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MASTER THESIS

AN INPUT-OUTPUT ANALYSIS OF WATER CONSUMPTION AND INTERSECTORAL WATER USAGE IN TURKEY

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ÖZ

TÜRKİYE'DE SU TÜKETİMİ VE SEKTÖRLER ARASI SU KULLANIMI GİRDİ-ÇIKTI ANALİZİ

Suat MUMCU

Günümüzde artan nüfus ve iklim değişikliği su kaynaklarının verimsiz kullanımına neden olmaktadır. Türkiye, 2018 yılı baz alındığında 1.366 metre küp kişi başına düşen yenilenebilir su miktarıyla su stresi yaşayan ülkeler katagorisinde yer almaktadır. Türkiye, 20 yıl içersinde nüfusun artış hızı hesaba katıldığında kişi başına düşen yenilenebilir su miktarının 1.000 metre küpün altına düşeceği varsayımıyla su kıtlığı çeken ülkeler katagorisinde yer alacaktır. Bu doğrultuda kıt bir kaynak olan suyun ulusal ya da bölgesel ölçekte verimli bir şekilde kullanımı önem arz etmektedir. Bu çalışma, Türkiyede su kaynaklarının sürdürülebilirliğinin ekonomik sektörler bağlamında analizini amaçlamaktadır. Ulusal ölçekte su kaynaklarının sürdürülebilir bir şekilde kullanımı amacına ulaşmak ve gelecekte yaşanacak su kıtlığı krizini hafifletmek için su ayak izi analizlerinde etkin bir metot olan Çevresel Olarak Genişletilmiş Girdi-Çıktı (EEIOA) metotu kullanılmıştır. Çalışmanın ampirik kısmında Türkiye'nin 2018 yılına ait girdi-çıktı tablosu ve sektörel su tüketim verileri kullanılmıştır. Analiz kapsamında temel göstergeler olarak, sektörlere ait su çarpanları oluşturulmuş, ileri/geri bağlantı analizleri kullanılarak Türkiye'nin su tüketiminde 'anahtar sektör' olarak niteleyebileceğimiz sektörler belirlenmiş, temelde sektörler arası su akışını gösteren matrisler oluşturulmuş ve sektörel bazda su tüketiminin ekonomik faydasını ifade eden katsayılar tespit edilmiştir. Çarpan analizinin sonucunda çıktı başına en yüksek doğrudan su kullanımına sahip 'birincil' (tarım, avcılık, ormancılık ve balıkçılık) sektörün su çarpanı görece düşük çıkmıştır. Buna ek olarak 'gıda, içecek ve tütün mamulleri' sektörünün çıktı başına dolaylı su tüketimi göstergesinin en yüksek olduğu ve aynı doğrultuda dolaylı su çarpanı göstergesi de en yüksek olan sektörlerden birisi olduğu tespit edilmiştir. İleri ve geri bağlantı analizleri sonucunda ‘birincil’, ‘su temini’ ve ‘elektrik temini’ sektörlerinin Türkiye ekonomisinde anahtar sektörler olduğu tespit edilmiştir. Senaryo analizleri sonucunda ‘birincil’ sektörün nihai talebinde yüzde 20’lik bir artışın su kullanım miktarını yüksek miktarda artırdığı ancak nihai talepteki artışın katma değerde yarattığı etkinin görece düşük kaldığı tespit edilmiştir. Ayrıca, gıda, içecek ve tütün mamulleri sektörünün nihai talebindeki artışın da su tüketim miktarı üzerindeki etkilerinin bir hayli yüksek olduğu tespit edilmiştir.

Anahtar Kelimeler: Sürdürülebilir Su Tüketimi, Su Muhasebesi, Su Ayak İzi, Su Çarpanı, İleri ve Geri Bağlantı Analizi, Girdi-Çıktı Modeli

ABSTRACT

AN INPUT-OUTPUT ANALYSIS OF WATER CONSUMPTION AND INTERSECTORAL WATER USAGE IN TURKEY

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Today, increasing population and climate change cause inefficient use of water resources. Turkey is included in the category of water stress country that suffers from water scarcity with the amount of renewable water source of 1.366 cubic meters per person based on 2018. Turkey will be a country that experiences water scarcity with the renewable water falling below 1.000 cubic meters per person considering the increasing population in 20 years. In this respect, efficient use of water, which is a scarce resource, on a national or regional scale is important. This study aims to analyze the sustainability of water resources in Turkey in the context of economic sectors. The Environmentally Extended Input-Output Analysis (EEIOA), which is an effective method in water footprint analysis, has been used to achieve the goal of sustainable use of water resources on a national scale and to alleviate the water scarcity crisis to be able to experience. In the empirical part of the study, Turkey's input-output table for 2018 and sectoral water consumption data were used. Within the scope of the analysis, the water multipliers belonging to the sectors, so-called 'key sectors' in Turkey's water consumption reached by using forward/backward linkages analysis, the matrices that show the water flows between the sectors, and the coefficients expressing the economic benefit of water consumption on sectoral basis have been obtained as the fundamental indicators. As a result of the multiplier analysis, the water multiplier of the agriculture, hunting, forestry, and fishing sector, with the highest direct water use per output, was relatively low. As a result of forward and backward linkages analysis, it has been determined that the 'agriculture, hunting, forestry, and fishing', 'water supply', and 'electricity supply' sectors are 'key sectors' in the Turkish economy. As a result of the scenario analysis, it has been determined that a 20 percent increase in the final demand of the agriculture, hunting, forestry, and fishing sector increases the amount of water use by a large amount, but the effect of the increase in the final demand on the value added remains relatively low. In addition, it has been determined that the increase in the final demand of the food, beverage, and tobacco products sector has a very high effect on the amount of water consumption.

Key Words: Sustainable Water Consumption, Water Accounting, Water Footprint, Water Multiplier, Forward and Backward Linkages Analysis, Input-Output Model

PREFACE

Growing concern about the sustainability of renewable water resources has determined the writing of this thesis. There are lots of academic work about water economics in the literature that is mainly written in the countries that are faced with the water scarcity problem. The population is the most important pressure on the water resources. It has been seen in the report of the Worldwide Fund for Nature (WWF)[1] about the future of the water resources of Turkey that, with its increasing population, developing industry, and rapidly growing cities, it is estimated that Turkey will be a country suffering from water shortage in 2030. In the light of this information, it is inevitable for Turkey to take its place among the countries suffering from 'water scarcity' 20 years from now on. This study is important because not only it is the first study in which sectoral and intersectoral quantitative analysis of water consumption in Turkey has been made, but also because it shows policymakers that concrete evaluation of water consumption in respect of its economic value. Although the people, who are aware of sustainable water consumption, try to reduce household water consumption, this study shows that the agriculture, hunting, forestry, and fishing sector has the largest share in total water consumption, which means that it is more important that we save on water consumption in agricultural production. The most important inference is that with the implemented policies, not individual but mass and sectoral solutions should be developed in Turkey.

First, I would like to express my gratitude to those who have contributed in some way to my thesis. Above all, I would like to thank my advisor Prof. Dr. Bekir KAYACAN, who guided in all steps and encouraged me to work on this important subject, for his patience and advice that make me take part in academic life.

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[1] Worldwide Fund for Nature (**WWF**), http://awsassets.wwftr.panda.org/downloads/su_ayak_izi_raporweb.pdf

thesis on this difficult journey. I would like to thank my older brother Sadık MUMCU who made me believe that I could finish my thesis on time, even though I did not have enough time to write a thesis. For his belief in me that I could accomplish my master thesis and infinite recommendations over making me stay in academic life, my father Selçuk MUMCU deserves a special thank.

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CBS	: Netherland's Central Bureau of Statistics
DEBWC	: Direct Economic Benefits of Water Consumption
DSI	: Turkish States Hydraulic Works
EBWCM	: Economic Benefits of Water Consumption Multiplier
EEIOA	: Environmentally Extended Input-Output Analysis
EUROSTAT	: European Statistics
GRP	: Gross Regional Product
IO	: Input-Output
ISIC	: International Standard of Industrial Classification
IWC	: Indirect Water Consumption Multiplier
NAMEA	: National Accounting Matrix Including Environmental Accounts
NAMWA	: National Accounting Matrix Including Water Accounts
OECD	: Organisation for Economic Co-operation and Development
RIZA	: Integrated Water Management and Wastewater Treatment
SEEA	: System of Integrated Environmental and Economic Accounts
SEEAW	: System of Environmental-Economic Accounting for Water
SNA	: System of National Account
TEBWC	: Total Economic Benefits of Water Consumption
TURKSTAT	: Turkish Statistical Institute
UK	: United Kingdom
UN	: United Nations
US	: United States
WCM	: Water Consumption Multiplier
WWF	: Indirect Water Consumption Multiplie

INTRODUCTION

Economics is a science that deals with how to meet endless human needs with scarce resources. Water is one of the scarcest resources that is used as an input in a production process of a good and has a crucial role in the economic growth of the countries. Even if the water resources seem to be endless such as oceans, seas, lakes, rivers, and other water resources, renewable water resources are limited on the earth.

Seas and oceans, whose waters are salty, account for approximately 97.5% of the water resources on earth. The remaining proportion of total water resources is 2,5% composed of glaciers, underground, and surface waters which are freshwater resources of the earth. About 98.8% of fresh water is found in glaciers and groundwater which correspond to 68,7% and 30,1%, respectively. Therefore, very little of the fresh water on earth, 1,2%, consists of surface waters[2]. Since technological disadvantages in the abstraction of underground water, all underground water resources aren't reachable nowadays, which is of course good for the sustainability of the water resources. But the significant point here is to induce that we can't reach all freshwater easily and, thus, the adequate water supply may become challenging in any shock that may occur in water demand.

Concerns about water use have been increasing since the early 1900s since water consumption has increased ten times. However, towards the end of the 1980s, studies and conferences on the future of water accelerated. As a result of these actions, the concept of water as an 'economic good' was adopted by policymakers. This perspective is one of the important milestones in sustainable water management. After such growing interest in this subject, the Falkenmark water stress index, which states the level of renewable fresh water available for each person each year in a given region to determine the level of water scarcity, was developed by a well-known water expert Malin Falkenmark. This index has

[2] United States Geological Survey (**USGS**), https://www.usgs.gov/special-topics/water-science-school/science/where-earths-water

become a widely accepted indicator to show the countries' water potential. Turkey's water potential indicators are shown in **Table 1-1**, whose bottom line is adjusted according to the Falkenmark index.

Table 1-1: *Turkey's water resources potential*

Annual average precipitation	574 mm/year
Amount of annual precipitation	450 billion m^3
Annual runoff	186 billion m^3
Available surface water	94 billion m^3
Annual withdrawable groundwater	18 billion m^3
Total available water resources	112 billion m^3
Population (2018)	82 million
Amount of available water per person per year	1.366 (m^3/per person-per year)

Source: Web site, https://www.dsi.gov.tr/Sayfa/Detay/754

Evaluating the falkenmark index from a regional perspective will provide a more accurate assessment because the transportation of water from one region to another is a high-cost operation and the demand for water in the region is also provided by the water resources within the region. Therefore, population planning may be imposed in a certain region by policymakers to consume the water resources efficiently. According to the falkenmark index, based in 2015, there are 5 regions with 'absolute water scarcity', which shows that the region has renewable water resources below 500 m^3 per person per year in Turkey[3].

Although the population and climate change seem to be the greatest pressure on water resources, there are many more obstacles to the sustainable consumption of water resources. The high use of water in irrigation is the most important problem that is needed to be given importance by policymakers. The amount of water consumption in agriculture,

[3]Türkiye Sınai Kalkınma Bankası (**TSKB**) https://www.tskb.com.tr/i/assets/document/pdf/TSKBBAkis_SUYeniElmas_Subat2019.pdf

hunting, forestry, and fishing sector constitutes 69% of the total water consumed in Turkey in 2018. The reason behind the amount of water used in agriculture, hunting, forestry, and fishing sector is so high is because of unconscious irrigation and subsistence farming rather than modern agriculture.

The volumetric flow rate of water is used to calculate a process's water footprint. The total footprint (sum) of processes in a product's whole supply chain is divided by the number of product units. Its calculation is important for the sustainability of water resources. It is necessary to calculate the water footprint of all the products in the system one by one to see the sectoral relations in the system. The analysis of this is so time-consuming and almost impossible because the statisticians most probably will be faced with data gathering problems. Several products are produced in a company and companies don’t keep their water statistics product by product. Even if the statisticians reach these data, they must calculate all product’s water footprints to see the economy as a whole. To obtain the intersectoral water flow detailed, the EEIOA, which is the basic and useful tool for water footprint analysis, is used in this thesis. By using this method entire water flow from one sector to the others can be seen easily. By keeping the water appropriation data in as many sectors as possible, the calculations can be more accurate in this method.

Although they are a limited number, there are water footprint analyzes and evaluations in Turkey. However, such analysis mostly approaches the water from a hydrological perspective rather than the economic one. Therefore, this thesis has a crucial role in terms of improving the literature in Turkey. As mentioned above, irrigation has the greatest pressure on water resources. The problem here is how much agriculture, hunting, forestry, and fishing sector affects the growth of a country. This thesis focuses on the nexus between economic sectors and water consumption in Turkey (i.e., direct water consumption per unit of produced) as well as the intersectoral water consumption relationships (i.e., the matrices that demonstrate the intersectoral relations). The results show that agriculture sectors have very little effect on Turkey’s growth while the water used in agriculture has increased considerably. Furthermore, food, beverages, and tobacco products sector, with the highest indirect water consumption, has little effect on growth relatively, while it has a significant effect on water resources because of its purchases as an intermediate input to produce from the other sector specifically the agriculture sector. Thus, both high direct and indirect water consumer sectors should be considered for sustainable water management by policymakers.

This thesis aims to answer the following three questions. What is the allocation of water resources to sustain economic activities and how does the use of water affect economic sectors in the monetary base in Turkey in 2018? We will try to answer this question using our water flow matrices. Which sectors create the greatest pressure on Turkey's water resources? Even if we think that the highest direct water consumer sector has the highest pressure on water resources, indirect water consumer sectors are significant sectors as well. Thus, we will determine the highest direct and indirect water consumer sectors together for the Turkish economy. How does a demand shock affect water consumption and economic activities as a whole and sectoral base? Determining the effect of this shock, we will use the simulation imposed on both the highest direct and indirect water consumer sectors.

