WATER SECURITY INDEX FOR FOUR NEIGHBOUR CITIES IN THE AEGEAN REGION INCORPORATING FUTURE CHALLENGES

by

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ABSTRACT

WATER SECURITY INDEX FOR FOUR NEIGHBOUR CITIES IN THE AEGEAN REGION INCORPORATING FUTURE CHALLENGES

Water security has been a global issue since accessing clean water is a challenge for poorer communities. This problem is becoming even more complex as water resources continue to deplete. Climate change and population growth should now also be taken into consideration in water planning, since unstable weather conditions and increasing demands of the population would make it harder to predict future water supply levels. In this study, a water security index for the 4 neighbour provinces in the Aegean region (Aydın, Denizli, Muğla and Uşak) is developed through the adoption of Pressure-State-Response (PSR) method, which is based on the cause-effect relations between human activities and the environment. Baseline index calculations show that the study area's water resources are currently in "poor conditions", whereas the current water security of the region is in "medium conditions". Integration of climate change scenarios (RCP8.5 and RCP4.5) and population growth projections into baseline results do not alter the baseline conditions, yet when combined, they substantially pull the water security level of the area of interest down. Sole effect of RCP8.5 scenario on the water resources of the 4 cities as a whole is also significant.

ÖZET

EGE BÖLGESİ'NDEKİ DÖRT KOMŞU İL İÇİN SU GÜVENLİĞİ ENDEKSİ: BÖLGENİN GÜNCEL DURUMU VE GELECEK SENARYOLARININ ETKİLERİNİN DEĞERLENDİRİLMESİ

Su güvenliği, görece fakir toplumların temiz suya erişimde yaşadığı zorluk göz önünde bulundurulduğunda, küresel bir problem olarak karşımıza çıkmaktadır. Bu problem, su kaynaklarının azalmaya devam etmesiyle birlikte daha da karmaşık bir hal almaktadır. Bu noktada, yapılan su planlamalarında iklim değişikliğinin ve nüfus artışının da dikkate alınması gerekmektedir, çünkü istikrarsız hava koşulları ve artan nüfusun beraberinde getirdiği talep artışı, gelecekteki su arzı miktarlarının öngörülmesini zorlaştırmaktadır. Bu tez çalışmasında, insan faaliyetleri ve çevre arasındaki neden-sonuç ilişkilerine dayanan Baskı-Durum-Tepki (PSR) metodu kullanılarak, Ege Bölgesi'nde yer alan 4 komşu il (Aydın, Denizli, Muğla ve Uşak) için bir su güvenliği endeksi oluşturulmuştur. Geçmiş yılların verisi kullanılarak yapılan hesaplamalara göre, çalışma alanının su kaynaklarının mevcut durumda "zayıf koşullar" altında olduğu ortaya çıkmış, bölgedeki su güvenliğinin şu anki durumunun ise "ortalama koşullar" altında olduğu saptanmıştır. RCP8.5 ve RCP 4.5 iklim değişikliği senaryoları ve nüfus artışı tahminlerinin mevcut durum sonuçlarına entegre edilmesi ise mevcut durum sonuçlarını değiştirmemiş, ancak yine de iklim değişikliği senaryoları ve nüfus artışı tahminlerinin çalışma alanının su güvenliği üzerindeki birleşik etkisi değerlendirildiğinde, endeks sonucunun kayda değer miktarda aşağı çekildiği gözlenmiştir. Bir yandan, RCP8.5 iklim değişikliği senaryosunun 4 komşu ilin su kaynakları üzerinde tek başına yarattığı etkinin de önemli derecede olduğu ortaya çıkmıştır.

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LIST OF SYMBOLS/ABBREVIATIONS

Symbol	**Explanation**	**Unit**
°C	Celsius	
i	Monthly Heat Index	
I	Annual Heat Index	
NH_4^+	Ammonium	mg/L
NO_2^-	Nitrite	mg/L
NO_3^-	Nitrate	mg/L
°K	Kelvin	
α	Calibration Constant	

Abbreviation	**Explanation**
Agr.	Agricultural
AI	Aridity Index
Avg.	Average
AWPI	Agricultural Water Poverty Index
BOD	Biological Oxygen Demand
CORDEX	Coordinated Regional Climate Downscaling Experiment
CV	Coefficient of Variation
DPSIR	Driver-Pressure-State-Impact-Response
E	Evaporation
EU	European Union
FAO	Food and Agriculture Organization
GCM	Global Climate Model
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GWP	Global Water Partnership
HH	Household
ICTP	International Centre for Theoretical Physics
LT	Long Term
MAM	Marmara Research Center
MENA	Middle East and North Africa

NCCARF	National Climate Change Adaptation Research Facility
NCEP	National Center for Environmental Prediction
OECD	Organisation for Economic Co-operation and Development
P	Precipitation
PET	Potential Evapotranspiration
PhD	Doctor of Philosophy
PSR	Pressure State Response
Q	Streamflow
RCP	Representative Concentration Pathway
S	Storage
SKKY	Su Kirliliği Kontrolü Yönetmeliği
TL	Turkish Lira
TURKSTAT	Turkish Statistical Institute
TÜİK	Turkish Statistical Institute
UN	United Nations
UNICEF	United Nations International Children's Emergency Fund
WB	Water Budget
WCI	Water Crowding Index
WHO	World Health Organization
WPI	Water Poverty Index
WQ	Water Quality
WSI	Water Stress Index
WW	Waste Water
WWF	World Wide Fund for Nature
WWTP	Waste Water Treatment Plant

1. INTRODUCTION

It is now evident that most of our planet's water resources are under the threat of becoming scarce, due to rapidly increasing population, undergoing industrialization and economic growth, as well as climate change. While economic growth and industrial activities force the pace of climate change, accelerating needs of the increasing population exert even more pressure on water resources of our planet. The effects of climate change upon water bodies make future water quantities less predictable due to changing precipitation patterns and occurrence of extreme weather events. Easterling et al. (2000) give extreme daily temperatures (very low or very high), or heavy monthly or daily rainfall amounts that occur on a yearly basis, and more complex event driven extremes such as drought, floods or hurricanes which have ambiguous time and location, as examples of climate extremes. In addition to that unfavourable outlook, environmentally harmful production activities and excessive use of fertilizers and pesticides in the agricultural sector jeopardize water quality levels, thus rendering clean water less accessible. Edoardo Mansur, the Director of FAO's Land and Water Division claimed that the share of agricultural pollution in the degradation of inland and coastal waters has surpassed the contamination coming from settlements and industries. Water bodies will be affected more from agricultural pollution as food production will continue to go up in order to meet the growth in demand. As a result, access to clean water will become even harder in the future as population will continue to rise, while water resources remain finite.

Access to clean water has already been a globally widespread issue that needs great efforts to be overcome. Even though 1.4 billion people gained access to basic sanitation, and percentage of global population that uses safely managed drinking water services increased approximately by 10% between 2000 and 2015, 2.3 billion people still lacked a basic sanitation service, and 28.84% of the world still has no access to safe drinking water in 2017 (WHO/UNICEF, 2017). These facts point to the problem of "water security", which UN defines as:

"*The capacity of a population to safeguard sustainable access to adequate quantities of acceptable quality water for sustaining livelihoods, human well-being, and socio-economic development, for ensuring protection against water-borne pollution and water-related disasters, and for preserving ecosystems in a climate of peace and political stability." (2013, p.1).*

This definition is quite inclusive since it has a broad view relative to other definitions that exist in literature. Some other definitions that take place within the literature will be discussed in detail in Section 2. Yet, UN’s definition, which is also the most widely accepted one in the previous work regarding water security, will be adopted in this work.

