact Score	Impact Level
1 - 3	1	Low
3 - 5	2	Medium
6 - 9	3	High
9<	4	Very High

3. Results

An Example: Water Intended for Human Consumption Sector

Four different indices are determined for the sensitivity parameter of the water intended for human consumption sector specific to Büyük Menderes River Basin by taking into consideration the River Basin Protection Action Plans (SYGM, 2016; TUBİTAK MAM, 2004 and 2010). The indexes and impact ratios are given in Table 3.1.

Table 3.1.
Sensitivity Indices for water intended for Human Consumption Sector

Index	Index Definitions	Impact Ratio
Index I	Sensitivity of Humans to Climate Change	60%
Index II	Population Density	20%
Index III	Climate Index (t25)	10%
Index IV	Climate Index (CDD)	10%

• Index I - Sensitivity of Humans to Climate Change: It is foreseen that the quantity of water intended for human consumption would be differentiated depending on climate change, but the sensitivity of humans or other living species in this aspect would be very high. Therefore, it is suggested that the humans have the same high sensitivity regardless of any classification.

• Index II – Population Density: Population density is calculated for every river basin in Turkey, grading being made for each of the river basins based on population density.

• Index III – Climate Index (t25): The climate index value indicating the number of the summer days above 25°C is calculated by averaging 3 models for every river basin and then graded.

• Index IV – Climate Index (CDD): The climate index value indicating the number of consecutive dry days is calculated by averaging 3 models for every river basin and then graded.

The weighted index value for the sensitivity parameter for the water intended for human consumption sector is given in Table 3.2.

Table 3.2.
Weighted Index Value for Sensitivity of the Sector "Water Intended for Human Consumption"

Index	Index Definitions	Index Value	Impact Ratio	Weighted Index Value
I	Sensitivity of Humans to Climate Change	4	60%	2.40
II	Population Density	2	20%	0.40
III	Climate Index (t25)	2	10%	0.2
IV	Climate Index (CDD)	2	10%	0.2
			Overall Sensitivity	3.20

Economic value (ED)

Two different indices for economic value parameter are determined for water intended for human consumption sector as are given in Table 3.3.

Table 3.3.
Economic Value Indices for the Sector "Water Intended for Human Consumption"

Index	Index Definitions	Impact Ratio
I	Equivalent population	70%
II	Ratio of water loss due to leakage and/or technical failure	30%

• Index I – Equivalent Population: It indicates permanent population together with animals like cows and cattle, sheep and goats. Equivalent population values of year 2014 are used.

• Index II – Ratio of Water Loss due to leakage and/or technical failure: It indicates an average seepage loss value that is a ratio known for the cities in the river basin. The corresponding value for the basin is determined in line with the ratio of the cities in the basin.

The weighted index value for the economic value parameter for water intended for human consumption sector is given in Table 3.4.

Table 3.4.
Weighted Index Value for the Economic Value of the Sector "Water Intended for Human Consumption"

Index	Index Definitions	Index Value	Impact Ratio	Weighted Index Value
I	Equivalent Population	2	70%	1.40
II	Ratio of water loss due to leakage and/or technical failure	2	30%	0.60
III	Overall Economic Value	2.00	10%	0.2
IV	Climate Index (CDD)	2	10%	0.2
			Overall Sensitivity	3.20

Adaptation capacity (UK)

Two different indices for adaptation capacity parameter are determined for water intended for human consumption sector as given in Table 3.5.

Table 3.5.
Adaptation Capacity Indices for water intended for Human Consumption Sector

Index	Index Definitions	Impact Ratio
I	Technical Feasibility	50%
II	Socio-Economic Development	25%
III	Financial Development	25%

• Index I – Technical Feasibility: It refers to the availability of applicable methodologies to reduce the seepage loss ratio.

• Index II – Socio-Economic Development: It is calculated by multiplying development indices of the cities with the related population ratios in the basins.

• Index III – Financial Development: It is calculated by multiplying financial development indices of the cities with the related population ratios in the basins.

Table 3.6.
Weighted Index Value for Adaptation Capacity for Sector "Water Intended for Human Consumption"

Index	Index Definitions	Index Value	Impact Ratio	Weighted Index Value
I	Technical Feasibility	3	50%	1.5
II	Socio-Economic Development	2	25%	0.5
III	Financial Development	3	25%	0.75
			Overall Sensitivity	2.75

4. Discussion and Conclusion

Discussion

The results of the sectorial impact application of the above –mentioned methodology is given in Table 4.1. The values of sensitivity, impact, economic value, risk and the adaptation capacity parameters are calculated according to the current situation of the river basins.