The fundamental concern of the thesis is the accounting of Turkey's water consumption. In this thesis, we use the Input-Output transaction table taken from OECD. The table shows the intersectoral monetary flow of Turkey in dollar terms and is based on 2018 data. Sectoral water data, which consists of the water distributed in 16 economic sectors, are taken from EUROSTAT, TURKSTAT, and DSI. The main result shows that agriculture, hunting, forestry, and fishing sector (the highest direct water consumer sector) and food, beverages, and tobacco products sector (the highest indirect water consumer sector) have significant pressures on water consumption in Turkey in 2018. According to the results, most manufacturing industries (from 3 to 12 in our tables) are indirect water consumer sectors.

CHAPTER ONE

THEORETICAL FRAMEWORK OF ENVIRONMENTAL ACCOUNTS AND FOOTPRINT ANALYSIS

The theoretical framework of this study will be expressed in this chapter. Therefore, along with some definitions, information about some works which have accelerated environmental accounts and footprint studies from past to present will be defined. In the first subtitle, environmental accounts, what kind of classifications have been made from the past to the present, and which methods have been developed for the accounting of water will be mentioned. In addition, global, national, and regional studies that have been analyzed by top-down and bottom-up methods in water footprint analysis will be compiled.

1.1. Environmental Accounts

With the rapid increase in the consumption of natural resources since the early 1900s, the interest in this subject has also increased. The beginning of studies examining the relationship between economy and natural resources dates back to the 1960s (Velazquez, 2006: p. 227). In the mid-1980s, studies began to gain momentum to determine and measure the integration between economy and natural resources. It has been observed that the excessive use of natural resources causes great harm to sustainable development. With the boom in all economic activities, the increased consumption of natural resources has become a problem. The problem was addressed in Brundtland Report (1987) and the outcomes of the report have earned extensive international support at the UN Conference on Environment and Development in Rio de Janeiro in 1992. In agenda 21 (1992), It has been argued that for the integration of sustainability into economic activities, a better method of measurement should be established that demonstrates that the environment is a natural capital and a sink for by-products generated in the production process. In this agenda, it was also foreseen that all members of the

United Nations should use the system of integrated environmental and economic accounts to strengthen international cooperation. For this purpose, The United Nations et al. (1993), in collaboration with other international organizations[4], developed a system known as the System of Integrated Environmental and Economic Accounts (SEEA) to integrate international environmental accounts. As a further study, National Accounting Matrix including Environmental Accounts (NAMEA) has been developed by the Netherland's Central Bureau of Statistics (CBS) (de Boo et al., 1993; de Haan et al., 1993), which shows the number of emissions per sector in general following SEEA indicators.

Following SEEA and NAMEA indications, some countries developed their NAMEAs. In this context, Swedish Statistics Bureau developed the system which demonstrates the monetarization of environmental damage in addition original NAMEA (Hellsten et al., 1999: p. 41-42). The original NAMEA, which was completely developed by Dutch Statisticians in 1993 as a result of 2 years of work, was started to use in 1994 in an integrated way with the national accounts of the Netherland (Keuning et al., 1999: p. 15). And other countries such as England (Vaze, 1999) and Japan (Ike, 1999) have also adopted the NAMEA's indicators and integrated it into their national accounting system.

The monetarization and accounting of water consumption in national accounts is just as important as environmental pollution such as carbon emission. With this growing need, the Netherland Statistical Bureau has developed a new system that shows the integration of water consumption with the National account. The new system called the National Accounting Matrix including Water Accounts (NAMWA) firstly was practiced over four river basins, which are Meuse, Scheldt, Ems, and Rhine, in Netherland by Statistics Netherland in collaboration with the National Institute for Integrated Water Management and Wastewater Treatment (RIZA) (as in cited Schenau et al., 2010).

NAMEA's extension, NAMWA, provides data on the physical water system's interconnections with the economy at the national and river basin levels. Within this

[4] United Nations and European Commission, International Monetary Fund, and the Organisation for Economic Cooperation and Development World Bank.

context, the matrix represents that the supply of goods and services is represented by each column, while the demand for those goods and services is represented by the rows. The monetary flows occur in the opposite direction: receipts are represented by columns, while expenditures are represented by rows (Veeren et al., 2004: p. 1).

In general, all methodologies that are mentioned above are basically SEEA which is an extension of the System of National Account (SNA). The final draft of SEEA (2003) is published, as a handbook that can be used as a guideline for the country which wants to adopt it to their national account system. After these ambitious works on the integration of environmental accounts into national accounts, in 2005, the final draft of the System of Environmental-Economic Accounting for Water (SEEAW) was mentioned in the first meeting of the United Nations Committee of Experts on Environmental-Economic Accounting. It has been adapted to the system to be used in national accounting since 2007 (United Nations, 2012).

According to this methodology, several works have been implemented on national or regional bases. Supply and use tables, which show the physical water flow between the economy and environment, form the core of the methodology. They also demonstrate interlinkages between economic sectors in terms of water flow. With some manipulations, the matrices enable us to derive some monetary indicators which show the productivity of water in the economy.

1.2. An Overview of Footprint Analysis

All subjects that are mentioned in the previous chapter include the footprint analysis fundamentally but the footprint analysis, with its more comprehensive tools, can be calculated at an individual and global level as well as regional and national levels as in the System of National Account. In general, a 'footprint' has come to be characterized as a quantifiable measure of human appropriation of natural resources (Hoekstra, 2008: p. 10). A "footprint" is a term for how human actions can have varying degrees of burden or impact on global sustainability. Humans leave "footprints" that future generations will have to deal with. One of the objectives of sustainability is to reduce such footprints (Jensen et al., 2009: p. 7).

Since all footprint analysis is related to natural resources which are allocated by human beings, this subject has been examined in terms of many natural resources and pollutions that are generated in the production process of the goods and services. With these viewpoints, footprint analyses are diversified such as carbon, energy, emission, land, nitrogen, biodiversity, and water footprints as environmental footprints analysis. There are also analyses organized from different perspectives such as social and economic footprint as well as composite and combined footprint analysis, which combine two or more individual indicators or 'sub-indicators' into one number such as ecological footprint and sustainable process index etc. (Cucek et al., 2012).

1.2.1. Water Footprint

A lot of fresh water and underground water is consumed by human beings last century. Agriculture, industry, mining and quarrying, electricity production, and domestic use of water are the main sources of water consumption related to the irrigation, bathing, washing, cleaning, and cooling processes (Hoekstra et al., 2011). A hidden water cost which is called virtual water consumption structure is evident in almost all processed products. This water used in production is transferred between sectors and countries inside the products. For this reason, the necessity of keeping track of the water used in the production has emerged.

The water footprint concept, which was developed by Arjen Y. Hoekstra in 2002 (as cited in Hoekstra & Chapagain, 2007: p 36), is perceived as both direct and indirect water consumption of a person by people but it expresses a more comprehensive concept than this since it can be calculated at the regional, national, global, producer, business, or product levels as well. As long as the scope, the aim, the time, and the location are determined, it can evaluate every perspective. The water footprint analysis is an eligible tool for policymakers that shows how, and which human activities affect the sustainability of water. There are different calculation methods for different perspectives:

- A consumer's water footprint is calculated by adding up the direct and indirect water (total water consumption) consumed via buying the product and services,
- A product’s water footprint is calculated by adding up the direct and indirect water consumed in the production process of the given product,
- The water footprint of a geographical area can be defined as the total fresh water (surface and underground water) consumption and pollution in this area,
- The water footprint of a nation is calculated by summation of all residents’ water footprint who live in this nation (Hoekstra et al., 2011).

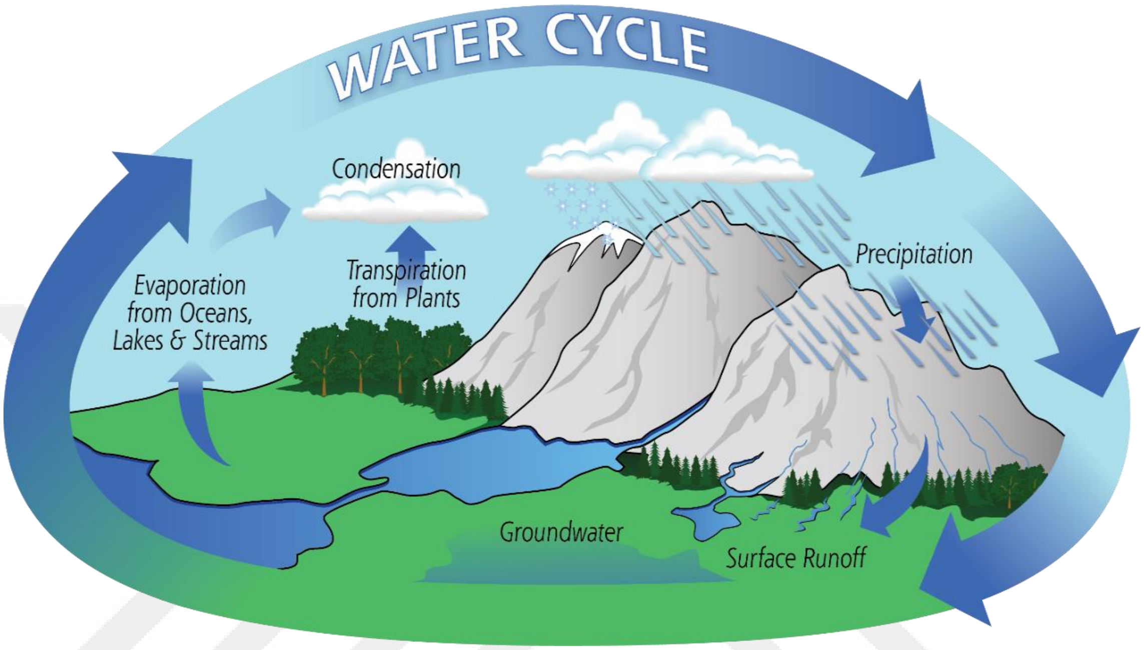
In addition to what environmental accounting does, the biggest innovation in water footprint analysis has been the evaluation of the form of water with more emphasis. In the water footprint analysis, some definitions have been considered more in terms of measuring polluted water and using water optimally in different sectors. These are the form of water which are blue water, green water, and grey water. Blue water simply indicates underground and freshwater resources which are used for agriculture, industry, and domestic sectors. Since it is scarer and has a high opportunity cost among others, it draws more attention to the accounting of water (Hoekstra et al., 2011).

The high amount of green water used in the agriculture and forestry sectors has led to an increase in the importance given to it. The idea of green water, which is introduced by Falkenmark in 1995 (as cited in Jewitt, 2006), has become so important for water management. Green water is rain that falls on land but does not run off or recharge the groundwater, but instead is held in the soil or remains on top of the soil or vegetation for a short time. Thereafter, this part of the precipitation evaporates and transpires through plants, and water recycling is done (Hoekstra et al., 2011). The use of green water for irrigation purposes (agriculture and forestry) especially in crop production ensures a more efficient use of water resources. Green water has more share in the agriculture and forestry sectors in comparison to industry and domestic sectors because blue water is mostly used in these sectors (Hoekstra & Chapagain, 2008). For this reason, green water management is not as important in the industry and domestic sectors as it is in the agriculture and forestry sectors.

As mentioned above and seen in **Figure 1-1**, there is a cycle in the water resources. This system is formed by the increased water via evaporation from the oceans, lakes, and streams, and the transpiration of plants and comes back to the earth by precipitations. In the production process, blue water cannot turn into green water due to the way the water is applied and transported. Therefore, blue water used will be more than green water used. The losses occur in the system which shows the quality and pollution of water. This polluted water needs to assimilate via dilution. The term grey water refers to the volume of diluted water. (Hoekstra & Chapagain, 2008: p. 107). However, before Hoekstra define the term in a cooperated way with the terminology, Falkenmark and Lindh (1974) were the first to emphasize that this polluted water must be diluted to a certain level. Although, grey water can be perceived as a 'dilution water requirement', it does not reflect the concept. The main idea behind the concept, the reducing pollutants in the water, possibly down to zero, not to dilute it to a certain level. With increased population growth, climate change, and high use of water in industry, agriculture and domestic sectors, the percentage of water polluted has been increased among the other form of water. The reuse of grey water in economic sectors, especially in agriculture, has vital importance for sustainable water management. Thus, new greywater treatment techniques should have been developed or already developed techniques should have been applied cost-effectively.

Water has been treated as a public good which has so-called nonexcludable and nonrivalrous until the Dublin conference in (1992). In Guideline principle 4 of the conference report, the necessity of perceiving it as an economic good was alleged because it has an 'economic value'. Perception of water as a public good has led to water pollution and damages the water resources. The view of evaluating water as an economic good, later, emerged as a categorization of the economic efficiency of water under three-level. The user level, which is the lowest, is the first level. It aims to reduce the water use through

Figure 1-1: *Water Cycle*



Source: Web Site, https://gpm.nasa.gov/education/water-cycle

enhanced water-saving technologies, measures such as water pricing and awareness-raising. Second-level efficiency specifies the allocation and re-allocation of water to higher value-uses and fair uses by all stakeholders. Among all, the trade-in water is the highest level of efficiency. Since the transport of water from one area to the other is a high-cost operation, the virtual water concept emerged as an explanatory concept that shows the water embedded in the goods and services (Hoekstra & Chapagain, 2003).

The relationship between the trade and water, which later led to being derived the virtual water term, was mentioned by John Anthony Allan in (1992). Water and food trade relation, which shows the 'self-sufficiency' of countries in terms of the food source, as a comparative analysis among some Asia and the Middle East Countries, investigated in this work. The virtual water term was defined as the water embedded in water-intensive commodities such as agricultural products (Allan, 1999). However, later, the term was expanded not only for agricultural products but also for industrial products. Although the virtual water embedded in the service sector is lower in comparison with others, the virtual water concept can be applicable for service trade between countries.