It is a challenge for water managers to make efficient water allocation decisions. Decreasing supplies, increasing demands, deteriorating water qualities and adverse effects of climate change worsen the situation by increasing the pressure on decision-makers. Thereby, it is necessary to replace fragmented water management schemes with holistic ones. In other words, social, economic and environmental consequences of policies must be considered all together in order to have an interdisciplinary approach to water management. Indicators and indices are great tools that shed light on integrated water management practices. Dickson (2016) claims that indices and indicators are useful in the sense that they simplify complex realities into a single measurement, and they can be useful to bridge science-policy and science-society gaps. These tools make it easier to simultaneously evaluate social, economic and environmental statuses of a specific region. Moreover, trends of those statuses can be observed by simply looking at the changes of index or indicator values over time. Furthermore, different future scenarios like precipitation projections and change in population growth rates can be applied to these gauges to see whether water resources and communities benefiting from those reserves will be under risk. It is not certain whether the water resources of a catchment will remain in adequate levels to maintain the ecosystem health and to continue to feed the population if the effects of climate change and population growth are taken into consideration. Indicators and indices are crucial in the sense that they reveal existing and potential risks at different dimensions so that water policies and decisions related to water management can be prioritized and arranged accordingly.

The purpose of this thesis is to introduce a water security index comprised of several indicators for 4 neighbour cities in the Aegean region (Aydın, Denizli, Muğla and Uşak), which are located in the Western part of Turkey. These 4 cities constitute a major part of the Büyük Menderes River Basin, whose water resources are said to be fragile against climate change, although there is no water budget deficit yet. In this regard, estimation of the effects of potential future changes on this area is crucial and this is why these 4 neighbour cities are selected in this work. Büyük Menderes River Basin area could not be selected as a total due to data availability.

The primary problem of the region is water pollution, resulting from intense industrial production – especially stemming from the textile and leather industries, which the economy of the region is heavily dependent on (Büke et al., 2013). Heavy fertilizer use in agriculture is also a major contributor to the water pollution in the area. When the problems of climate change and population growth are brought to the scene, the water security challenge of the region is exacerbated. Also, developing an index that shows the imperilment of the water resources of a particular area perfectly suits for conducting research on such problems. Development of an index is a promoted tool when dealing with plenty of data coming from a variety of sources, since it has the advantages of handling existing data in the calculation process and the calculations being simple (Sullivan et al., 2008). According to OECD (1993), the following criteria should be fulfilled in the development process of an ideal environmental indicator:

Policy relevance and utility for users. An indicator should provide a representative picture of environmental conditions, pressures on the environment or society's responses; be simple, easy to interpret and able to show trends over time; be responsive to changes in the environment and related human activities; provide a basis for international comparisons; be either national in scope or applicable to regional environmental issues of national significance; have a threshold or reference value against which to compare it so that users are able to assess the significance of the values associated with it,

Analytical soundness. An indicator should be theoretically well-founded in technical and scientific terms; be based on international standards and international consensus about its validity; lend itself to being linked to economic models, forecasting and information systems,

Measurability. The data required to support the indicator should be readily available or made available at a reasonable cost/benefit ratio; adequately documented and of known quality; updated at regular intervals in accordance with reliable procedures.

In this thesis, Pressure-State-Response (PSR) methodology is used as the main tool in the generation of the indicators that form the structure of the index which reveals current water quality and quantity statuses and economic, demographic and social conditions and capacities of the region regarding water security and sustainability. The calculation process includes 2 steps: first, baseline values (past data) is incorporated into the structure of the index, and second, future scenarios (climate and population projections) are applied to the baseline conditions in order to discover the actual risk that the 4 neighbour provinces' water resources face. Section 2 briefly introduces literature review of water security, indices of water security and the "Pressure-State-Response" framework which is the main methodology adopted in this study. Study area (Aydın, Denizli, Muğla and Uşak) accompanied with recent works focusing on the main problems of the Büyük Menderes River Basin is shared in detail in Section 3. Integration of the PSR method into index formation, with a detailed explanation regarding the calculation process of each pressure-state-response variable for each indicator for the baseline scenario is also introduced in Section 3. Section 4 gives elaborative information about overall index results and analysis of baseline and future scenarios. Lastly, Section 5 entails the discussion of the challenges faced during this study and possible future studies, as well as the current and future challenges of the study area.

2. LITERATURE REVIEW

2.1. Water Security

Apart from the well-accepted definition of water security presented by UN, there has been an improvement in the approach to water security since the 90s. According to Cook and Bakker (2012), there was no use of the term "water security" in literature in 1990, however, the number of articles regarding water security rose exponentially within the following two decades and reached to 25 in 2010. Srinivasan et al. (2017) suggest that the nonexistence of an absolute definition of water security results in different framings, thus injecting a dynamism in the concept. In their analysis, Cook and Bakker (2012) found out that 4 complementing themes stand out in water security research: water availability, human vulnerability to water related hazards, human needs and sustainability. In another study, Mukhtarov and Cherp (2015) assert that prominent water security definitions back in the 1990s focused only on the quality and quality of water supply for humans and economic development, however, the functioning of the biosphere has been attached as an additional necessity to the basis of human well-being more recently. Therefore, water security definitions have evolved towards the scope of "water-food-energy nexus" with an emphasis on the connections between these 3 resources. Asian Development Bank (2016) also claims that water security is beyond enabling people and industries to reach sufficient quantities of water, and environmental health but preventing water related disasters should also be taken into account while defining water security. Another point of view is seen in Grey and Sadoff (2007), mentioning that water security has 3 main scales: the hydrologic environment itself (physical amount of water and its inter-annual and intra-annual variability), socio-economic environment (structure of the economy and how do its actors behave) and climate change (future factor). In this work, UN's approach to water security which is mentioned above is adopted, since it embodies sustained water qualities and quantities, human well-being, socio-economic environment and the capacity of population as main elements while enabling the incorporation of potential future changes into those, which makes it the most comprehensive definition among the various others presented. Another popular definition of water security which is similar to UN's is that of Global Water Partnership's (GWP):

"*Water security, at any level from the household to the global, means that every person has access to enough safe water at affordable cost to lead a clean, healthy and productive life, while ensuring that the natural environment is protected and enhanced" (2000, p.12).*

Unfortunately, access to clean water is not distributed equally throughout the world and water security has not been ensured at a global level. What is worse, Vörösmarty et al. (2010) find out that approximately 80% of the global population are actually exposed to high levels of risk in relation to water security in their work that is a pioneer in combining the human and biodiversity components of water security at a global level. In the same study, they emphasize the spatial connectedness of river systems across the world, and claim that human activities taking place in one location can lead to water insecurity in different regions. This means that the problem of water security can only be mitigated through global co-operative endeavors.