The impact changes are further calculated as a function of exposure parameter through the 10-year-intervals where the exposure parameter is the only variable in the developed methodology for the 10-year-period during the projection time.

When the exposure level for this example is considered as a value of 2 for the 2060s, the resulting impact levels indicated in the Table 4.1 as an example regarding the sectors can be obtained.

Table 4.1.
Impact levels obtained on sectorial basis for the 2060s in case the exposure level is foreseen as 2

	Exposure (M)	Sensitivity (D)	Impact (E)	Economic Value (ED)	Risk (R)	Adaptation Capacity (UK)	Impact (ET)
Water intended for human consumption	2	3.20	6.40	2.00	12.80	2.75	5
Agriculture	2	2.17	4.34	2.13	9.25	3.25	3
Industry	2	2.75	5.50	2.5	13.75	2.85	5
Ecosystem	2	2.20	4.40	1.5	6.60	2.4	3
Tourism	2	3.23	6.47	2.2	14.23	2.45	6

Impact levels of the basin are given in Table 4.2. Accordingly, the impact level for water intended for human consumption sector may be inferred as of medium intensity for the years of 2060s, and as high intensity for the tourism sector.

Table 4.2.
Impact Level of the Basin on Sectorial Basis

Impact Interval	Impact Score	Impact Level
1 - 3	1	Low
3 - 5	2	Medium
6 - 9	3	High
9<	4	Very High

Conclusion

Adaptation to climate change is the overall actions and measures taken by the societies and ecosystems to cope with the varying climatic conditions. In other words, adaptation to climate change is the process of strengthening, developing and executing the strategies to struggle with the effects of climate events (risks), and to manage them.

Adaptation activities have quite a systematic structure. Initially, it is required to carry out the impact determination studies related to water resources, agriculture and food security, public health, natural ecosystems and biodiversity, coastal zones, etc. "Impact assessment" should be executed related to water shortage, drought, desertification, rise in disasters, decline in crop yield, food security, deterioration in public health, deterioration in terrestrial and marine ecosystems, negative effects on energy, tourism and fisheries. These experiences depend on the mentioned impacts and related to threats on coastal zones caused by sea level rise. "Adaptation action plans" including adaptation actions and measures for those being prepared and integrated to sectorial development plans (SYGM, 2016).

Analysis methodology have been developed for the 4 main sectors (water intended for human consumption, agriculture, industry and ecosystem) in the 3 pilot river basins (Büyük Menderes, Meriç-Ergene and Ceyhan River Basins) to execute sectorial impact analysis with the results of "the Effects of Climate Change on Water Resources Project" (SYGM, 2016).

In this study, sectorial impact assessment is examined for the water intended for human consumption sector by scrutinizing the Büyük Menderes River Basin as an example within the scope of calculating the values of sensitivity, impact, economic value, risks and adaptation capacity for impact assessment. Exposure level has been determined based on 2060s according to the water potential results within the scope of "the Effects of Climate Change on Water Resources Project", the impact level is determined as "medium" for the water intended for human consumption sector. The study has also been repeated for the other sectors as well. According to the results presented in Table 4.1, tourism is the most vulnerable sector (High Impact), whereas the agriculture and the ecosystem sectors are found as the least vulnerable (Medium Impact) sectors due to climate change in the 2060s. This study is expected to form a basis for the future projects which aim to determine the most probable sectors to be affected from the results of climate change in Turkey.

5. References

IPCC (2013). *5th Assessment Report (AR5) Climate Change 2013: The Physical Science Basis*.

IPCC (2013). *4th Assessment Report* (AR4).

SYGM, (2016). *İklim Değişikliğinin Su Kaynaklarına Etkisi Projesi, Orman ve Su İşleri Bakanlığı,* Su Yönetimi Genel Müdürlüğü (SYGM).

TÜBİTAK MAM. (2010). *Havza Koruma Eylem Planları, T.C. Orman ve Su İşleri Bakanlığı adına TÜBİTAK Marmara Araştırma Merkezi.*

TÜBİTAK MAM. (2014). *Havza Koruma Eylem Planları, T.C. Orman ve Su İşleri Bakanlığı adına TÜBİTAK Marmara Araştırma Merkezi.*

UNFCCC Publications, (2007). Climate Change: Impacts, Vulnerabilities and Adaptation in Developing Countries.