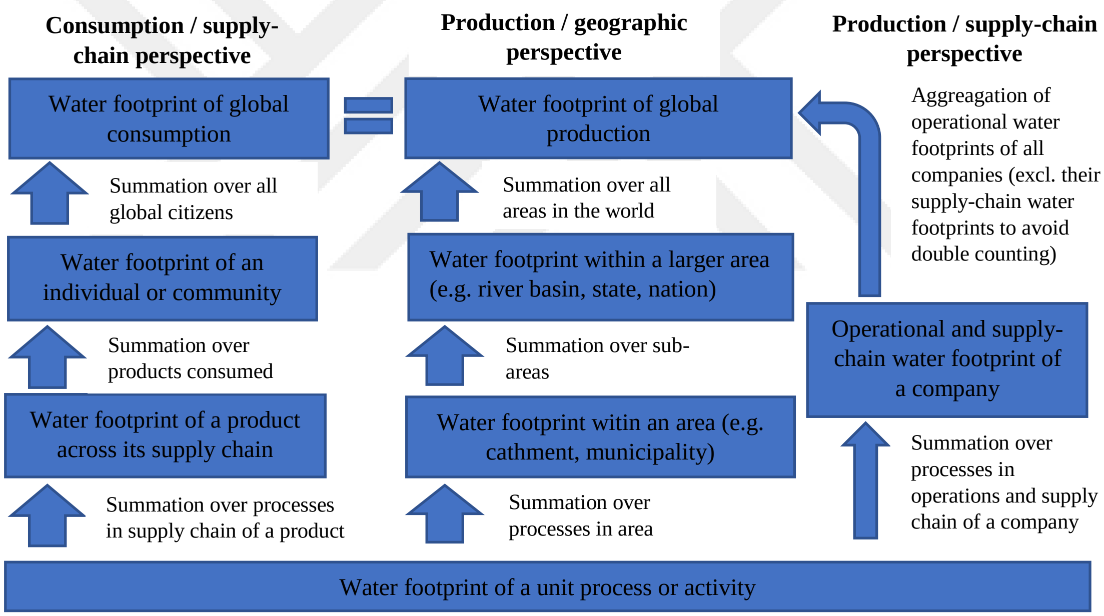
The main success of the virtual water concept is that it generates a better policy for water management because the trade of water in the product exogenously can be very harmful to the natural resources. One region or nation which has scarce water resources can import water-intensive products such as grain. As for the country which abundant water resources can export their products, which are mainly water intensive. The difficulties in the global management of water resources alleviate in this way. But, of course, it is not simple as it is mentioned. The water footprint analysis is more multidimensional. The evaluation of water from all perspectives is an elaborated and demanding task but it is needed to take better solutions in the policy that acted. While virtual water refers to the only volume of the water that is produced, the water footprint analysis gives a more comprehensive idea by considering the form of the water (blue, green, grey) that is used, and when and where the water is used. (Hoesktra et al., 2011: p. 46). However, the composite studies, which are evaluated regarding water footprint and virtual water, are more beneficial for policy generation about water management.

1.2.1.1. Global Water Footprint

The categorization of dimensional thinking is vital for water resources management at both global and national levels or river basins. For policymakers, it gives better solutions both on sustainable water resource management and international and domestic trade perspectives. However, there is a gap in knowledge about how global trends affect national or local decisions. Although methodologies have been developed for virtual water trade modeling, it isn't answered yet how global dynamics can cooperate with the national and local decisions (Zhuo et al., 2021: p 1). Therefore, the incorporation of global with the national and local decisions should be mentioned more in future works.

With the growing globalization, the degree of the interconnections of countries has increased. Consequently, indirect water that is consumed by an individual, a group of individuals, or residents of a nation in the product has also increased via the goods and services that have been traded. Therefore, the location of a water resource and the place where the product, which is produced by drawing from this water resource, is consumed may be different. Consequently, equality in consumption and production perspectives can be provided only on global level, as shown in **Figure 1-2**.

Figure 1-2: *The relation between different water footprints.*



Source: Hoekstra A. Y. (2017: p. 3065)

Studies on the virtual water trade show that the most important product is crop and livestock products because they transfer a high amount of water from one area to the others with trade, respectively. Therefore, in the literature, virtual water trade and water footprint of both livestock and crop products have been worked more than the other sector's products. The Global water withdrawal for crop-related products has been working since 1997. The first assessment was carried out by Shiklomanov (1997: p. 61) that demonstrates the global water withdrawal for agriculture (water used for irrigation) was about 2500 Gm^3/yr in 1995 and 2600 Gm^3/yr in 2000. Later, J. Rockström and L. Gordon

(2000) estimated the global water withdrawal for cropland as 5.400 Gm^3/yr considering the total vapor flow for agricultural crop products (the total of green and blue water). After virtual water became a widely applied concept in water footprint analysis, the global volume of crop-related virtual water trade between nations was calculated as 695 Gm^3/yr on average over the period 1995-1999. As it can be seen, 13% of the total amount of water consumed for crop production in the world wasn't used for domestic consumption, but it is used as virtual water (Hoekstra & Hung, 2002: p. 25).

Since food products have highly embedded freshwater, along with the consideration of whether the countries are self-sufficient in case of their water resources to meet their demand, especially for crop and livestock products, nations should ask the questions themselves: Which product can be produced in the border of the country without depletion of water resource, which product can be traded both for economically and environmentally well-being of the country? With the global water footprint assessment, these questions can be answered. It can be known which countries are net exporters or net importers. This knowledge gives us a better idea of how to allocate the countries' water resources effectively. The concept of virtual water has been considered by governments to implement sustainable water management since developed. Thus, the connections of countries in terms of the flow of virtual water among them have increased. In one of the latest studies conducted by (Carr, et al., 2013), the top 5 virtual water exporter and importer countries have calculated for the year 2010 in the context of the crop, crop-derived food commodities, and animal products. The result shows that China, Japan, Germany, Iran, and Italy are net importer countries, respectively, from first to fifth. Brazil, the United States of America, Argentina, Indonesia, and Canada are net exporters countries, respectively, from first to fifth. There are more elaborated studies in the literature. The work conducted by Hoekstra and Makonnen (2012) demonstrates the water footprint of humanity by calculating the nations' water footprints considering both consumptive water and greywater. Additionally, the nations' water footprints were calculated by production and consumption perspectives related to countries' agriculture, industry, and domestic sectors in this work.

Although there are many studies conducted on water footprint and virtual water models, it should be given more emphasis to this subject. More detailed maps, time series, and other data can be developed for agriculture and industry sectors, pollutants, climate conditions, soil properties, farming practices, and trade statistics so that water footprint accounts use as input for further improvement (Hogeboom, 2020: p. 221).

1.2.1.2. National Water Footprint

The better sustainable management of water resources is one of the sources of economic development and environmental stability. The appropriation of water for endless human needs leads to depleting the water resources of countries. Almost all human activities depend on water which shows the interactive relationship between water and national economies. National economies express the research and management of the economy and the environment in the context of the macroeconomic framework. Therefore, it is important to explore the nexus between water and the national economy (Čegar, 2020: p. 148).

There are two types of approaches to water footprint which are called bottom-up and top-down. The bottom-up approach, which is calculated by considering one product, shows the volumetric flow of water used in the production process of the product while the top-down approach, which is mainly applied by Input-Output analysis, covers the water footprint by tracing the whole domestic supply chain of the country. Although these two methods are basically used to determine water footprints, they are different in terms of their application way, outputs that are obtained, and their properties. The bottom-up approach uses a detailed description of the individual production process, while the top-down (input-output) approach is a more economic approach that shows the sectoral flows of water. The input-output analysis calculates the water footprint by tracking whole domestic supply networks, whereas the bottom-up approach does not trace the entire industrial supply chain (Feng et al., 2011). The top-down approach is preferred to look at the country's economy as a whole. Since the bottom-up approach shows the more comprehensive result for the individual product, it is mostly used for the calculation of water abundant products such as crops and livestock. It is important to mention the differences between these two approaches in this chapter because there are many analyzes conducted with both approaches in the literature. Therefore, the water footprints of different nations calculated by individual products' processes and input-output methods will be investigated in this chapter.

Since China is one of the water-scarce countries, the relevant literature is quite extensive. North China is a water-scarce region, while South China has relatively abundant water resources. Therefore, the virtual water flow with trade between regions is vital for water management in China. the water flow between regions was quantified by Ma et al. (2005) by using the water footprint analysis. One of the main results shows that North China exports approximately 52 billion m^3 of water embodied in the products to South China in 1999.

Since the growing demand for food products, food security and self-sufficiency is important for the Chinese government. The government pays more attention to the self-sufficiency of food products than to water use efficiency. Given the increased shortage of water, future food policy should encourage the active use of virtual water techniques to improve food security and water sustainability in China (Liu, Zehnder, & Yang, 2007). It seems that the food consumption pattern of China increased the water requirement. According to Liu and Savenije's calculations (2008), the total water requirement for food has calculated as 1.127 km^3y^{-1} for 2003, and the per capita water requirement for food has calculated as being increased from 255 $m^3/cap^{-1}/y^{-1}$ in 1961 to 860 $m^3/cap^{-1}/y^{-1}$ in 2003.

Although the food consumption pattern determines the highest pressure on water resources due to the population, considering the rapid growth in the Chinese economy, a holistic evaluation of inter-sectoral water flow is also an issue that should be considered. In a further study in which China's water footprint was calculated using an input-output method applied with 23 sectors (Zhao et al., 2008), the results show that China's water footprint was calculated as 381 m^3/cap/yr in 2002 and China is net virtual water exporter unlike previous studies alleged. However, in almost all studies, China has been determined as a virtual water importer country until today. Depending on different scenario analyses has been conducted by Zhuo et al. (2016), China will turn from a net importer country to a net exporter country. The other result also shows that China's water footprint per capita for food consumption is expected to decrease to 44% by 2050. In addition to that, Tian et al. (2018) applied cluster analysis, which shows China's water footprint in a global supply chain, using time series data apart from the multiregional input-output analysis. As a result of all studies, considering that China is a virtual water exporter, policies should be implemented regarding both food security and water management because the water self-sufficiency problem can be devastating in China.

India's water resources are at risk because of its high population. In the next fifty years, the population is expected to increase by 1.6 billion. Thus, feeding the population with higher welfare than at present would be demanding. Since agriculture is the main consumer of water, the increased food demand will increase the pressure on water resources in India (Kampman, 2007). Some countries don't have enough water to meet their water needs, while others have more available water than their demand. In this case, virtual water transfer between regions or countries is an alternative to reduce water consumption (Kumar & Jain, 2007). However, according to Verma, et. al. (2009), the virtual water flows among regions in India are against what they should be according to Hecker Ohlin trade theory. As can be seen in **Table 1-2**, the net exporter regions in India have relatively low water resources, while the net importer regions are water abundant. Since agricultural productions are not only based on the distribution of water resources but also on factors such as soil properties, climate, precipitation, and temperature, food production couldn't produce only where the water is abundant.

India is the country with the second-largest water footprint within its territory, with a total water footprint of 1.182 Gm^3/y. With the largest blue water footprint within its territory: 243 Gm^3/y, India's consumption contains 24% of the global blue water footprint (Hoekstra & Makonnen, 2012). In the period 1995-1999, India is the fifth net virtual water exporter country with a volume of 161,1 billion m^3 regarding the international crop trade. Even though, India's share in the global trade has become huge. the country's self-sufficiency is 100% (Hoekstra & Hung, 2002). However, its external water dependency has an increasing trend, with a value of under 4% (Hoekstra & Makonnen, 2012: p. 3234). Considering the scenario analysis mentioned above, the country's external water dependency will increase more.

Table 1-2: *Virtual water trade balances and per capita water resources*

States	Per capita water resources					Net virtual water import ($\times 10^9$ m^3/yr)
	Green (G)	Blue (B)			Total (B + G)	
		Internal	External	Total		
	m^3/capita/year					
Major virtual water exporters						
Haryana	1121	391	663	1055	2176	−14.1
Uttar Pradesh	863	575	1485	2059	2922	−20.8
Punjab	1102	193	2260	2452	3554	−20.9
Major virtual water importers						
Jharkhand	2082	1970	528	2498	4580	9.3
Bihar	789	628	5482	6109	6898	15.3
Orissa	3446	3079	2185	5264	8710	4.8

Source: Verma et al., (2009)

The United States is the country with the third-largest total water footprint within its territory, with a total water footprint of 1.053 Gm^3/y. While the water footprint of the global average consumer was 1.385 m^3/y, the average consumer's water footprint in the United States was 2.842 m^3/y and it is the top net virtual water exporter (Hoekstra & Makonnen, 2012). It is the country that needs to be investigated with the other important countries like China and India in this chapter when these properties are considered.

There is comprehensive work in the literature conducted by combining water footprint analysis, which was moved in concert with the assumptions of the bottom-up approach and input and output analysis. Marston et al. (2018) calculated the water footprint of the United States by combining these two approaches. The results show that the U.S. economy directly makes use of 730 billion m^3/y to produce goods and services. 603 billion m^3/y is from rainfall employed to grow crops for food, feed, and fuel.

Apart from being one of the driest continents, Australia has a highly fluctuating climate that includes frequent droughts, resulting in a rather unpredictable water supply (Lenzen & Foran, 2001: p. 321). For this reason, water management in Australia can be classified in the category of important countries such as China, India, and the United States, and the literature on national accounting of water has developed in the same direction. Net water consumption for the period 1996-1997 in Australia is 22.186 GL of which 15.502 GL was used in the agricultural sector corresponding to 70% of total water consumption (McLennan, 2000: p. 8).

Turkey's product-based water footprint studies are available, albeit in limited numbers. Turkey's annual blue and green water footprint of wheat consumption was calculated as 47,9 Gm^3/y, with blue water accounting for 32% of the total. The internal consumption water footprint of internal consumption is 38.9 Gm^3/y. Internal consumption accounts for about 81% of wheat's total consumptive water use, while imports account for the remaining 19%, corresponding to 9,2 Gm^3/y. Turkey's virtual water exports are negligible in comparison to virtual water imports, at roughly 0,37 Gm^3/year (Muratoğlu, 2020a: p. 9).

The above-mentioned studies have generally focused on the environmental burden of water use (more hydrological) and its evaluation in the context of trade. However, the studies that applied input-output methods will be compiled below to evaluate water consumption more economically (monetary base).

Agriculture is the highest water consumer sector for all economies, even if its share in the total water consumption can be different from country to country. For the Macedonian economy, Hristov et al., (2013) calculated that the share of water consumption of agriculture in total consumption is 37%. The other result reveals that sectors with high indirect water consumption such as tobacco, coke and refined petroleum, and raw materials can be considered the driving force of the Macedonian economy (2013).