In more recent studies like Gunda et al. (2019), the importance of grounding water security on quality-quantity-society nexus is underlined. Future research on water security and water management practices necessitate the integration of these 3 elements in order to understand the trade-offs that they create in between. James and Shaifee-Jood (2017) also emphasize the need for interdisciplinary information in the assessment of water security. They claim that strong observations and data collection is needed in all of the following dimensions, in order to maintain water security: hydrological, engineering, economic, financial, environmental, social, political and legal.

2.2. Water Security Indices

There are many studies in literature that include index development for the measurement of water security. It is obvious that water security is a developing concept itself, so, indices in relation to it must also be in a similar progress. Literature shows us that first, it was water scarcity rather than water security that was scrutinized in the evaluation of the relationship between human needs and environmental limits. One of the earliest attempts to understand water scarcity was the Falkenmark Water Stress Index (Falkenmark et al., 1989). This measure, which is basically the annual renewable freshwater available per capita, is quite popular in literature. Water Resources Vulnerability Index (Raskin et al., 1997) defined as the ratio of total annual withdrawals to available water resources, was another attempt to measure water withdrawals. However, Srinivasan et al. (2017) criticizes these two approaches because of only accounting “physical water scarcity” and not including capacity constraints like inadequacies in water infrastructure. Water Poverty Index, developed by Sullivan (2002) goes one step further and adds the economic component to the indices mentioned above.

Nevertheless, none of these three well-accepted indices account for the ecosystem health. Instead, they are gauges only for the development of water resources to meet human needs (Srinivasan et al., 2017). Environmental sustainability and societal capacity should also be included in the structure of water security related indices in order to attain an extensive overview of the current situation of water resources regarding the area of interest. In that sense, "Watershed Sustainability Index" introduced by Chaves and Alipaz (2007) is more integrative since it is based on hydrological, environmental, life and water policy issues and responses. Chaves and Alipaz also use the Pressure-State-Response methodology as a tool for index development. Water security index regarding the 4 neighbour cities in the Aegean region which will be introduced below also leans upon the same methodology, which will be discussed in detail in the following section.

2.3. Pressure-State-Response Method

Previous studies show that the Pressure State Response (PSR) concept was firstly introduced by OECD (1993) as a framework that is established on cause-effect relationships: human activities create pressures on environmental resources, altering their quality and quantity, and society responds to these changes through environmental, economic and sectoral policies. In short, *pressure* variables represent human activities that affect environmental resources, *state* variables stand for the current quality and the quantity of the natural resources and the *response* variables are accepted as the responses of the society to the changes occurring in natural ecosystems through environmental, economic and sectoral policies within the PSR model. In a more recent article published by OECD (2003), it is mentioned that by underlining cause-effect relationships, PSR method is advantageous in the sense that it helps decision makers and the public see environmental, economic and governmental issues are co-dependent. After the introduction of this method by OECD, the PSR method is widely used by the academicians as well.

Firstly, Walmsley (2002) refer to the PSR methodology as a physical environment framework, which tends to favor strong sustainability (i.e. the idea that natural resources and environmental services cannot be replaced by economic production). In this study, physical framework is introduced as systematic and useful for organizing data from a variety of sources. The PSR framework is illustrated in this work of Walmsley as follows (Figure 2.1):

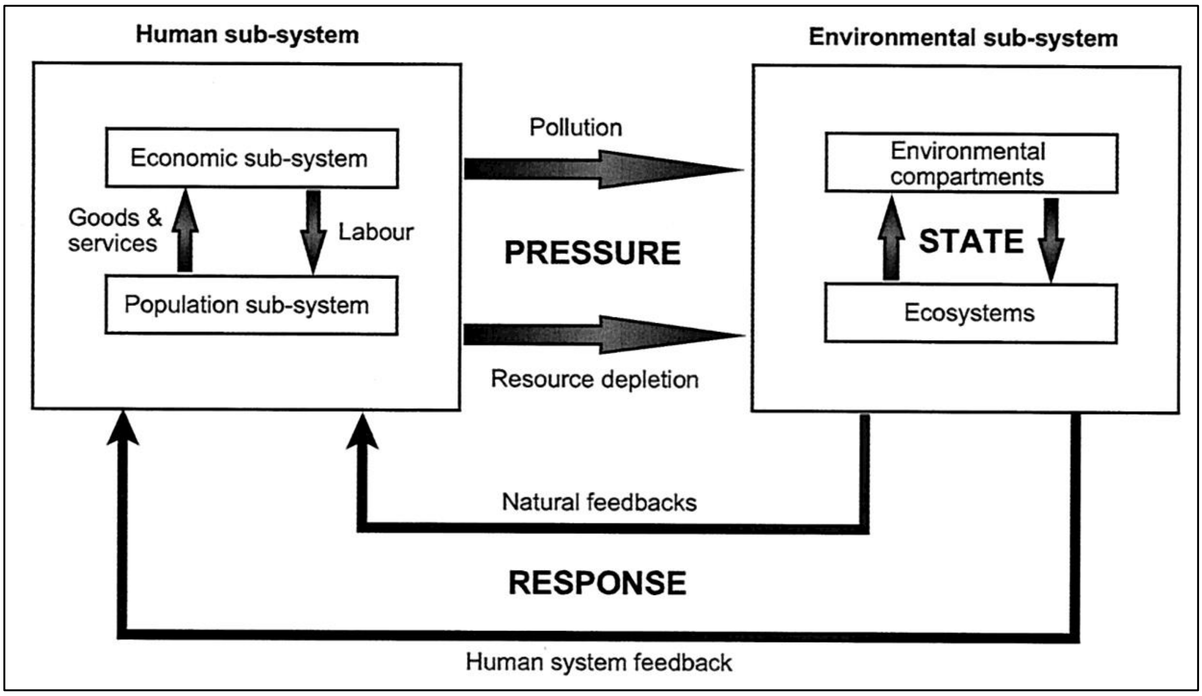

Figure 2.1. PSR framework illustrated by Walmsley (2002).

Walmsley (2002) gives emissions, consumption and utilization as examples for pressure indicators, defines the condition of the resource or ecosystem as state indicators, and puts laws, policies, programs and research in the category of response indicators. Chung and Lee (2009) also adopt the PSR framework as a multi criteria decision making technique for sustainability assessment around which indicators and indices can be organized. By the help of different multi-criteria decision making techniques (i.e. various computer programming methods) and a sustainability evaluation model, Chung and Lee (2009) assess the hydrologic vulnerability with the “watershed evaluation index”, which basically numerically integrates factors like potential flood damage, potential streamflow depletion and potential water quality deterioration. PSR method is important here in the sense that it is helpful in the selection of sustainability criteria. In another study regarding the calculation of a watershed sustainability index for a basin area in Brazil, Chaves and Alipaz (2007) use the same methodology since it has an advantage of embodying cause-effect relationships. In their endeavor to enhance the Water Poverty Index (WPI), which was originally introduced by Sullivan (2002), Perez-Foguet and Gine (2011) also embark on PSR model as a multi-dimensional water poverty assessment tool. They categorize the pressure variables as the pressures exerted on the environment (or simply water resources), which includes both human activities, development trends, as well as the existence of environmental conflicts. State variables are classified as the gauges for water quality and quantity, plus the existing capacities for water management. Response variables reflect actions to reverse environmental damage, to prevent adverse effects of human activities on the environment and conserving water resources, at individual and societal levels. These variables are then used to form the 5 components, named as resource, use, access, capacity and environment, which in turn constitute the overall index: eWPI (enhanced Water Poverty Index). This index is then applied to the Jequetepeque Basin in Peru.