United Nations Framework Convention on Climate Change, Rio de Janerio, 1992.

Extended Turkish Abstract (Genişletilmiş Türkçe Özet)

İklim Değişikliğine Adaptasyon Kapsamında Sektörel Etki Analizi Metodolojisi

İklim değişikliğine uyum, toplumların ve ekosistemlerin değişen iklim şartları ile baş edebilmelerine yardımcı olmak için gerçekleştirilen eylemler ve alınan önlemlerdir. Bir diğer deyişle iklim değişikliğine uyum; iklim olaylarının (risklerinin) etkileriyle mücadele etmek, fayda sağlamak ve etkileri yönetebilmek için stratejilerin güçlendirilmesi, geliştirilmesi ve uygulanması sürecidir.

Uyum çalışması oldukça sistematik bir yapıya sahiptir ve iklim değişikliğine uyum konusunda öncelikle etkilenebilirliğin tespiti gereklidir. Etkilenebilirlik, bir sistemin maruz kaldığı iklim değişikliğinin ve değişkenliğinin özelliği, boyutu ve hızının, duyarlılığının ve uyum sağlama kapasitesinin bir fonksiyonudur.

Hükümetler arası İklim Değişikliği Paneli (IPCC); iklim değişikliğinden etkilenebilirliği 3 ana unsurun bir fonksiyonu olarak tanımlar. Bunlar;

- İklim değişikliğinin etkilerine maruz kalma türleri ve boyutu,
- Sistemlerin, belirli düzeyde maruz kalmaya duyarlılığı,
- Sistemin başa çıkma veya uyum sağlama kapasitesidir.

Öncelikle iklim değişikliğinden olumsuz etkilenebilecek su kaynakları, tarım ve gıda güvenliği, halk sağlığı, doğal ekosistemler ve biyoçeşitlilik, kıyı bölgeleri vb. sektörlere ilişkin "etkilerinin belirlenmesi" çalışmalarının yapılması gereklidir. Bu etkilere bağlı olarak yaşanacak su sıkıntısı, kuraklık, çölleşme, afetlerdeki artış, tarımsal üretimde düşüş, gıda güvenliği, halk sağlığında bozulma, kara ve deniz ekosistemlerindeki bozulma, enerji, turizm ve balıkçılığın olumsuz etkilenmesi, deniz seviyesindeki yükselmeye bağlı kıyı bölgelerinde yaşanacak tehditlere ilişkin "etkilenebilirlik değerlendirilmesi" yapılarak, bunlar karşısında gerçekleştirilecek uyum eylem ve önlemlerini içeren "uyum eylem planlarının" hazırlanması ve bu planların mutlaka ulusal, sektörel gelişme planlarına "entegre edilmesi" gerekmektedir.

Bu hedefler ile gerçekleştirilen "İklim Değişikliğinin Su Kaynaklarına Etkisi Projesi" sonucu elde edilen sonuçlar ile sektörel etki analizlerinin gerçekleştirilebilmesi için pilot havzalarda (Büyük Menderes, Meriç-Ergene ve Ceyhan Havzaları) 5 ana sektör için (içme kullanma suyu, tarım, sanayi, ekosistem ve turizm) analiz metodolojisi geliştirilmiştir. Böylelikle, havzanın her sektörden etkilenme şiddetini 4 sınıfta değerlendirebilecek şekilde 1: Az etki; 2: Orta etki; 3: Yüksek etki; 4: Çok yüksek etki derecesi ile bir sınıflandırma yapılmıştır.

Bu çalışmada, örnek teşkil etmesi amacıyla Büyük Menderes Havzası incelenerek, duyarlılık, etki, ekonomik değer, risk ve uyum kapasitesi değerleri çerçevesinde yine örnek olarak içme ve kullanma suyu sektöründe sektörel etkilenebilirlik analizi metodolojisi irdelenmiştir. Su potansiyeli sonuçlarına göre tespit edilen maruziyet seviyesi 2060'lı yıllar baz alınarak belirlenmiş olup, bu kapsamda içme ve kullanma suyu sektörü etkilenme şiddeti "Orta Şiddet"te olarak tespit edilmiştir. Çalışma, diğer sektörler için de taslak olarak tamamlanmıştır. Sonuçlara göre 2060'lı yıllarda iklim değişikliğinden en çok etkilenmesi beklenen sektörün Turizm (Yüksek Şiddet), en az etkilenmesi beklenen sektörün ise Tarım ve Ekosistem (Orta Şiddet) olduğu belirlenmiştir.