In Morocco, The amount of water used in the agriculture sector constitutes 86.88% of the total amount of water used. It is seen that the 20% increase in the final demand of the agriculture sector increases the amount of water used by 9%, while the value added only increases by 5.831 billion dirhams. On the contrary, the manufacture of food and tobacco products sector with high indirect water consumption creates 9.253 value added while the 20% increase of final demand in this sector increases the water consumption by 8% (Boudhar et al., 2017). Contrary to the water consumption pattern of most countries, for the Croatian economy, the oil-processing sector has the largest share of total water consumption with 29,06%. Following that, according to linkages analysis, the oil processing, chemical, and power sectors are the key sectors that give rise to an above-average change in water use caused by a unit change in the final demand in Croatia (Čegar, 2020).

1.2.1.3. Regional Water Footprint

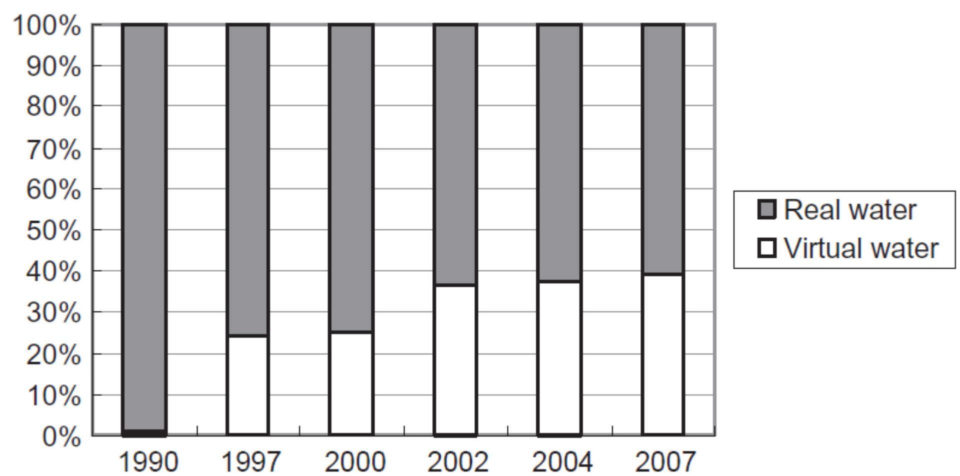
While some regions have abundant water resources, the others can be water-scarce. In addition to the water resources insufficiency, the growing population in such regions decreases their water footprint per capita. Some developed countries faced with water scarcity can divert the water among the regions to deal with water scarcity. But the less developed countries such as African countries can't afford to build this kind of transfer channel because of its high-cost operation value. Therefore, the virtual water trade comes out as an alternative policy to transfer the water. In this context, we are going to review some studies on water accounts of some regions by looking at their virtual water trade aspect as well in this chapter.

Some regions of China are water-scarce as mentioned above. For this reason, interregional virtual water trade is as important as international virtual water trade for China. Beijing, the capital of China, is one of the water-scarce regions. The empirical results show that the real water proportion to water footprint is on the decline (**Figure 1-3**), indicating that Beijing has implemented efficient water conservation measures (Wang

& Wang, 2009). In another case in China, although Zhangye City has insufficient water resources, there is no evidence that the city reduces the pressure on its water resources by importing virtual water in the form of economic inputs produced in other regions. On the other hand, agricultural water consumption in Zhangye City is responsible for 95% of the total water consumption in the region (Wang et al., 2009).

Further study related to the Hai river basin in China, conducted by Liu X. (2012), reveals that the agricultural sector accounts for 81,2% of direct total water consumption. The industry and service sectors are responsible for 53,2% of the indirect total water consumption. When considering water consumption per unit output, the result shows that the agricultural sector has the highest consumption intensity with a value of 96,91 m^3 while 28 industrial and service sectors were smaller than 1 m^3.

Figure 1-3: *The proportions of real water and virtual water to water footprint in Beijing*



Source: Wang & Wang (2009)

The Guadiana River basin, with its property of being one of the semiarid regions in Spain, was examined by Aldaya and Llamas (2008). According to the results, irrigation is responsible for 95% of the total blue and green water. However, considering the blue water productivity in the basin, the industry and domestic sector's productivity are higher than the agricultural sectors'. In addition, high virtual-water low economic value crops are common in the Upper and Middle Guadiana regions.

The focus on sectors such as agriculture, where direct total water use is intense, for policymaking in terms of water management isn’t reasonable on its own. Thus, direct and indirect total water consumption must be taken into account in planning the productive economy of a region or nation. In this context, agriculture with high direct and low indirect total water consumption must be considered together with ‘food and agriculture industry’ and ‘hotel and catering trade’ sectors for water management planning in Andalusia (Velazquez, 2006). In terms of virtual water trade, the Andalusian agricultural sector accounts for 90% of annual water consumption, and 52% of the agricultural final demand is exported to other Spanish regions and abroad. The results indicate that stopping the export of agricultural and food processing sectors abroad would reduce water consumption by 16%, while GRP would fall by only 3% (Dietzenbacher & Velazquez, 2007).

The province of Bali, located in Indonesia, is one of the regions currently experiencing water shortages. The agriculture sectors have the highest proportion of total water consumption in Bali. However, the manufacturing and service sectors consume a large amount of indirect water. Furthermore, as expected, hotels and restaurants are the ‘key sectors’ since Bali is one of the main tourism regions (Mohan et al., 2021).

Similar findings are also available in another study. Yu et al., (2010) calculated the water footprint of the South-East and North-East of the UK as a comparative study. The South East's domestic water footprint per capita is 22% larger than the North-East's domestic water footprint per capita. Agriculture, with its high direct water consumption, is the largest water consumer in the UK and the South-east and North-East. Another result shows that food products and service sectors such as Retail and Trade and Hotels, Accommodation, and Catering have high indirect water consumption.

The average consumptive water footprint of Diyabakır, which is a province in Turkey, has been calculated as 3.43 billion m^3/y considering agriculture, livestock, industry, and domestic sectors. The majority of the water resources in the province are used for the agriculture sector, with a rate of 86%, 49% of the freshwater is supplied from surface and groundwater, and this rate rises to 62% in the dry season (Muratoğlu, 2020b, p. 846).

The water footprint of the Upper Tigris River basin was calculated as 7,2 Gm^3/y and 1.748 $m^3/cap/y$. Crop production has the highest share with 79% of the total water footprint while the livestock and domestic plus industrial sectors shares' are 16% and 5%, respectively. Additionally, pistachio production could harm the sustainability of the basin with its high virtual water content (15.849 m^3/ton) and extremely blue water share (81%) (Muratoğlu, 2019).

CHAPTER TWO

ALGEBRA OF METHODOLOGY AND ITS THEORETICAL BACKGROUND

The theoretical development of EEIOA analysis, which is the analytical subject of the study, and the mathematical expression of methods will be explained and examined in this chapter. The mathematical expression of the method will be shown in two parts which are the basic IO and water IO models.

2.1. Theoretical Background of Environmentally Extended Input-Output Method and Its Limitations

The IO method, introduced to the literature by Wassily Leontief, is a frequently used tool in national and regional accounting. Its extension, the EEIOA, is a simple tool used to measure the natural resources demanded to meet human needs and the pollution that arises while meeting this demand. One of the earliest studies has been conducted by Hartman (1965) to examine the usefulness of the IO model regarding water consumption and allocation (as cited in Yu et al., 2010: p. 1142). Later, Leontief (1970) has been tried to extend the IO method by considering the pollution as a by-product with the way of adding a new row to the IO transaction table. Proop (1977) has derived direct and indirect indices, which show the direct and indirect energy required to produce a unit of the final output, using the IO methodology.

The method developed over time started to be applied in both national and regional studies (Lenzen & Foran, 2001; Velazquez, 2006; Boudhar et al, 2017; Mohan et al., 2021) in water footprint calculations. Input-output analysis has lately been integrated with the concepts of water footprint and virtual water trade to enhance the analysis of water accounting. The quantification of the virtual water associated with trade is necessary to calculate the nation's or region's water footprint (Yu, et al., 2010: p. 1142). Although it has been paid little attention to compared to bottom-up approaches, there are also some studies in which virtual water measurements are made by applying the input-output method. (Pac & Sanchez-Choliz, 1998; Dietzenbacher & Velazquez, 2007; Wang, et al., 2009).

Although the IO method is a basic and useful tool to demonstrate the burden of production on the environment, of course, it has some limitations. These limitations result from both data sources and their hypothetical drawbacks. There are many years between the publication times of the input and output tables. For example, the Turkish Statistical Institute (TURKSTAT) publishes input-output tables every 8 years. Since the input-output analysis is static, only the results of the past years can be obtained in the measurements. In addition, the high aggregation of water data narrows the scope of analysis and doesn't reflect the intersectoral relations healthily. Another problem is the homogeneity of products which is closely related to the aggregation of both IO tables and water data. The water data is gathered according to industrial classifications. Most companies, institutions, and organizations pruduce by-products that violate the homogeneity assumption.

2.2. Algebra of Methodology

In this chapter, the basic framework of Leontief's IO model and the EEIOA will be examined algebraically. Correspondingly, the mathematical structure of the basic IO model and how to integrate the physical data, the amount of water consumption, into the IO model that consists of the monetary transaction will be illustrated.

2.2.1. The Basic IO Model

In the simplest term, the IO model comprises a system of linear equations ($n \times n$), each one of which identifies the pattern of an industry's product throughout the economy. According to Miller and Blair (2009), the fundamental information employed in input-output analysis concerns product flows from each industrial sector, which is considered a producer, to each of the sectors, which is considered a consumer, including itself and others. Since the IO system comprises a set of n linear equations with n unknowns, matrix representation can be used. In this structure, the rows express the distribution of a producer's output throughout the economy while the columns express the system of inputs required by a specific industry to produce its output. In **Table 2-1**, the column of final demand, which consists of household consumption, investment, and exports, specifies the sales of each sector to the final market for their productions. The row of value added explains non-industrial inputs to production, such as labor, depreciation of capital indirect business taxes, and intermediate import products (Miller & Blair, 2009).

Table 2-1: *IO transaction table*

Producer Sectors	**Consumer Sectors**			**Final Demand**			**Total Output**
	Agriculture	Mining	etc.	Household Consumption	Investment	Net Exports	
Agriculture							
Mining		Z_{ij}			F_i		X_i
etc.							
Value added		V_j			V_j^F		V_i
Total Inputs		X_j			F_j		

Note: The capital letters state matrix notation

The Leontief model's core equation states that an economy's production is determined by its intersectoral relations and final demand. The set of equations that expresses these relationships for the sector i can be summarized as follows:

$$X_i = \sum_{j=1}^{n} z_{ij} + F_i \tag{1}$$

The technical coefficient for z_{ij} and x_j, which demonstrates the production of sector i bought by sector j as an input and the direct input requirement by sector j, denotes a_{ij}, and is calculated as:

$$a_{ij} = \frac{z_{ij}}{X_j} \quad (2)$$

With this manipulation, the production of sector i bought by sector j can be considered as the output function of sector j ($x_{ij} = a_{ij}.X_j$). Thus, Equation (1) can be rewritten by adding the technical coefficient (a_{ij}) to it as:

$$X_i = \sum_{j=1}^{n} a_{ij}.X_j + F_i \quad (3)$$

Considering the economy as a whole, we can write n linear equations with n unknown for illustration of the dependence of inter-industry flows on the total outputs of each sector. With this regard, since the $F_1,\ldots,F_n$ are known numbers and the a_{ij} are known coefficients, the $X_1,\ldots,X_n$ can be found (Miller & Blair, 2009: p. 19). These equation systems also can be written in matrix form.

$$X = A.X + F \quad (4)$$

To predict production levels of industries ($X_1,\ldots, X_n$), they need to be defined by the technical coefficients and the final demands. We will obtain the following equation by solving the matrix (4):

$$X = (I - A)^{-1}.F \quad (5)$$

Equation (5) determines what the new production levels of the industries should be to meet the anticipated final demands where the direct requirement matrix (A), whose elements are a_{ij}, is constant. The expression of $(I - A)^{-1}$ seen in the equation above is called the Leontief inverse matrix or the total requirement matrix. To become more apparent the dependence of each of the gross outputs on the values of each of the final demands this matrix $(I - A)^{-1}$ can be rewritten as:

$$(I - A)^{-1} = L = l_{ij} \quad (6)$$

Since l_{ij} are the elements of the total requirement matrix $(I - A)^{-1}$, equation (6) can be rewritten for the production of sector i as:

$$X_i = \sum_{j=1}^{n} l_{ij}.F_i \tag{7}$$

l_{ij} can be identified as $\frac{\partial X_i}{\partial F_i}$ in mathematical terms which explains the change in the production generated by sector i if the demand of sector j changes by one unit. The column sums of this matrix express the total requirements of a sector to meet its final demand. The diagonal elements of the matrix are the direct effect while the column sum of the off-diagonal elements is equal to the indirect effect (Mohan, et al., 2021).

2.3.2. Water IO Model

In this chapter, we will deal with how to integrate the water data into the IO model in general terms. Parallelly, the key findings, which are the direct and indirect water consumption, water consumption multipliers, and backward and forward linkages, of the IO model in terms of water will be illustrated. Additionally, we will examine the mathematical background of the economic benefits of water consumption. Furthermore, we will examine how to implement the scenario analysis.

2.3.2.1. The Fundamental Equations of Water IO Model

As described in the previous chapters, we will extend the conventional IO model using water data. We will reach this new model by adding the amount of water used (physical data) in the sectors as an additional row to the input-output table. In this chapter, the distinction between the direct and indirect water uses of the sectors will derive. These notions included in the model allow us to obtain the matrix of inter-sectoral water relations and to examine consumption according to this distinction (Velazquez, 2006: p. 231).

Production vector (X) states the monetary unit. The indicator of total direct consumption per unit produced (w^d) is identified as the amount of water consumed directly by each sector (w) per currency unit produced (X). The indicator of total direct consumption per unit produced (w^d) is expressed as a column vector where the elements are defined as in equation (9) (Velazquez, 2006: p. 231):

$$w_j^d = \frac{w_j}{X_j} \quad (8)$$

In matrix notation, it can be rewritten as:

$$w^d = w.\hat{X}^{-1} \quad (9)$$

where $\hat{X}$ specifies a diagonal matrix with the elements of X on the leading diagonal and w^d states the row vector with the elements of the indicator of total direct consumption per unit produced.