The use of PSR framework in literature is not just limited to watersheds, it is a well-accepted framework in a variety of works on sustainability and environmental evaluation. Susi-Wolff (2010) makes benefit of the PSR framework to understand the changing city culture and heritage through different park conservation projects have taken place in Finland. Levrel et al. (2009) utilize the PSR methodology in their analysis of the sustainability of biodiversity in the Ushant Brittery Island, located in western France. Wolfslehner and Vacik (2008) make use of PSR method for the evaluation of sustainable forest management. Lu et al. (2016) integrate future land use scenarios with the PSR framework in the assessment of landscape ecological security in Huangshan City of China.

Pressure State Response method also enables the interpolation of different future scenarios within index measurements, like the impacts of climate change on current states of environmental resources. This is another reason why a lot of scholars prefer this method in environmental literature. An extension of the PSR methodology is the "'Driver-Pressure-State-Impact-Response" (DPSIR) strategy, adopted by Jun et al. (2011) in the development of their spatial water resource vulnerability index considering climate change impacts. They use the DPSIR method for the determination of indicators that they in turn use to assess water quality deterioration, potential flood damage and drought risk that climate change brings along. In this work of theirs, Jun et al. (2011) criticize Chaves and Alipaz's (2007) and Chung and Lee's (2009a) aforementioned works for not considering the effects of climate change in their PSR structures, and for not developing basin specific environmental and water scarcity indices. Robert and Herbert (2001) are also among the promoters of the PSR framework from the perspective that this methodology breaks the unilateral causality of climate change and development, and compounds socio-economic development and environmental change in an integrative style. The work of Sullivan and Byambaa (2013) on Climate Vulnerability Index is among the studies which combine future climate scenarios with the PSR methodology. They apply future scenarios to the baseline (current) condition assessments in order to estimate the effects of potential future changes on Mongolia's water resources, and underline that policy decisions can depend both on past information and future expectations.

Although there are many advantages of using the PSR methodology, it has some deficiencies and thus criticized by some scholars. Rao and Rogers (2006) claim that the PSR framework finds support for enabling a systematic identification of variables to define indicators, but they criticize it for not addressing the integration of those into a single index. PSR framework is also criticized for suggesting only linear relationships between human activities and the environment, thus being unsuccessful in addressing system complexity (Wolfslehner and Vacik, 2008).

Previous works mentioned above prove that PSR framework is well-integrated in the environmental literature, however, only a number of those studies take the effects of climate change into account, and there is hardly any work that blends future scenarios into an index through the usage of pressure, state and response variables, which would be helpful in the development of indicators for sustainability. In one study, Hanasaki et al. (2012) analyses different climate change scenarios through the application of future values into an index with an aim of assessing the change in water scarcity, however, they do not use the pressure-state-response framework as a tool. In another work of Raskin et al. (1997), demographic and economic projections, future consumption and production estimations in developing countries, potential technological improvements and absence of major policy changes that have an impact on water use are incorporated into indices such as coefficient of variation of precipitation, storage-to-flow ratio and socioeconomic coping capacity index, all of which facilitate an analysis of future water vulnerability levels. Raskin and his colleagues' (1997) work did not utilize the PSR framework. In that regard, this thesis project is an attempt to fill this gap since it places the PSR methodology on index development while also enabling the assessment of potential future changes.

3. METHODOLOGY

3.1. Study Area

Study area is Turkey's Western part, where the 4 neighbour cities (Aydın, Denizli, Muğla and Uşak) within the Aegean region are located. The area of focus covers more than 80% of the Büyük Menderes River Basin area (Table 3.1), where Büyük Menderes River and its 3 major contributors (Çine, Akçay and Çürüksu rivers) are present.

Table 3.1. Provinces of the region of study and their areas within Büyük Menderes Basin (TÜBİTAK MAM ÇE, 2010).

Provinces	Total Area (ha)	Area of the province within B. Menderes Basin (ha)	Proportion of the province area within B. Menderes Basin (%)	Distribution of B. Menderes Basin by provinces
Aydın	800700	761548	95,11	29,28
Denizli	1186800	834602	70,32	32,09
Muğla	1253800	247118	19,71	9,50
Uşak	534100	362512	67,87	13,94
Total	3775400	2205780	-	84,81

Table 3.1 shows that the area of study covers a total of 3775400 ha (37754 km^2) which is the addition of the total areas of the 4 provinces (Aydın, Denizli, Muğla, Uşak). Boundaries of the Büyük Menderes River Basin (light blue line) as well as the provincial borders of Aydın, Denizli, Muğla and Uşak are shown in Figure (3.1). According to TÜİK's data, in Aydın, the population density is 137,67 people per km^2 as of 2017. Population densities of Denizli, Muğla and Uşak are 87,13 people per km^2, 73,05 people per km^2 and 68,33 people per km^2, respectively. In that sense, the most crowded city of the area of study is Aydın, since Turkey as a whole has a population density of 105 people/km^2 as of 2017.

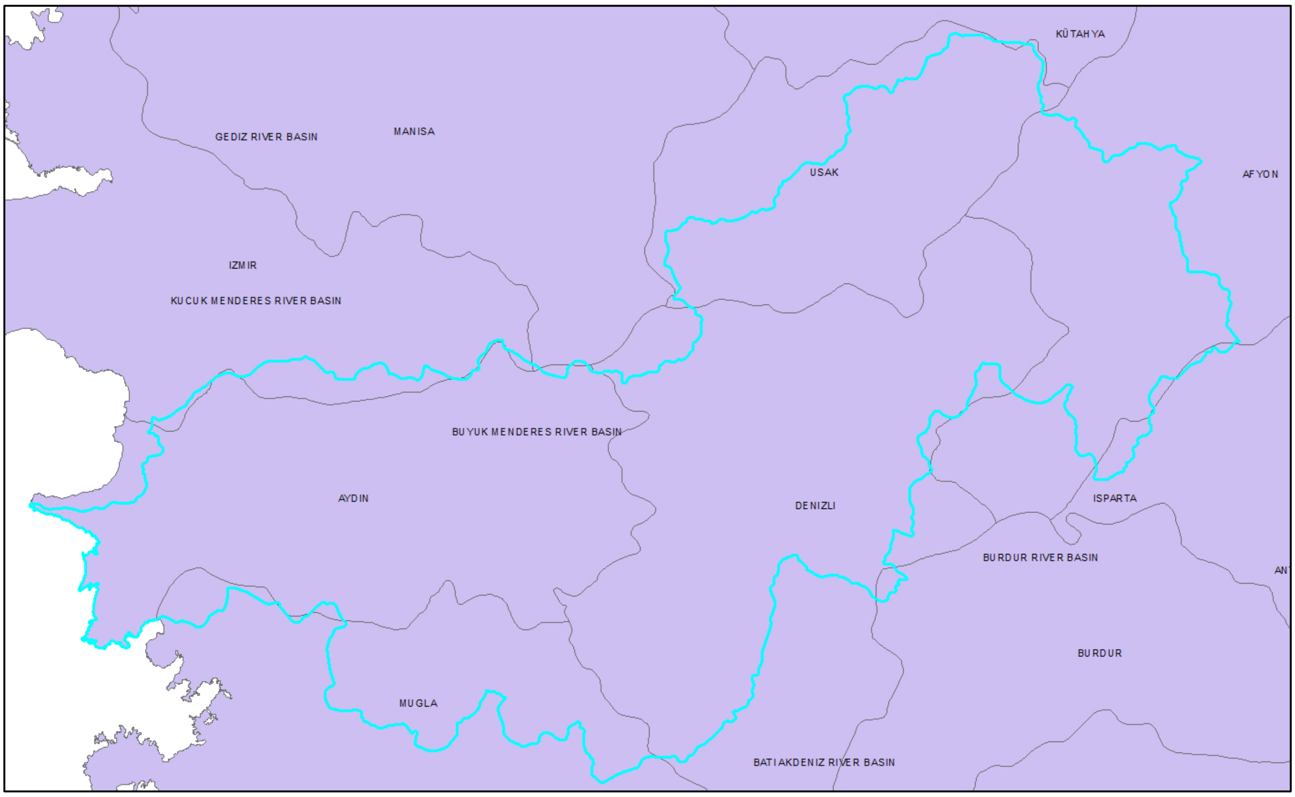

Figure 3.1. Büyük Menderes Basin area and the provincial borders of Aydın, Denizli, Muğla and Uşak.

A great percentage (79%) of Büyük Menderes Basin's water resources is used for agricultural activities taking place within the area of study, whereas the remaining 21% is used for domestic and industrial purposes (Büke et al., 2013). In the same study, it is mentioned that agricultural and industrial activities taking place within the region are great contributors to Turkey's economy, with nearly half of the Büyük Menderes Basin area is used for agriculture. According to the findings of Büke et al. (2013), Denizli province, which provides 80% of the basin's exports, outstands as the 8th largest city in Turkey's export ranking.

Climate of the region is diverse, allowing a variety of crops to grow, thus making the study area one of the most productive agricultural regions of Turkey. Interior provinces (Uşak and Denizli) are more arid than the coastal provinces (Aydın and Muğla), and the weather conditions in interior parts are closer to continental climate (hot summers and cold winters). Climate in coastal parts show the properties of Mediterranean climate, where the summers are usually hot and dry. More than 70% of the total annual precipitation falls between November and May in the high flow season, and less than 30% of the total falls from June to October (Durdu, 2009). In summer months, evaporation may exceed precipitation, causing runoff to stop. Large and fertile agricultural lands of the region give water resources the top role when it comes to the development of the region (Özonat, 2013).

According to Turkish State Meteorological Service (2011), Aydın's long term annual total average rainfall is 618,4 mm, while the city's long term average temperature is 17,6 °C, with an increasing trend. In Aydın, the warming effect of the sea and the winds that bring precipitation reach the interior parts because the Büyük Menderes valley is a channel that opens towards the coast. Denizli and Uşak's climatic properties show a mixture of Mediterranean and continental climates (Töz et al., 2009; Atasoy, 2018). Muğla shows the properties of typical Mediterranean climate (Topay, 2007). The region of study outstands with its agro-business, especially in cotton, fig and grape production. Furthermore, vast cultivation of water demanding crops (cotton, fig and some grains) leads to overexploitation of water resources, including groundwater. When overexploitation coincides with long dry periods, water balance is substantially disrupted. Therefore, water resources must be used efficiently to sustain agricultural practices that make a significant contribution to the region's and Turkey's economy.

Other than the differences between the climatic properties of Aydın, Denizli, Muğla and Uşak, there are some remarkable distinctions between the socioeconomic statuses of these four neighbour cities. In this study, the most deterministic factors of socio-economic well-being are accepted as education and income. TÜİK's data regarding education (illiteracy rates, number of people that are not illiterate but did not finish any school and faculty or higher education graduates) implies that Uşak lags behind the other 3 provinces in education. In all provinces, illiteracy rates are below Turkey's average. However, Uşak has the highest number of illiterates among the provinces of interest as of 2017. In addition, in Aydın, Muğla and Turkey in general, number of people that are not illiterate but did not finish any school has decreased between 2008 and 2017, nevertheless, in Denizli and Uşak, it has increased. As of 2017, Uşak has the highest percentage of people that are not illiterate but did not finish any school. Another proof of Uşak is lagging behind Aydın, Denizli and Muğla in education is that the percentage of faculty or higher education graduates in all provinces of interest except Uşak are higher than Turkey's average. Uşak has the lowest percentage of faculty or higher education graduates with 12,3%. On the other hand, income data of TÜİK reveals that Aydın had the lowest GDP per capita of 19121 TL (approximately 1593,42 TL per month), and Muğla had the highest with 27061 TL (approximately 2255,08 TL per month), whereas Turkey as a whole had a GDP per capita of 26489 TL (about 2207,42 TL per month), as of 2014. Lastly, in the 2011 survey of development levels of national provinces and regions, the Ministry of Development (2013) has put Muğla in the 1st (highest) category of developed cities, whereas Denizli and Aydın fall into the 2nd category of developed cities, and Uşak is situated in the 3rd category, out of a total of 6 ranking categories that are based on gauges in relation with demography, demployment, education, health, competitive and innovative capacity, finance, transportation and life quality, including a total of 61 indicators.

There are not many extensive works for the 4 provinces of interest. However, the literature on Büyük Menderes River Basin is not dense but growing, and these works that are mentioned below were quite helpful for the development of the water security index for Aydın, Denizli, Muğla and Uşak. Büke et al. (2013) is one of the most detailed and comprehensive investigations regarding the basin area and its water resources. In this study, which is actually a joint work of WWF-Turkey and Ege Derneği, Büke et al. (2013) refer to many aspects of the area, including the political, social and economic history, geographical properties, socioeconomic conditions, water quality and quantity, problems in relation to water quality, as well as sectoral uses of water resources and contributions of those to the national economy. Another extensive study for the region was conducted by the Ministry of Forest and Water Affairs of Turkey (2016), which contains highly valuable information about Büyük Menderes River Basin’s water resources and its uses, wastewater sources and quantities, water potential and water budget, and analysis of the effects of climate change on the water resources of the basin through future projections until the year 2100 made with hydrogeological models such as CNRM-CM5.1, MPI-ESM-MR and HadGEM2-ES. Sütgibi (2015) also analyses flow-climate relations within Büyük Menderes River Basin, between the years 1990 and 2011. Results show that there is a statistically significant upward trend in the basin’s temperature within the study period, and there is no statistically significant upward or downward trend in precipitation levels. However, it is also observed that arid and humid periods with unequal lengths follow each other, although there is no striking change in rainfall amounts. Sütgibi (2015) emphasizes that there is no doubt that these changing trends in temperature and arid and humid periods will have an effect on agricultural practices within the region. A recent study of Ministry of Environment and Urban Planning conducted in 2016 is also elaborative since detailed information about the current statuses of basin’s water resources and usages of those, wastewater treatment infrastructure, point and non-point pollution loads, and the pressure factors within the region is presented through graphs and various data. Observations of this study reveal that basin’s water resources suffer the most from ammonium nitrogen, nitrite nitrogen and chemical oxygen demand, which cause the water quality in many regions of the basin to drop to 4th class. Class IV is the worst water quality level, according to Turkish standards (SKKY, Resmi Gazete, 2004). It is also underscored in the same work that intensifying industrial activity and large scaled agriculture are the biggest contributors to point and non-point pollution within the basin. TÜBİTAK Marmara Research Center’s (MAM) Institute of Environment has also conducted an exhaustive work (2010) on preparing a proper basin protection action plan in relation to Büyük Menderes River Basin's water resources, with an aim of detecting the impacts of the pressures stemming from urban, industrial, agricultural and economic activities on water quality and quantity within the region. Furthermore, since a large variety of aspects of the overall status of the basin area like fertilizer and pesticide uses, water uses of organized industrial zones and households, water uses in irrigation, land use, basin's water potential, urban and industrial wastewater infrastructure statuses and urban, agricultural and industrial pollution loads are scrutinized in this work, data that is hard to access is made available with this study. The findings of this study also point to high levels of surface water and groundwater pollution, which is the biggest problem of the basin area. Lastly, Duygu (2015) is important with regards to the detailed discussion of the effects of aridity -with climate change projections taken into consideration- on Büyük Menderes River Basin's water budget, on agriculture and livestock industries and on water intended for human use. Results of this study show that aridity can substantially drag the water levels of the basin down. Moreover, Duygu (2015) mentions that irrigation practices are directly affected from the decline in water levels, since 72% of the basin water is used for agricultural production. Besides, according to climate change modelling results and scenarios conducted in the same study, basin's surface water budget may decrease by 6%-33% on average in the following 100 years, while the same modelling outcomes show that groundwater budget will not be in a downward trend in the same period of time.