This matrix can be manipulated to reach the distinction between direct and indirect effects. The total water consumption of the economy as an indicator of the water consumed directly multiplied by the quantity generated by each sector will be expressed in the new equation. In matrix notation, it will be:

$$w^d.\hat{X} = w \quad (10)$$

Now, we can express equation (10) by substituting the X in equation (5). The new equation will be as follows:

$$w = \hat{w}^d.(I - A)^{-1}.F \quad (11)$$

Equation (11) stands for the water consumed directly and indirectly in the economy concerning its demand. The expression $w^d.(I - A)^{-1}$ in the equation states the row vector of which each element specify the total amount of water consumption in the economy if the demand of a specific sector change by one unit.

Now, we have the total water consumption and the indicator of total direct water consumption (w^t) which enable us to obtain the indirect water consumption by subtracting the total water consumption from direct water consumption. The indicator of total water consumption can be rewritten as:

$$w^t = w^d.(I - A)^{-1} \quad (12)$$

The indicator of indirect water consumption will be:

$$w^i = w^t - w^d \tag{13}$$

substituting the $w^d(I - A)^{-1}$ in equation (13), we will obtain the equation as:

$$w^i = w^d.(I - A)^{-1} - w^d \tag{14}$$

then, the following equation will come out:

$$w^i = w^d.[(I - A)^{-1} - I] \tag{15}$$

2.3.2.2. The Water Consumption Multipliers

The basic IO model considers the 'drag effect' which shows how the evaluation of a given sector can drag the total economic production. In the water IO model, this effect is called as water consumption multiplier (wcm) (Velazquez, 2006). Wcm can be obtained by dividing the indicator of total water consumption (w^t) by the indicator of the total direct water consumption (w^d):

$$wcm_j = \frac{w_j^t}{w_j^d} \tag{16}$$

Equation (16) can be identified as the amount of total water consumption in the economy per unit of water consumed directly to meet the demand of sector j. As seen in the equivalences of w^t and w^d, wcm can be considered as the column sum of the Leontief inverse matrix $(I - A)^{-1}$ in terms of water consumption.

Then, the indirect water consumption multiplier (iwc) can be easily obtained by subtracting 1 from each sector's wcm. The indicator will be:

$$iwc_j = wcm_j - 1 = \frac{w_j^t}{w_j^d} - 1 \tag{17}$$

Equation (17) states the amount of water consumed indirectly for each unit of water consumed indirectly by sector j to meet its demand.

2.3.2.3. The Intersectoral Water Relationships Matrix and Related Matrix

We have identified the fundamental consumption indicator of the water IO model in the earlier sections. Now, we can introduce the matrix that shows the intersectoral relationships among the sectors which are determined by mentioned indicators. Equation (12), which has the characteristic of a row vector, determines the total water consumption if the output of any given sector changes by one unit (Wang et al., 2009: p. 896). According to the equation, the intersectoral water relations matrix ($n \times n$) can be derived by subtracting total direct water consumption from total water consumption:

$$w^{int} = \widehat{w}^{d}.\left[(I - A)^{-1} - I\right] \tag{18}$$

where $\widehat{w}^{d}$ states a diagonal matrix with the elements of total direct water consumption on the leading diagonal. (w_{ij}^{int}), as the elements of (w^{int}), can be identified as the additional amount of water consumed by the economy as a whole for each unit of additional output in sector j (Wang et al., 2009: p. 896). Therefore, the sum of all elements of column j is equivalent to iwc. By dividing the elements of (w^{int}) by the indicator of total direct water consumption of respective sectors, a new matrix, which is called the matrix of water distribution coefficients, can be obtained whose elements are expressed as:

$$w_{ij}^{*} = \frac{w_{ij}^{int}}{w_{j}^{d}} \tag{19}$$

The element (w_{ij}^{*}) of this matrix states, how much the additional amount of water will be consumed by sector i when the demand for sector j increases by one unit.

2.3.2.4. Backward and Forward Linkages

The inter-industry linkage analysis is necessary to demonstrate the drag effects on the entire economy. Thus, we will use the backward and forward linkages indices which show the ‘key sectors’ in the economy that have the greater impact on the whole water consumption. The key sector term can be identified as having interconnections of this sector with others in the economy through its purchases input from them which affects whole water consumption greater in terms of backward linkages. In terms of forward linkages, this term explains having the greater effect of this sector on whole water consumption with its sales to others.

Backward linkage can be explained as the column sum of $\widehat{w}^{d}.(I-A)^{-1}$ of respective sectors where $\widehat{w}^{d}$ expresses the diagonal matrix with the elements of w^{d} on the leading diagonal. Backward linkage (BL_j) of sector j shows how much this sector has impacts on others through its purchases in terms of water consumption. The formulation is as follows:

$$BL_j = \widehat{w}^{d} \sum_{j=1}^{n} r_{ij} \tag{20}$$

where r_{ij} expresses each of the elements of Leontief inverse matrix $(I-A)^{-1}$.

Forward linkage can be derived from the row sum of $\widehat{w}^{d}.(I-A)^{-1}$ of respective sectors in the supply where the notation r_{ij} expresses each of the elements of Leontief inverse matrix $(I-A)^{-1}$ in the supply side IO model (Yu, et. al., 2010: p. 1143). Forward linkage (FL_i) of sector i shows how much this sector has impacts on others through its sales in terms of water consumption. This effect can be written algebraically as:

$$FL_i = \widehat{w}^{d} \sum_{i=1}^{n} r_{ij} \tag{21}$$

The new indexes can be normalized by using the general average. The normalized index for backward linkages for sector j can be calculated as (Kayacan, 2019):

$$U_{BL_j} = \frac{\frac{1}{N} BL_j}{\frac{1}{N^2} \sum_{j=1}^{n} BL_j} = \frac{BL_j}{\frac{1}{N} \sum_{j=1}^{n} BL_j} \tag{22}$$

The normalization of forward linkages for sector j is as follows:

$$U_{FL_i} = \frac{\frac{1}{N} FL_i}{\frac{1}{N^2}\sum_{i=1}^{n} FL_i} = \frac{FL_i}{\frac{1}{N}\sum_{i=1}^{n} FL_i} \tag{23}$$

In conclusion, when U_{BL_j} is greater than 1, it means that the one unit increase in final demand in sector j will lead to an above-average increase in the amount of water consumption of all sectors in the whole economy On the contrary when U_{FL_i} is greater than 1 means that one unit increase in the final demand of all sectors will create an above-average increase in the amount of water consumption of sector i (Yu et al., 2010). As seen in **Table 2-2**, if normalized backward (U_{BL_j}) and forward (U_{FL_i}) linkages are higher than 1 together, we can say that these sectors are the 'key sector' in terms of water (Pac & Sanchez-Choliz, 1998).

Table 2-2: *Classifications of sectors considering linkage analysis*

	$U_{BL_j} > 1$	$U_{BL_j} < 1$
$U_{FL_i} > 1$	Key sectors	Sectors that exhibit forward linkage in terms of water consumption
$U_{FL_i} < 1$	Sectors that exhibit backward linkage in terms of water consumption	Others

2.3.2.5. Changes in the Value Added

In this chapter, change in the final demand of a given sector's effect on the value added of all sectors will be investigated. Using the equivalence we will obtain in this section as well as equation (11), impact analysis will be made in which the effect of the change in final demand on both value added and water consumption is evaluated comparatively. The mentioned effect on value added can be calculated as:

$$\delta_j = \frac{V_j}{X_j} \tag{24}$$

The value added technical coefficient (δ) can be identified as a row vector whose element δ_j represents the direct value added by each sector per unit of its output (Boudhar, et. al, 2017). In matrix notation, it will be:

$$\delta = V.\hat{X}^{-1} \tag{25}$$

where ^ states that the elements of the output vector (X) are placed along the diagonal of the matrix. The change that emerged in the value added of the sectors by force of the change in final demand of any given sector can be calculated as:

$$V = \hat{\delta}.(I - A)^{-1}.F \tag{26}$$

where $\hat{\delta}$ expresses a diagonal matrix with the elements of δ on the leading diagonal.

CHAPTER 3

WATER FOOTPRINT OF TURKEY: RESULTS AND DISCUSSION

This chapter aims to analyze the intersectoral water consumption relations among 16 aggregated sectors in Turkey for 2018. The direct and indirect water consumption coefficients of the sectors will obtain from the empirical results. With these results, the scenario analysis will conduct. Additionally, to examine the 'drag effect' of certain sectors, we will empirically analyze the water consumption multipliers (wcm and iwc). We will identify the key sectors of water consumption in Turkey by using forward and backward linkage analyses that show in which direction (via purchasing intermediate input or selling output) economic sectors affect water use. We will derive matrices that show the intersectoral water relationship in Turkey. Last but not least, we will give some recommendations on how to gather the water data and how to manage the water resources effectively in Turkey considering the challenges that we faced and the empirical results.

3.1. Data Sources

The data used in this analysis are of two types: the first is Turkey's national IO table which is used for quantitative modeling that shows the interrelations among sectors. The second is the water withdrawal data is gathered from 16 sectors for Turkey. The analysis is conducted using the data in 2018.

3.1.1. National IO Data

In this analysis, the IO transaction table, which shows the monetary transactions among 51 sectors in the million US Dollar terms, is taken from OECD. IO table represents the sell and purchase interactions between producers and consumers. It also demonstrates flows (sales and purchases) of final and intermediate commodities and services that characterized by industry outputs. The indicator imports content of exports refers to degree of vertical specialization[5]. The classification of the sectors is made by the International Standard Industrial Classification (ISIC Rev 4). The IO table is aggregated into 16 sectors according to the availability of the water consumption data in sectors.

3.1.2. Water Data and Its Limitations

The water consumption data states the freshwater drawn from sources (surface water and groundwater) appropriated to the sectors. The unit of the data has been calculated as million cubic meters. The water abstraction data in the agriculture, hunting, forestry, and fishing sector has been obtained from Turkish State Hydraulic Works (DSI). The data expresses the water consumption for irrigation purposes. The mining and quarrying sector's water data is available in TURKSTAT datasets. It is collected under one sector as 'mining and quarrying' (section B). It specifies the water drawn from the source for all mining and quarrying operations excluded petroleum and natural gas extraction (section B-division 6) sector. The manufacturing sector's water data has been collected under ten sectors in TURKSTAT datasets. The data covers Manufacturing industry establishments' local units having 50 or more employees. The water data of the electricity supply sector has been obtained from TURKSTAT. According to TURKSTAT, the data was collected from all operating thermal power plants with an installed capacity of more than 100 megawatts. The public water supply sector's water data is available in TURKSTAT again. It covers the amount of water data that was taken from municipalities and villages recorded with the purpose of distributing water to the public for domestic consumption. For villages, the data was estimated with information obtained from villages network and treatment plants. The construction sector's data are taken from EUROSTAT datasets. The data states that the water is distributed to construction sectors from the public water system. Lastly, the amount of water used in the service sector is not in any dataset. Thus, it is the estimated value calculated by the author based on the information was taken from European Environment Agency[6]. The agency calculated the sectoral distribution of

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[5] **OECD**, https://stats.oecd.org/OECDStat_Metadata/ShowMetadata.ashx?Dataset=IOTS_2021&Lang=en
[6] **EEA**, https://www.eea.europa.eu/data-and-maps/indicators/use-of-freshwater-resources-3/assessment-4

the amount of water used in 2017 by taking the averages of the countries that are members of the European Union. According to this information, 3,3% of total gross water consumption was used in the service sector in 2017. Correspondingly, the value has been estimated as 2.368,4 million m^3 for Turkey.

As seen above, there are some limitations to the analysis in addition to using the dummy variable for the service sector and the data availability in the construction sector. But the significant effect on analysis comes from the fishing sector's data. In the IO table, the fishing sector's monetary transactions are calculated separately from the agriculture, forestry, and hunting sectors. However, water use data for the fishing sector is not available other than the estimated value. The analysis conducted using the estimated water consumption value of the fishing sector gave insignificant results because its proportion to total gross water abstraction was as high as not possible with a ratio of 12,68%. Thus, it has been counted in the agriculture, hunting, and forestry sector.

3.2. Application of Water IO Model and Empirical Results

The analysis performed in this work will give us ideas on how water resources in Turkey are distributed among sectors and how these resources can be used more effectively. But of course, more comprehensive work is needed in this field. For example, price sensitivity and virtual water analyses can be performed in addition to our analysis so as to show Turkey's situation in the case of water resources and their relation to the economy more efficiently. In this chapter, we will analyze Turkey's sectoral water consumption indicators and intersectoral water consumption relations among the sectors using the tools of EEIOA. While doing this, EEIOA will help us to show these relationships quantitatively. For the policy-makers, such quantifications would be crucial because the scale and scope of the measures in case of water management to be taken and the expected results can be determined according to the results of this kind of analysis more accurately. The related empirical results will be shown in the next chapters.

3.2.1. Direct and Indirect Water Consumption Indicators and Water Consumption Multipliers

In this chapter, we will fundamentally investigate the indicator of direct water consumption per unit produced (w^d), the indicator of total water consumption per unit produced (w^t), and the indicator of indirect water consumption per currency unit produced (w^i) as well as the water consumption multiplier (wcm), and indirect water consumption multiplier (iwc).

Table 3-1 covers the data which are the direct water consumption (w), the direct water consumption per currency unit produced (w^d), the total water consumption per currency unit produced (w^t), the indirect water consumption per currency unit produced (w^i), and their proportions in sectoral total.

As seen in the table, when compared to other sectors, the amount of water consumed by agriculture, hunting, forestry, and fishing sector (1) is the highest value, constituting 69% of the total amount of water consumed. This data shows us the sector that creates the greatest pressure on Turkey's water resources is the agriculture, hunting, forestry, and fishing sector (1). In addition, electricity and gas supply (13), and water supply (14) sectors are the second and third highest water consumer sectors with the proportions 12,4 and 10,3 respectively. The total water consumptions of these three sectors exceed the amount of 58 billion m^3 with 91,7% of total water consumption in Turkey. We can also mention service sector (16), and basic and fabricated metal products sector (10) with 3,3% and 3% respectively. Although these sectors are the fourth and fifth-highest water consumer sector, their water consumptions are negligible when compared to the agriculture, hunting, forestry, and fishing sector (1), electricity and gas supply sector (13), and water supply sector (14).