3.2. Application of the PSR Method

The Pressure-State-Response (PSR) methodology was implemented in the identification of indicators that constitute the structure of the water security index for Aydın, Denizli, Muğla and Uşak. Forouzani and Karami's work (2010) was a great source of inspiration for this study in terms of structure development for our index that measures the level of water security in the area of study. In their case study for Iran, Forouzani and Karami divided the Agricultural Water Poverty Index (AWPI) into 5 components: resources, access, capacity, use and environment. They define these 5 components as water that is available currently in the region (resources), the extent to which farmers have access to agricultural water resources in the region (access), estimated productivity of the amount of available agricultural water (use), farmers' current potential to manage agricultural water at the farm level (capacity) and environmental factors influencing quality and quantity of agricultural waters (environment). They constructed this categorization by conducting research on numerous past studies that contain the use of water poverty indicators. In their attempt to enhance the Water Poverty Index, Perez-Foguet and Gine (2011) identify 5 components that constitute the eWPI (enhanced Water Poverty Index), each builded on the PSR framework. Perez-Foguet and Gine's (2011) component classification is the same as Forouzani and Karami's (2010): resources, access, capacity, use and environment, yet, their definitions are slightly different. In the case of eWPI, resource component is again defined as the water availability, access component takes into account whether the population has access to safe water and improved sanitation, capacity component includes socio-economic indicators in relation with human development, adequacy of water supply and management, as well as the adequacy of sanitation services, sector related institutional framework and gender issues. Use component is comprised of domestic and productive sector uses, and lastly, environment component covers water quality and stress (a measure of quantity), plus the indicators that have an effect on ecological integrity like poor land use practices.

Since water security is related to the concepts of environment, societal well-being and sustainability, it was deemed suitable in this work to divide the overall water security index to 4 components (i.e. sub-indices): resource sub-index, access and use sub-index, capacity sub-index and sustainability sub-index (Figure 3.2). These sub-indices are classified in accordance with the characteristics of the study area.

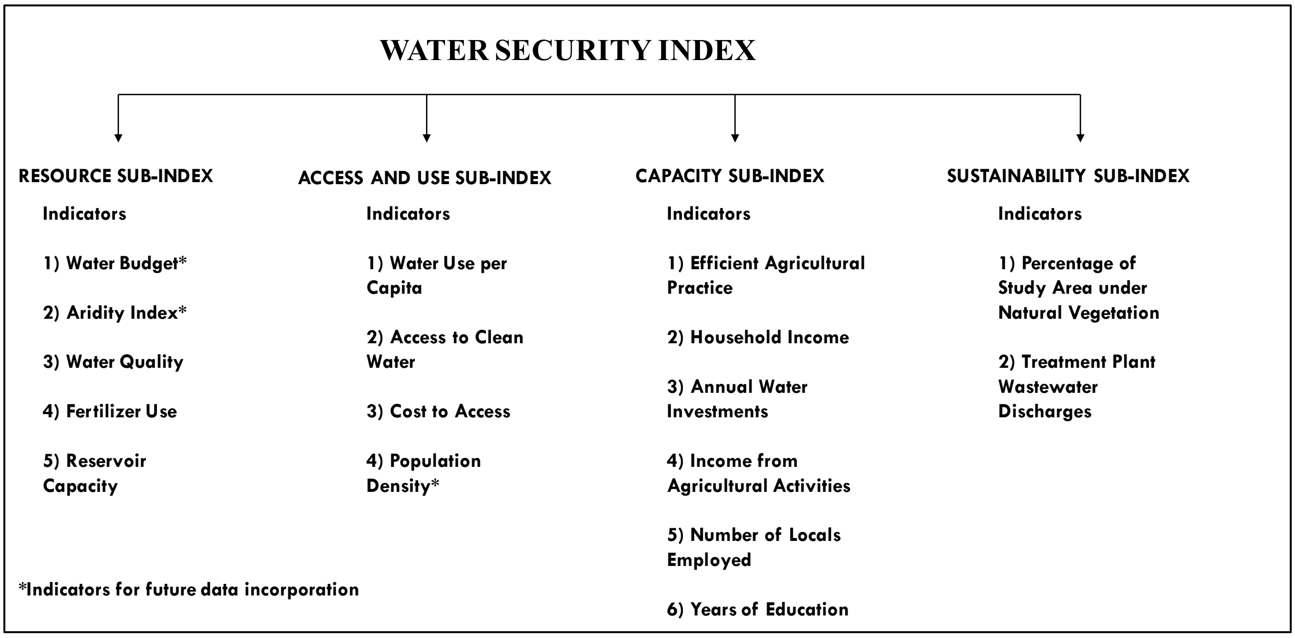

Figure 3.2. Water security index and its 4 sub-indices.

Each sub-index presented in Figure 3.2 is consisted of indicators which contain pressure, state and response variables. As a result, it becomes easier to observe cause-effect relationships within each sub-index. Indicators of each sub-index and their reference PSR variables are shown in Table 3.2.

In this study, not all indicators contain pressure, state or response variables due to their nature. The state variable of an indicator contains the information about the current status of that indicator, which can be monitored by the sample mean over time (such as water quality level, water use, average household income), the pressure variable indicates the variance of the state variable over the study period (the coefficient of variation of the state variable shown in percentage) in most cases and the response variable is the societal response which can be detected by examining the general trend of the state variable within the study period (negative or positive improvement of the state variable within the study period shown in percentage, or the percentage difference between the first and the last state parameter). Detailed descriptions of all of the PSR variables are explained in the following sections.

According to Sullivan et al. (2008), the total number of variables should be kept at a reasonable number to avoid the variables' influence being washed out by too many competing variables. Following this guidance, in this study, minimum and also equal number of indicators were assigned to each sub-index.