The aforementioned sectors with high direct water consumption may have high output. Therefore, the direct water consumption and the indicators of direct water consumption per unit of output produced should be compared. As seen in the third column

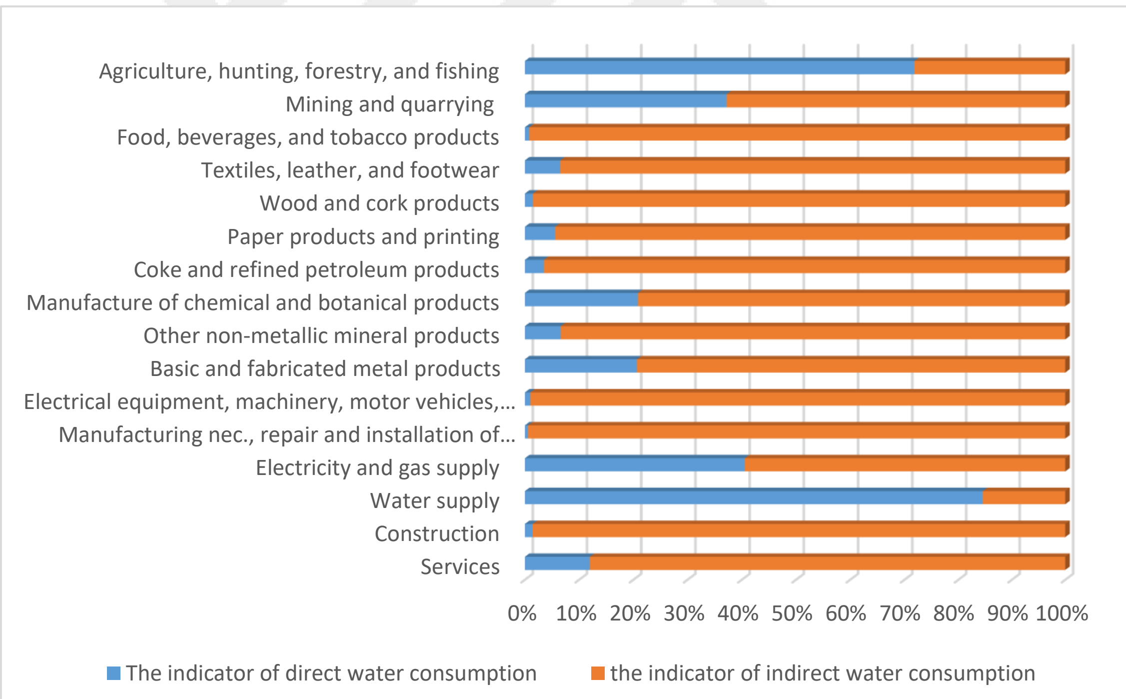
Table 3-1: *Direct water consumption (million m^3) and the indicators of direct, indirect, and total water consumption per currency unit produced (thousand m^3/million dollars)*

No.	Sectors	w	%	Rank	w^d	Rank	w^t	Rank	w^i	Rank
1	Agriculture, hunting, forestry, and fishing	43.950,0	68,97%	**1**	455,70	**1**	634,39	**1**	178,69	**3**
2	Mining and quarrying	240,9	0,38%	**7**	16,45	**5**	44,20	**9**	27,75	**15**
3	Food, beverages, and tobacco products	156,3	0,25%	**9**	2,05	**11**	257,83	**4**	255,77	**1**
4	Textiles, leather, and footwear	230,8	0,36%	**8**	3,10	**7**	47,58	**7**	44,48	**7**
5	Wood and cork products	10,3	0,02%	**15**	1,76	**12**	119,24	**6**	117,47	**4**
6	Paper products and printing	32,8	0,05%	**12**	2,37	**10**	42,56	**11**	40,19	**9**
7	Coke and refined petroleum products	27,5	0,04%	**14**	1,25	**13**	35,74	**14**	34,49	**14**
8	Manufacture of chemical and chemical products, botanical products	452,3	0,71%	**6**	9,74	**6**	46,74	**8**	37,00	**12**
9	Other non-metallic mineral products	73,2	0,11%	**11**	2,89	**9**	43,87	**10**	40,97	**8**
10	Basic and fabricated metal products	1.878,7	2,95%	**5**	26,04	**4**	126,08	**5**	100,04	**5**
11	Electrical equipment, machinery, motor vehicles, other transport equipment products	30,7	0,05%	**13**	0,40	**15**	40,11	**12**	39,71	**10**
12	Manufacturing nec., repair and installation of machinery and equipment	5,6	0,01%	**16**	0,21	**16**	38,48	**13**	38,27	**11**
13	Electricity and gas supply	7.867,7	12,35%	**2**	131,09	**3**	323,31	**3**	192,22	**2**
14	Water supply	6.584,0	10,33%	**3**	452,88	**2**	535,62	**2**	82,74	**6**
15	Construction	76,9	0,12%	**10**	0,50	**14**	35,42	**15**	34,92	**13**
16	Services	2.102,8	3,30%	**4**	3,01	**8**	25,14	**16**	22,13	**16**
	Total	**63.720,5**	**100,00%**							

of **Table 3-1**, even electricity and gas supply sector (13) has a high direct water consumption, its indicator of direct water consumption per unit of output produced is relatively low with the value of 131,09 compared to agriculture, hunting, forestry, and fishing (1), and water supply (14) sectors' because of its high output. In fact, its proportion of direct water consumption in total and of direct water consumption per unit of output produced in total are in balance approximately, 12,4% and 11,8% respectively. As regards to agriculture, hunting, forestry, and fishing sector (1), we can say that its water productivity is over moderate because its direct water consumption proportion in total is 69% and its per unit of output produced proportion is 41,1%. However, its direct water consumption per currency unit produced indicator is the highest with the amount of 455,7 m^3 per thousand dollars. As we can see in the fourth column in the table, we can conclude that the water supply sector (14) is the least productive sector considering water as an input. This is an expected result because its output is water. It has two basic functions such as purification of water and distribution to the consumer, and the low price of water causes the output of this sector to be low in monetary terms. For this reason, it is one of the sectors with high water consumption but low production. The water supply sector (14) accounts for 10,3% of total water consumption but its water consumption per unit of output produced constitutes 40,8% of the total. Service (16) is one of the sectors that we can make this comparison. It is the fourth highest sector in the case of direct water consumption and its share is 3,3% in total consumption, but looking at the indicator of direct water consumption per currency unit produced, its proportion is 0,27% in total.

We can also cross-check the indicator of direct water consumption per currency unit produced and the indicator of total water consumption per currency unit produced. This comparison shows us which sector consumes the water directly and which sector consumes it indirectly. Agriculture, hunting, forestry, and fishing sector (1) consumes the water mostly direct. In addition to that sector, water supply (14) is the other sector that consumes the water directly. On the other hand, food, beverages, and tobacco product sector (3) consumes water indirectly. There are other sectors that consume water indirectly. However, the amount of water consumed by food, beverages, and tobacco product sector (3) is extremely high compared to others. The other important sector that consumes water indirectly in Turkey is wood and cork products sector (5). **Figure 3-1** visualizes that all industrial sectors intensely consume water indirectly, except for manufacture of chemical and botanical products (8) and basic and fabricated metal products (10). This result shows that the direct consumption of water in the production processes of these sectors is low, but the water consumption of the raw materials used in these production processes is intense. Thus, intensive consumption of water is necessary for these sectors as well.

Figure 3-1: *The proportions of direct and indirect water consumption per currency unit produced in the total water consumption per currency unit produced in each sector.*



To demonstrate the ‘drag effect’ of the sectors that consume water indirectly, we will examine the water consumption multipliers of sectors. The assumption that is mentioned above can be proved by the data in **Table 3-2**. If we focus only on sectors with intense direct water consumption, we would ignore the sectors such as manufacturing nec., repair and installation of machinery and equipment (12), and food, beverages, and tobacco products (3), which consume indirect water intensively. The lowest values of wcm belong to the sectors such as agriculture, hunting, forestry, and fishing (1), water supply (14), and electricity and gas supply (13) indicating that these sectors have a characteristic of the essential direct water consumer sector.

Table 3-2: *Water consumption multiplier (wcm) and indirect water consumption multiplier (iwc) of each sector*

No.	Sectors	*wcm*	*iwc*
1	Agriculture, hunting, forestry, and fishing	1,39	0,39
2	Mining and quarrying	2,69	1,69
3	Food, beverages, and tobacco products	125,61	124,61
4	Textiles, leather, and footwear	15,37	14,37
5	Wood and cork products	67,59	66,59
6	Paper products and printing	17,95	16,95
7	Coke and refined petroleum products	28,57	27,57
8	Manufacture of chemical and botanical products	4,80	3,80
9	Other non-metallic mineral products	15,16	14,16
10	Basic and fabricated metal products	4,84	3,84
11	Electrical equipment, machinery, motor vehicles, other transport equipment products	99,57	98,57
12	Manufacturing nec., repair and installation of machinery and equipment	179,91	178,91
13	Electricity and gas supply	2,47	1,47
14	Water supply	1,18	0,18
15	Construction	70,19	69,19
16	Services	8,35	7,35

Although we couldn't see it clearly in **Table 3-1**, mining and quarrying (2) is one of the highest direct water consumer sectors with 2,69 wcm because of its low total direct water consumption. In other words, these data represent that for each 1 m^3 of water consumed directly in agriculture, hunting, forestry, and fishing (1), water supply (15), electricity and gas supply (14), and mining and quarrying (2) sectors increase the total water consumption in the economy, in turn, by 0,39, 0,18, 1,47 and 1,69 m^3. Thus, the 'drag effect' of these sectors is insignificant for the Turkish economy in terms of water consumption.

Compared to the sectors mentioned above, the iwc indicators of the sectors with intensive indirect water consumption are quite high. Such five sectors with extremely high iwc compared to others are manufacturing nec., repair and installation of machinery and equipment (12), food, beverages, and tobacco products (3), electrical equipment, machinery, motor vehicles, other transport equipment products (11), construction (15), and wood and cork products (5) sector from highest to lowest. For example, this value shows that for each 1 m^3 water consumed in manufacturing nec., repair and installation of machinery and equipment (12), and food, beverages, and tobacco products (3) increase the total water consumption by 179,91 and 125,61 in turn. They have a significant impact on the other sectors' water consumption. Thus, we can say that these sectors have the feature of being the driving force in the Turkish economy because of their high demand for the other sectors' production. In other words, the demand of these sectors influences the production of other sectors to meet this demand.

3.2.2. Intersectoral Water Relationships Matrices

We will analyze two matrices that show the intersectoral water relationship in this chapter. **Table 3-3** illustrates the intersectoral water relationships matrix. This matrix can be evaluated by taking into account the rows or columns of the matrix. Column j represents the water purchases, which are embedded in the products, from the rest of the sector i made by sector j. So, the row sum of the matrix shows us what the total water requirements of sector j are. On the contrary, row i can be interpreted as the water sold by sector i to the rest of sector j. Thus the column sums represent the total amount of water sold by sector i (Velazquez, 2006).

Table 3-4 shows the water distribution coefficients. This new matrix demonstrates how much the additional amount of water is consumed by sector i if the amount of water demanded by sector j increases by one unit. As can be seen in the table, many water distribution coefficients remain low in general. According to these results, most of the water distribution coefficients can be ignored due to the lack of interdependency between sectors except for some. In general, we can say that the higher indirect water consumer sector such as industrial sectors demand water from agriculture, hunting, forestry, and fishing sector (1). Furthermore, it is seen that most of the intermediate goods used by food, beverages, and tobacco products (3), wood and cork products (5), and manufacturing nec., repair and installation of machinery and equipment (15) which are the sectors that consume water extremely indirectly, come from the agriculture, hunting, forestry, and fishing sector (1). In other words, each 1 m^3 of water consumed directly by food, beverages, and tobacco products (3), wood and cork products (5), and manufacturing nec., repair and installation of machinery and equipment (15) sectors force to increase water consumption in agriculture, hunting, forestry, and fishing sector (1) by 118,18, 53,49 and 66,79 m^3 respectively to meet these sector's demands for its productions. Additionally, construction (15), being one of the higher indirect water consumer sectors, increases the agriculture, hunting, forestry, and fishing (1) sector's water consumption with the value of 15,42 m^3 for an increase of 1 unit of m^3 in the construction sector. Even if textiles, leather, and footwear (4) and paper products and printing (6) sector have moderate indirect water consumption multipliers, it is important to show the interrelations between agriculture, hunting, forestry, and fishing sector (1).