To overcome problems of incommensurability that comes from the differences in margins of data points, it was necessary for some values to be normalized so that each component has a common distribution (Sullivan et. al., 2008). In this study, Sullivan and his colleagues' method for the normalization process was followed, in which scores for each indicator are calculated as:

$$\text{Normalized Value} = \left[\frac{x_i - x_{min}}{x_{max} - x_{min}}\right] \times 100 \qquad (3.1)$$

where x_i is the original value, $x_{min/max}$ is the minimum/maximum value within the dataset. Equation (3.1) allows the dataset to fit into the range (0,100). After the application of this formula to each component of the dataset when necessary, scores between 0 and 1 is given to each result. High normalized values may indicate both favourable and unfavourable conditions, according to the type of the variable. For instance, a normalized value of 67 falls into the range (60,80), and usually gets the score 0,75. However, it might also get a score of 0,25, if the variable score has an inverse relationship with its value. Scoring of each variable is explained in detail in Section 3. Scoring table for the normalized values is presented in Table 3.3.

Table 3.2. Indicators of each sub-index and their reference PSR variables.

Sub-Index Name	RESOURCE SUB-INDEX						ACCESS AND USE SUB-INDEX					
			Water quality (2 sub-indicators)					Access to clean water (3 sub-indicators)				
Indicator Name	Water budget	Aridity index	1) Water Conta-mination	2) Population % receiving WW treatment service	Fertilizer use	Reservoir capacity	Water use per capita	1) Population % receiving wastewater treatment service	2) Population % receiving wastewater treatment service	3) Population % receiving drinking and tap water network service	Cost to access	Population density
State Variable	WB=P–E–Q (LT avg)	P/PET (LT avg.)	Surface water contamination	LT avg. of population % receiving WW treatment service	LT avg. of fertilizer use	Mean occupancy rates (%)	LT avg. of water use	LT avg. of 1	LT avg. of 2	LT avg. of 3	Average cost to access	No state variable
Pressure Variable	Variation relative to LT avg.	Variation relative LT avg.	Variation in surface nitrate levels relative to LT avg.	Variation relative to LT avg.	Variation in fertilizer use relative to LT avg.	Variation in occupancy rates relative to LT avg.	Variation relative to LT avg.	Variation relative to LT avg.	Variation relative to LT avg.	Variation relative to LT avg.	Variation in access relative to LT avg.	Number of people per km^2 (%)
Response Variable	Improvement in study period	Improvement in study period	% increase in all WWTP capacities	% increase in municipal WWTP capacities	Change in fertilizer use within study period	Change in occupancy rates during study period	Improvement in water use	Evolution in access of population	Evolution in access of population	Evolution in access of population	No response variable	No response variable
Sub-Index Name	CAPACITY SUB-INDEX						SUSTAINABILITY SUB-INDEX					
Indicator Name	Efficient agricultural practice (%)	HH income	Annual water investments	Income from agricultural activities	Number of locals employed	Years of education	% of study area under natural vegetation			WWTP discharges per capita		
State Variable	Share of eff. agr. practice in total irrigation area	Avg. HH income	Total expenditures for water related investments	Mean of agricultural GDP per capita	Employment rate of 15+ individuals	Mean of years of education	% of study area under natural vegetation			LT averages of WWTP discharges per capita		
Pressure Variable	Cost ratio of ineff. to eff. agr. practice	% of HHs declaring to fail on meeting basic needs	% of water related projects as a share of total investments	Agricultural GDP per capita / GDP per capita (%)	Variation relative to LT avg.	Variation relative to LT avg.	% change in green areas			Variation relative to LT average		
Response Variable	Frequency of policies supporting efficient water use	No response variable	Evolution in investment incentives	Evolution in agricultural subsidies	Improvement in employment rates	Improvement in education levels	Evolution in conservation areas within the study period			% increase in municipal WWTP capacities		

Table 3.3. Scoring according to sub-ranges of normalized values.

Sub-range	Scores (positive relationship)	Scores (inverse relationship)
0-20	0	1
20-40	0,25	0,75
40-60	0,5	0,5
60-80	0,75	0,25
80-100	1	0

Once the normalization process is complete and scores are attributed to each PSR variable, each indicator's score is obtained simply by calculating the arithmetic mean of the pressure, state and response variable values, formulated as:

$$\text{Indicator score} = \frac{\text{Pressure Score} + \text{State Score} + \text{Response Score}}{3} \tag{3.2}$$

If an indicator lacks some of the PSR variables, due to its nature, then the absent one(s) are omitted in the calculation of the arithmetic mean. For instance, if an indicator of one of the sub-indices carries only the pressure variable, the value of that variable becomes the actual value of that indicator. In this case, the most effective approach is to give equal weights to PSR variables since one is not more important than the other. The same method is followed while calculating indicators, sub-indices and finally the main index, hence, it is ensured that equal weights are allocated to all components. This is because that none of the sub-indices (resource, access and use, capacity and sustainability) have higher importance than the other as a part of the index regarding the study area. Eventually, indicators, sub-indices and the main index get a score between -0,6 and 1, and this range is divided to 6 sub-ranges, for the assessment of the scores (Table 3.4). An indicator having a score between 0 and 0,20 means the conditions of that aspect are "very poor", 0,20-0,40 subrange means "poor conditions", a score between 0,40-0,60 indicates "medium conditions", 0,60-0,80 zone means "good conditions" and lastly, the subrange of 0,80-1,00 expresses "excellent conditions" (Chaves and Alipaz, 2007). (-0,6 – 0) sub-range is also added to Table 3.4 as a measure of "extremely poor conditions" because future climate data incorporations into the baseline water budget indicator pull the indicator's score down below 0.

Table 3.4. Scores and their meanings for indicators, sub-indices and the overall index.

Score	Meaning
(-0,6 – 0)	Extremely poor conditions
(0 – 0,2)	Very poor conditions
(0,2 – 0,4)	Poor conditions
(0,4 – 0,6)	Medium conditions
(0,6 – 0,8)	Good conditions
(0,8 – 1)	Excellent conditions

3.3. Calculation of PSR Variables and Sub-Indices

In this section, calculations for the baseline value of the water security index for 4 neighbour provinces in the Aegean region (Aydın, Denizli, Muğla and Uşak) is introduced. In other words, future scenarios such as the effects of changes in precipitation patterns (impact of climate change) and population growth on the water security level of the study area are excluded. Each of the 4 sub-indices mentioned above are assumed to have equal importance with regards to water security, hence, equal weights were accredited to them (each 0,25) in the calculation of the overall index. Indicators forming each sub-index were chosen in accordance with the characteristics and the most important problems of the area of concern and its residents, as well as data availability. Future scenarios and their associated impacts on the baseline value will be presented in the Section 4.

3.4. Resource Sub-Index

Resource sub-index is directly related to the environmental status of Aydın, Denizli, Muğla and Uşak's water resources, with an emphasis on water quantity and quality. It is composed of 5 indicators classified as water budget, aridity index, water quality, fertilizer use and reservoir capacity (Figure 3.3).

Fertilizer use is incorporated into this sub-index since it has a direct effect on water resources. Fertilizer use is quite common in modern agricultural practices since it enhances crop production. In that sense, fertilizers compensate the excess food demand of the growing population. However, they also create nutrient (nitrogen and phosphorus) surpluses if they are not applied in proper amounts since the plants cannot fully utilize these nutrients.