Table 3-4 also proves that some sectors' demand for water from electricity and gas supply (13) and water supply (14) sectors are significant indicators of the Turkish economy. The sectors that have the largest share of indirect water consumption from these sectors are manufacturing nec., repair and installation of machinery and equipment (12), electrical equipment, machinery, motor vehicles, other transport equipment products (11), and construction (15). When evaluated in terms of electricity and gas supply sector (13), for each 1 unit of m^3 consumed in manufacturing nec., repair and installation of machinery and equipment (12), electrical equipment, machinery, motor vehicles, other transport equipment products (11), and construction (15) sectors, it must consume the 32, 20, 26 and 13,95 m^3 respectively water to meet their demand for its productions. If we consider the data from the water supply sector's point of view, 1 unit of increase in direct water consumption of these three sectors will increase the water consumption of water supply

Table 3-3: *The intersectoral water relationships matrix (w; in thousands of m^3)*

No.	Sectors	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Sum
1	Agriculture, hunting, forestry, and fishing	167,633	16,460	242,569	29,763	94,376	16,440	12,633	15,861	8,760	6,666	6,145	14,286	7,660	6,430	7,782	10,658	**664,122**
2	Mining and quarrying	0,689	2,011	0,584	0,457	0,773	0,555	10,912	0,760	1,896	2,107	0,781	0,641	4,864	0,826	1,056	0,626	**29,536**
3	Food, beverages, and tobacco products	0,125	0,020	0,348	0,032	0,041	0,037	0,024	0,035	0,024	0,019	0,020	0,026	0,020	0,021	0,020	0,046	**0,859**
4	Textiles, leather, and footwear	0,027	0,075	0,039	1,319	0,048	0,099	0,058	0,073	0,078	0,034	0,052	0,195	0,035	0,032	0,039	0,036	**2,239**
5	Wood and cork products	0,005	0,005	0,006	0,006	0,376	0,009	0,005	0,009	0,019	0,009	0,010	0,160	0,004	0,009	0,043	0,005	**0,679**
6	Paper products and printing	0,026	0,019	0,063	0,048	0,082	0,704	0,028	0,069	0,071	0,032	0,038	0,054	0,025	0,022	0,029	0,038	**1,348**
7	Coke and refined petroleum products	0,070	0,171	0,050	0,033	0,052	0,038	0,171	0,054	0,104	0,048	0,037	0,036	0,079	0,053	0,062	0,059	**1,116**
8	Manufacture of chemical and botanical products	1,145	0,411	0,996	1,177	1,829	1,873	0,651	4,073	1,169	0,757	1,062	1,276	0,328	0,863	0,931	0,406	**18,946**
9	Other non-metallic mineral products	0,021	0,044	0,031	0,022	0,036	0,027	0,047	0,049	0,460	0,046	0,049	0,047	0,038	0,055	0,319	0,039	**1,329**
10	Basic and fabricated metal products	0,396	0,760	0,587	0,540	1,280	0,827	0,806	1,202	1,214	9,240	7,241	4,326	0,809	1,294	5,407	0,584	**36,514**
11	Electrical equipment, machinery, motor vehicles, other transport equipment products	0,006	0,015	0,007	0,007	0,008	0,008	0,012	0,008	0,011	0,012	0,090	0,020	0,014	0,011	0,025	0,009	**0,264**
12	Manufacturing nec., repair and installation of machinery and equipment	0,001	0,002	0,002	0,004	0,005	0,003	0,003	0,003	0,005	0,002	0,003	0,016	0,001	0,003	0,003	0,002	**0,058**
13	Electricity and gas supply	4,499	4,775	6,195	7,227	13,157	8,650	5,024	8,890	21,588	16,456	8,163	6,845	174,202	18,088	7,039	5,598	**316,397**
14	Water supply	3,120	2,088	2,963	2,488	4,091	9,557	2,815	4,565	4,240	63,517	14,778	9,100	2,835	53,835	10,885	2,858	**193,735**
15	Construction	0,007	0,009	0,008	0,007	0,013	0,009	0,015	0,009	0,014	0,015	0,010	0,011	0,016	0,061	0,103	0,013	**0,320**
16	Services	0,922	0,886	1,327	1,352	1,306	1,351	1,284	1,343	1,321	1,079	1,229	1,231	1,289	1,133	1,173	1,154	**19,380**
	Sum	**178,693**	**27,752**	**255,775**	**44,481**	**117,474**	**40,186**	**34,487**	**37,003**	**40,975**	**100,040**	**39,707**	**38,270**	**192,217**	**82,736**	**34,916**	**22,130**	***1286,841***

Table 3-4*: The matrix of water distribution coefficients*

No.	Sectors	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	Agriculture, hunting, forestry, and fishing	0,37	1,00	118,18	9,62	53,49	6,94	10,10	1,63	3,03	0,26	15,25	66,79	0,06	0,01	15,42	3,54
2	Mining and quarrying	0,00	0,12	0,28	0,15	0,44	0,23	8,72	0,08	0,66	0,08	1,94	2,99	0,04	0,00	2,09	0,21
3	Food, beverages, and tobacco products	0,00	0,00	0,17	0,01	0,02	0,02	0,02	0,00	0,01	0,00	0,05	0,12	0,00	0,00	0,04	0,02
4	Textiles, leather, and footwear	0,00	0,00	0,02	0,43	0,03	0,04	0,05	0,01	0,03	0,00	0,13	0,91	0,00	0,00	0,08	0,01
5	Wood and cork products	0,00	0,00	0,00	0,00	0,21	0,00	0,00	0,00	0,01	0,00	0,02	0,75	0,00	0,00	0,08	0,00
6	Paper products and printing	0,00	0,00	0,03	0,02	0,05	0,30	0,02	0,01	0,02	0,00	0,10	0,25	0,00	0,00	0,06	0,01
7	Coke and refined petroleum products	0,00	0,01	0,02	0,01	0,03	0,02	0,14	0,01	0,04	0,00	0,09	0,17	0,00	0,00	0,12	0,02
8	Manufacture of chemical and botanical products	0,00	0,02	0,49	0,38	1,04	0,79	0,52	0,42	0,40	0,03	2,64	5,97	0,00	0,00	1,84	0,13
9	Other non-metallic mineral products	0,00	0,00	0,01	0,01	0,02	0,01	0,04	0,01	0,16	0,00	0,12	0,22	0,00	0,00	0,63	0,01
10	Basic and fabricated metal products	0,00	0,05	0,29	0,17	0,73	0,35	0,64	0,12	0,42	0,35	17,98	20,22	0,01	0,00	10,72	0,19
11	Electrical equipment, machinery, motor vehicles, other transport equipment products	0,00	0,00	0,00	0,00	0,00	0,00	0,01	0,00	0,00	0,00	0,22	0,09	0,00	0,00	0,05	0,00
12	Manufacturing nec., repair and installation of machinery and equipment	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,01	0,07	0,00	0,00	0,01	0,00
13	Electricity and gas supply	0,01	0,29	3,02	2,34	7,46	3,65	4,02	0,91	7,46	0,63	20,26	32,00	1,33	0,04	13,95	1,86
14	Water supply	0,01	0,13	1,44	0,80	2,32	4,03	2,25	0,47	1,47	2,44	36,69	42,54	0,02	0,12	21,57	0,95
15	Construction	0,00	0,00	0,00	0,00	0,01	0,00	0,01	0,00	0,00	0,00	0,02	0,05	0,00	0,00	0,20	0,00
16	Services	0,00	0,05	0,65	0,44	0,74	0,57	1,03	0,14	0,46	0,04	3,05	5,76	0,01	0,00	2,32	0,38
	iwc	**0,39**	**1,69**	**124,61**	**14,37**	**66,59**	**16,95**	**27,57**	**3,80**	**14,16**	**3,84**	**98,57**	**178,91**	**1,47**	**0,18**	**69,19**	**7,35**

sectors 42,54, 36,69 and 21,57. The coefficients for the row of water supply sector (14) can be interpreted as the water production generated by it to meet respective sectors' demands.

Lastly, we can see the pressure created by each 1 unit of direct water consumption of electrical equipment, machinery, motor vehicles, other transport equipment products (11) manufacturing nec., repair and installation of machinery and equipment (12), and construction (15) sectors on the water consumption of basic and fabricated metal products sector (10).

3.2.3. Backward and Forward Linkages Analysis

Since the late 1950s, interindustry relationships have been investigated to identify 'key sectors' that are important for economic development (Drejer, 2002). In the water IO model, backward linkage analysis identifies the strength of a particular sector's interconnection with the others through the amount of water bought by its purchases embedded in the products from others. On the other hand, forward linkage analysis shows a particular sector's impact degree on others through its water sales to others. The sector with a backward and forward linkage index greater than 1 is defined as the 'key sector'. However, in this index, detecting whether the effects of sectors are higher than average or not can be difficult since the coefficients are rarely higher than 1. A new index, which shows the strength of linkages, was introduced by Rassmussen in 1957 (as cited in Miller & Blair, 2009) that can be formulated simply by dividing a sector's index by the average of all sector's indexes This index also can be identified as so-called normalized backward and forward indexes.

Table 3-5 represents the 'key sector' in the Turkish economy in terms of water consumption according to the results of backward and forward linkages analysis. It can be said that none of the sectors is a 'key sector'. However, according to the classification, agriculture, hunting, forestry, and fishing sector (1) displays the forward linkage characteristic. Water supply (15) and electricity and gas supply (13) sectors' backward

Table 3-5: *Backward linkages (BL) and forward linkages (FL) of sectors*

No.	Sectors	BL	Rank	FL	Rank
1	Agriculture, hunting, forestry, and fishing	0,63	**1**	**1,12**	**1**
2	Mining and quarrying	0,04	**9**	0,05	**5**
3	Food, beverages and, tobacco products	0,26	**4**	0,00	**11**
4	Textiles, leather, and footwear	0,05	**7**	0,01	**8**
5	Wood and cork products	0,12	**6**	0,00	**12**
6	Paper products and printing	0,04	**11**	0,00	**10**
7	Coke and refined petroleum products	0,04	**14**	0,00	**13**
8	Manufacture of chemical and botanical products	0,05	**8**	0,03	**6**
9	Other non-metallic mineral products	0,04	**10**	0,00	**9**
10	Basic and fabricated metal products	0,13	**5**	0,06	**4**
11	Electrical equipment, machinery, motor vehicles, other transport equipment products	0,04	**12**	0,00	**15**
12	Manufacturing nec., repair and installation of machinery and equipment	0,04	**13**	0,00	**16**
13	Electricity and gas supply	0,32	**3**	0,45	**3**
14	Water supply	0,54	**2**	0,65	**2**
15	Construction	0,04	**15**	0,00	**14**
16	Services	0,03	**16**	0,02	**7**

and forward linkages coefficients are higher than average even if they don't exhibit the backward and forward linkages. In addition, food, beverages, and tobacco products sector's (3) backward linkage coefficients seem to be higher than average. This argument can be proven by looking at **Table 3-6**.

Table 3-6 shows the normalized backward and forward linkages of sectors in terms of water in Turkey. Agriculture, hunting, forestry, and fishing sector (1) is one of the key sectors with the highest coefficients. Following agriculture, hunting, forestry and

Table 3-6: *Normalized backward linkages* (U_{BL}) *and normalized forward linkages* (U_{FL}) *of sectors*

No.	Sectors	U_{BL}	Rank	U_{FL}	Rank
1	Agriculture, hunting, forestry and fishing	**4,24**	**1**	**7,48**	**1**
2	Mining and quarrying	0,30	**9**	0,31	**5**
3	Food, beverages and tobacco products	**1,72**	**4**	0,02	**11**
4	Textiles, leather and footwear	0,32	**7**	0,04	**8**
5	Wood and cork products	0,80	**6**	0,02	**12**
6	Paper products and printing	0,28	**11**	0,02	**10**
7	Coke and refined petroleum products	0,24	**14**	0,02	**13**
8	Manufacture of chemical and botanical products	0,31	**8**	0,19	**6**
9	Other non-metallic mineral products	0,29	**10**	0,03	**9**
10	Basic and fabricated metal products	0,84	**5**	0,42	**4**
11	Electrical equipment, machinery, motor vehicles, other transport equipment products	0,27	**12**	0,00	**15**
12	Manufacturing nec., repair and installation of machinery and equipment	0,26	**13**	0,00	**16**
13	Electricity and gas supply	**2,16**	**3**	**2,99**	**3**
14	Water supply	**3,58**	**2**	**4,32**	**2**
15	Construction	0,24	**15**	0,01	**14**
16	Services	0,17	**16**	0,15	**7**

fishing sector (1), water supply (15), and electricity and gas supply sectors (16) exhibit the property of being ‘key sector’. In other words, we can say that these sectors’ impacts on the others’ water consumption through both selling their output and their intermediate input purchases from others are the highest among all sectors. As we can see, both construction (15) and service (16) sectors’ press on water consumption in the whole economy both regarding sales and purchases are very limited.

Last but not least, none of the industry sectors except for food, beverages, and tobacco products sector (3) display either backward linkage or forward linkage properties. With being the sector that displays forward linkage, this sector's effect can be interpreted as the 1 unit increase in final demand in food, beverages, and tobacco products sector (3) will push an above-average increase in the amount of water consumption of all sectors in the whole economy. It is not seen obviously but we can induce that the interdependency of this sector on agriculture, hunting, forestry, and fishing sector (1) through purchases from it, brings backward linkages property only rather than forward.

3.2.4. Scenario Analysis

Water management in Turkey is directly related to climate and current water resource potential. Apart from this, it should not be overlooked that water management has socio-economic reflections and should be evaluated with a more holistic approach. In this direction, the Ministry of Agriculture and Forestry of the Republic of Turkey created the 2019-2023 national water plan[7] and stated that socio-economic analyzes constitute an important input for policymakers. However, the lack of studies examining the national consumption of water in Turkey, especially in intersectoral relations, creates a big gap in the literature. Thus, the scenario analysis in this chapter will be a significant model for policymakers to demonstrate the increasing pressure on water resources and its reflections on Turkey's economy.

In this chapter, we will investigate the impacts of the demand shocks in the economy on water consumption and the value added increases that are resulted from it. In this regard, the tools of the water IO model were employed to observe the effect of the change in the final demand, which is an exogenous variable, at the sectoral level in Turkey. For this purpose, two sectors, which pose the main threat to water resources in Turkey, were chosen for the analyses. One of the aforementioned sectors is agriculture, hunting,

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[7] Turkey's National Water Plan for 2019-2023, https://www.tarimorman.gov.tr/SYGM/Belgeler/NHYP%20DEN%C4%B0Z/ULUSAL%20SU%20PLANI.pdf

forestry, and fishing sector (1), which is the highest direct water consumer and the other is food, beverages, and tobacco products sector (3), which is the highest indirect water consumer.

The results can be seen in **Hata! Başvuru kaynağı bulunamadı.**. ‘Scenario 1’ seen in the table is the simulation that expresses a 20% increase in final demand for the agriculture, hunting, forestry, and fishing sector (1). On the other hand, ‘Scenario 2’ specifies a 20% increase in the final demand for food, beverages, and tobacco products.

In the first scenario, as seen, a 20% increase in final demand for agriculture, hunting, forestry, and fishing sector (1) creates 7.283,81 million dollars value added in total. As it is expected that the effect of this increase on the other economic sector is weak due to the rarity of intermediate input purchases of this sector from the remaining sectors. It is the effect on value added essentially direct. In other words, a 20% increase in final demand of this sector leads to an increase of 4.873,18 million dollars additional value added in it which corresponds to 66,9% of the total increase in value added. When the proportion of total change in value added is considered, it is seen that the increase is lower than 1,1%. Furthermore, the integration of agriculture, hunting, forestry, and fishing sector (1) with service sector (16) can be deduced from the results of the additional 1.420,53 million dollars value added created in service sector.

If we look at the water consumption perspective, the results show that a 20% increase in the final demand for agriculture, hunting, forestry, and fishing sector (1) increases the water consumption of this sector by 10,9%. No significant increase is observed in other sectors. The increase in the amount of water consumption caused by the increase in final demand of this sector is 4.812,41 million m^3. Turkey needs to consume 4.897,88 million m^3 more water to meet the increase in final demand in this scenario analysis. As we can see, the amount of water needed to consume in agriculture, hunting, forestry, and fishing sector (1) accounts for 98,3% of total water needed to consume. The effect is direct again in terms of water consumption. The result reveals that the proportion of total change in water consumption resulting from the increase in final demand is 7,7%.

Table 3-7: Effects of 20% increase in final demand for agriculture, hunting, forestry, and fishing (1) and food, beverages, and tobacco products (3) sectors

No.	Sectors	Scenario 1(3) Water Consumption(1)	Scenario 1(3) Value Added (2)	Scenario 2(4) Water Consumption(1)	Scenario 2(4) Value Added (2)
1	Agriculture, hunting, forestry, and fishing	10,9%	4.873,18	5,9%	2.608,32
2	Mining and quarrying	2,2%	171,91	2,6%	200,69
3	Food, beverages, and tobacco products	0,6%	118,61	16,3%	3.146,43
4	Textiles, leather, and footwear	0,1%	24,91	0,2%	49,01
5	Wood and cork products	0,4%	6,80	0,6%	10,46
6	Paper products and printing	0,6%	31,70	2,0%	105,34
7	Coke and refined petroleum products	2,0%	63,54	1,9%	62,32
8	Manufacture of chemical and botanical products	2,0%	340,72	2,3%	407,76
9	Other non-metallic mineral products	0,2%	20,53	0,4%	40,37
10	Basic and fabricated metal products	0,2%	42,28	0,3%	86,12
11	Electrical equipment, machinery, motor vehicles, other transport equipment products	0,1%	38,85	0,2%	60,20
12	Manufacturing nec., repair and installation of machinery and equipment	0,2%	21,92	0,4%	43,13
13	Electricity and gas supply	0,4%	45,78	0,8%	86,69
14	Water supply	0,4%	24,92	0,5%	32,54
15	Construction	0,1%	37,62	0,1%	63,07
16	Services	0,3%	1.420,53	0,7%	2.811,27
	Total Changes in Economy	**7,7%**	**7.283,81**	**4,3%**	**9.813,70**

(1) Water consumption increases in percentage within the sector itself.

(2) Value added increases as an absolute value (million dollars) within the sector itself.

(3) The results of scenario analysis for agriculture, hunting, forestry, and fishing sector (1)

(4) The results of scenario analysis for food, beverages, and tobacco products sector (3)

Last but not least, a 20% increase in the final demand for agriculture, hunting, forestry, and fishing sector (1) results in a 7.283, 81 million dollars increase in total value added, while a 4.897,88 million m^3 increase in total water consumption. In other words, the amount of water that needs to be consumed per thousand dollars value added to meet the value added increase in the entire economy resulting from a 20% increase in the final demand is 672,4 m^3.

'Scenario 2' shows that a 20% increase in final demand for food, beverages, and tobacco products sector (3) ends up with additional 9.813,7 million dollars value added in the economy as a whole. This increase in final demand for food, beverages, and tobacco products sector (3) reveals the integrations of this sector with agriculture, hunting, forestry, and fishing (1) and service (16) sectors. By looking at this result, it can be seen that the 'drag effect' of this sector, which is the highest indirect water consumer, on which sector. This increase in final demand results in an additional value added of 3.146,43 million dollars, which corresponds to 32,1% of the total value added created in the economy as a whole, within the sector itself. The 20% increase in final demand for this sector results in an additional value added of 2.608,32 million dollars in agriculture, hunting, forestry, and fishing sector (1) and 2.811,27 million dollars in service sector (16) which account for 26,6% and 28,6% of total value added taken place after simulation, respectively. Compared to 'scenario 1', the results show that food, beverages, and tobacco products sector (3) has high integration with other sectors. Lastly, this increase in final demand leads to a 1,4% increase in value added compared to the value added before the simulation was performed.

Considering the water consumption of 'scenario 2', a 20% increase in final demand for food, beverages, and tobacco products (3) causes a 4,3% increase in water consumption in the economy as a whole. Total water consumption of this sector increases by 16,3% which constitutes only 0,3% of total water consumption in the economy. However, the 'drag effect' of the sector also comes out in the water consumption which shows the impact of this sector on other sectors. The proportional increase in the water consumption of agriculture, hunting, forestry, and fishing sector (1) resulting from the simulation is 5,9% which accounts for 94,1% of water consumption in the economy as a whole and the remaining change (5,6%) in the total water consumption comes from other sectors. As it can be seen that food, beverages, and tobacco product sector (3) has a strong 'drag effect' on agriculture, hunting, forestry, and fishing sector (1) in terms of water consumption. The 'drag effect' of this sector on the remaining sectors in terms of water can be said as moderate. However, mining and quarrying (2), manufacture of chemical and botanical products (8), paper products and printing (6), and coke and refined petroleum products (7) sectors, with the proportional increases of 2,6%, 2,3%, 2,0%, and 1,9%, respectively, within the sectors themselves, are the second, third, fourth and fifth mostly influenced by the simulation. Additionally, a 20% increase in the final demand for food, beverages, and tobacco products sector (3) results in a 9.813,7 million dollar increase in total value added, while a 2.737,93 million m^3 increase in total water consumption. In other words, the amount of water that needs to be consumed per thousand dollars value added to meet the value added increase in the entire economy resulting from a 20% increase in the final demand is 279 m^3. Although this amount is considerably less than the amount of 'scenario 2', 279 m^3 per thousand dollars is a significant amount compared to other simulation results. The other two scenarios that aren't included in the thesis can be a good example to show the pressures of agriculture, hunting, forestry, and fishing (1) and food, beverages, and tobacco products (3) sectors on water consumption. The first mentioned scenario performed on manufacturing nec., repair and installation of machinery and equipment (12), which is the lowest indirect water consumer sector per unit of output. The results come out that the amount of water that needs to be consumed per thousand dollars value added to meet the value added increase in the entire economy resulting from a 20% increase in the final demand is 40,6 m^3. In the other scenario performed in service sector (16). The results reveal that the amount of water consumption is 26,6 m^3 per thousand dollars.

With these results, it is seen that both high direct and indirect water consumer sectors have strong pressures on national water resources. The influence of high direct water consumer sectors exerts on themselves (direct) in terms of both water consumption and value added. However, the effect of high indirect water consumer sectors can be on several other sectors including themselves in terms of both water consumption and value added. Thus, policymakers should examine in detail these sectors to implement a policy when considering national water resources management.

CONCLUSION

Today, the pollution of water, the inefficient consumption of water resources in the sectors, and the increase in the water demand create a global, national and regional problem. Although Turkey doesn't face a big problem regarding the self-sufficiency of water resources today, it will inevitably face major problems in the coming years. It is vital for Turkey's water resources to diagnose the aforementioned problems and start treatment accordingly in advance.

In this thesis, EEIOA has been used for the economic planning of water resources in Turkey. One of the most important contributions of this thesis and the model is to quantify the water consumption relationship among all sectors in Turkey and in which sectors the pressure of production on water use plays a key role. This model allows for the production of more environmentally friendly policies by taking into account the excessive use of natural resources in production.

The distinction between direct and indirect water consumer sectors is vital to identify the sectors having the most pressure on water resources. As a result of the analysis, it has been observed that the agriculture, hunting, forestry, and fishing sector (1) has a high direct water consumption per unit of output (455,7m^3/1000$) and a high indirect water consumption per unit (178,69m^3/1000$). In addition, electricity and gas supply (13) is both high direct (131,09m^3/1000$) and indirect (192,22$m^3$/1000$) water consumer sector. On the other hand, Water supply sector (14) can only be classified as one of the highest direct water consumer sector with the value 452,88m^3/1000$. On the contrary, food, beverages, and tobacco products sector (3) is a high indirect (255,77m^3/1000$) and low direct water consumer sector (2,05m^3/1000$). Taking into account both high direct and indirect consumer sectors, thus, the above-mentioned sectors must be paid attention to for water management in Turkey since their high water demand. In general, it can be said that all industry (sectors from 3 to 12), construction (15), and service (16) sectors have characteristics of high indirect water consumption per unit produced and low direct water consumption but their coefficients remain low.

Another important result in the analysis is the water flow from agriculture, hunting, forestry, and fishing sector (1) to other manufacturing industry sectors (5, 7, 11, 12) especially food, beverages, and tobacco products (3). This result shows that these sectors are highly dependent on agriculture, hunting, forestry, and fishing sector's (1) productions and this dependency increases the water demand indirectly. Parallelly, construction sector (15) is the other highly dependent sector on agriculture, hunting, forestry, and fishing sector (1) in terms of water consumption. The water dependency of electrical equipment, machinery, motor vehicles, other transport equipment products sector (11) manufacturing nec., repair and installation of machinery and equipment (12) and construction (15) sectors on water supply (14) and electricity supply (13) sectors is also significant indicators for the Turkish economy.

Lastly, according to scenario analyses, an value added creation in the economy of the highest water consumer (agriculture, hunting, forestry, and fishing) and the lowest water consumer sector (food, beverages, and tobacco products) is lower compared to a water consumption increase when a 20% increase in final demand of these sectors. Thus, we can say that water productivity in these sectors is low.

When all the results are taken into account, it is observed that the agricultural sector is highly integrated with many sectors in the economy through its sales. Considering that the water consumption for irrigation purposes is so high too, traditional agricultural practices in Turkey must leave their place for modern agriculture as soon as possible, and modern irrigation systems are adopted. By doing so, both direct water consumption and indirect water consumption can be decreased.

Since we have a problem reaching accurate data for water consumption, data acquisition has a vital role. We believe that many arrangements should be made to reach accurate data in this area. First, all water consumption data should be classified according to Nace or ISIC codes and published in a data set of a statistical institute such as

TURKSTAT and DSI, etc. Because, in the process of gathering the data, different data sets can be misleading for the analysis. Even if the total aggregate water consumption can be equal in all data sets, sub-totals and their meaning are different. For example, one data can consist of the water data which specifies the water consumed only for cooling purposes or one data can consist of only surface water. Thus, the integrity of the data must be ensured. Second, construction and service sectors' water data should be calculated. The absence of these data causes only estimated results to be obtained. Third, metadata descriptions need to be comprehensive and industrial classification should be detailed under metadata. Another classification in which we face a problem is the types of water. The data should be collected from both surface and groundwater. Considering all the above-mentioned challenges, it is compulsory to establish 'National Water Information System' that facilitates access to all water data and to standardize the data.

As we deduced from our analysis, irrigation (agricultural water consumption) is the most important element that should be prepared in emergency action plans. Since the water potential of Turkey varies from basin to basin, the product pattern should be determined according to the basin water potential and other variables. Emergency action plans in irrigation should be prepared on a basin basis, not on a national basis. Farmers should be made aware of water consumption, they should receive training on this issue and the lands they cultivate should be regularly inspected. As it can be applied in all sectors of the economy, full cost-based water and wastewater pricing should be made and gradual tariffs should be applied to farmers to reduce their water consumption. Farmers using traditional irrigation methods should be encouraged to switch to modern irrigation methods, and if necessary, new government-supported financing models should be developed to switch their irrigation system. In addition to these ones, rainwater (green water) collection systems should be built for agricultural irrigation and the water collected in these systems should be actively used in crop cultivation. Because when we look at the water consumption patterns of the crops grown in Turkey, it is observed that the use of blue water is considerably higher than green water. The free use of groundwater, especially in agricultural irrigation, is quite high compared to other sectors. It is important to prevent and record the use of these waters through regular inspections. For the sustainability of groundwater resources, the aforementioned pricing system should be implemented to prevent wastage in water use. It is a fact that the lands to be opened for agricultural production in the world have reached the final limit and it is not possible to open new agricultural areas. For this reason, efficient use of existing agricultural lands without damaging water resources is the most important option in terms of agricultural productivity and food security. Since Turkey has limited water, soil and plant diversity in its geography, it should pay attention to this sensitive structure, analyze the requirements and manage water and agricultural production well.

It is a known fact that a significant part of the water taken from the source is lost until it reaches the receiver. For this reason, municipalities need to work to reduce the loss. In addition to this, inspections should be carried out in order to prevent the free use of groundwater for uses such as industry in the regions where water service is provided by the municipalities.

As known, water efficiency does not aim to limit water, but to prevent and reduce waste or maximize the benefit of water use. Thus, green and grey water consumption should be increased in all kinds of production and areas. It is important to give priority to the use of gray water in urban transformation areas and organized industrial zones. Studies should be started to increase awareness of the use of gray water and gray water use should be prioritized in places such as shopping malls, stadiums and large public buildings where water use is intense.

Lastly, Activities should be organized to increase the literacy of all segments of society about water, meteorology and climate change. In particular, people living in urban areas should be made aware of urban water use and domestic water consumption, while people living in rural areas should be made aware of modern irrigation methods and they should be encouraged to use high technology products in their own production.

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APPENDIX

Appendix-1: ISIC REV 4 classifications of aggregated sectors

ISIC REV 4 INDUSTRY CODES	SECTIONS	AGGREGATED SECTORS
D01-D02-D03	A	Agriculture, hunting, forestry and fishing
D05-D06-D07-D08-D09	B	Mining and quarrying
D10-D11-D12	C	Food, beverages and tobacco products
D13-D14-D15		Textiles, leather and footwear
D16		Wood and cork products
D17-D18		Paper products and printing
D19		Coke and refined petroleum products
D20-D21-D22		Manufacture of chemical and botanical products
D23		Other non-metallic mineral products
D24-D25		Basic and fabricated metal products
D26-D27-D28-D29-D30		Electrical equipment, machinery, motor vehicles, other transport equipment products
D31-D32-D33		Manufacturing nec., repair and installation of machinery and equipment
D35	D	Electricity and gas supply
D36-D37-D38-D39	E	Water supply
D41-D42-D43	F	Construction
from D45 to D98	G, H, I, K, L, M, N, O, P, Q, R, S, T	Services

Appendix-2: Volume Conversion

Cubic Meter (m^3)	Cubic Kilometer/Gigameter (Km^3/Gm^3)	US Gallon (Gl)
1	0,000000001	264
1.000.000.000	1	264.000.000.000
0,003785412	3.785.412	1