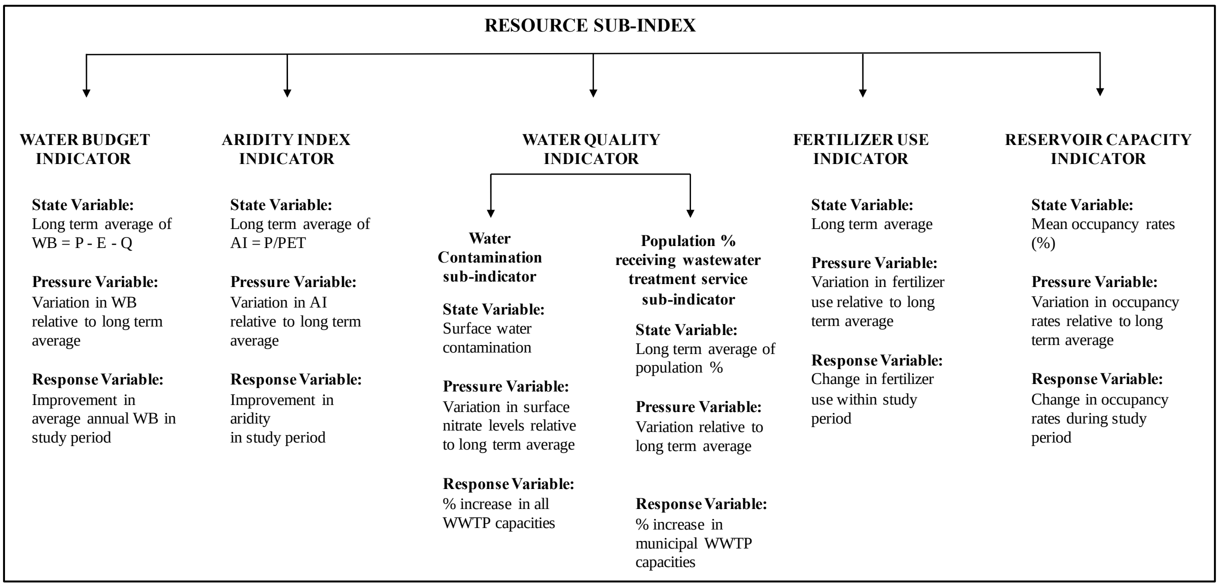

Figure 3.3. Indicators of the resource sub-index and their relevant PSR variables.

This excess nitrogen and phosphorus diffuse in water bodies with rainfall and snow melts, causing non-point source pollution, described as the excessive runoff of sediments, nutrients and pesticides (Dowd et al., 2008). If these nutrients are washed away from the farmlands in high amounts, they can cause eutrophication, defined as the over-enrichment of aquatic ecosystems with nutrients leading to algal blooms (Carpenter, 2005). Subsequently, eutrophication may lead to dissolved oxygen depletion (hypoxia and anoxia), which results in loss of critical habitat called as “dead zones”. Dian and Gozenberg (2008) mention that the magnitude of dead zones globally has grown significantly in recent years.

3.4.1. Water Budget

Water budget is the first and foremost indicator for the water security of a particular area, since it measures the quantity of water available for different purposes of use. A variety of methods exist in literature for the calculation of water resource balance, or water budget of a particular catchment area, yet the same idea underlies all of these different techniques: the subtraction of water outflows from water inflows gives the change in water storage. For instance, in their attempt to calculate the water balance of Mirror Lake located in New Hampshire, Healy et al. (2007) give precipitation, surface water inflow and groundwater inflow as positive variables for water budget, whereas they cluster the outflow variables as evapotranspiration, surface water outflow, groundwater outflow and change in lake volume. In another study, Manios and Tsanis (2006) construct their water resource balance model upon the following variables: rainfall, water from neighbouring districts, water reservoirs/dams as inflows, and water to neighbouring districts, industrial uses, irrigation, water for animal housing and farming and water uses of households as outflows. Jorgensen et al. (2012) introduce the simple short term water budget equation for a terrestrial ecosystem as:

$$P=Q+E+S \tag{3.3}$$

where P is precipitation, Q is streamflow, E is evapotranspiration and S is storage. If the subsurface flows are included in (3.3), the water budget equation becomes:

$$P+Q_i + L_i = E + Q_o + L_o + S \tag{3.4}$$

where Q_i and Q_o are surface inflow and outflow, respectively, and L_i and L_o are the corresponding subsurface flows. Uhlenbrook and Savenije (2006) also introduce the water balance equation as:

$$I(t) - O(t) = \frac{\Delta S}{\Delta t} \tag{3.5}$$

where I(t) is inflow, O(t) is outflow, and $\Delta S/\Delta t$ is change in storage. Thereupon, the long term water balance equation balance equation is given as:

$$P = R + E + \frac{dS}{dt} \tag{3.6}$$

where P is precipitation, R is runoff, E is evaporation and dS/dt is storage changes per time.

In the calculation process of the water budget indicator of the water security index for Aydın, Denizli, Muğla and Uşak, the methods of Jorgensen (2012) and Uhlenbrook and Savenije (2006) are adopted, due to the lack of sectoral water use and subsurface flow data. In addition, it was assumed that the study area is closed, which means that there are no water exports from or imports to the regions outside. Figure 3.4 shows the Turkish State Meteorological Service's weather stations located in Aydın, Denizli, Muğla and Uşak that measure the historical precipitation, evaporation and the temperature levels. The climatic observations of these 4 different stations are used as inputs for the calculation of water budget and the aridity index indicators of the resource sub-index.

Figure 3.4. Locations of the weather stations in Aydın, Denizli, Muğla and Uşak.

For the past data required for the streamflow parameter in the water budget equation (Equation (3.3)), observations of 4 different flowrate measurement stations nearest to the coordinates shown in Figure 3.4 are retrieved from the Directorate General of the State Hydraulic Works. Equalization of units was necessary for the calculation of monthly water budget levels of the 4 neighbour provinces for the period 2000-2017 since units of daily precipitation and evaporation data obtained from the Turkish State Meteorological Service were in mm, while the streamflow data obtained from the State Hydraulic Works was measured in m^3/sec. After the equalization of units to mm/month, monthly values of precipitation, evaporation and streamflow for Aydın, Denizli, Muğla and Uşak were incorporated in Equation (3.3) and then these monthly water budget values were summed up for the calculation of annual water budget for each province. However, due to lack of data, there were some inconsistencies between these provincial values. For example, for Uşak, water budget for only 4 years (2012, 2013, 2014 and 2015) could be calculated, while for Denizli, only the water budgets for the years 2000, 2001 and 2002 could not be calculated. For this reason, the averages – not the totals - of yearly water budget values obtained for each province were used in the determination of the final annual water budget levels of the study area for each year between 2000 and 2017. If the sums of the provincial annual water budgets were used in the calculation instead, there would be big differences between yearly water budget levels of the region of study since some yearly values are absent for some provinces. In Figure 3.5, averages of annual water budget levels of the provinces are presented, and these values are soon after used in the scoring of state, pressure and response variables. As it is illustrated in Figure 3.5, state variable of the water budget indicator is the long term average of water budget values, pressure variable is the variation in water budget values relative to long term average, and the response variable is the improvement in water budget level within the period of study.

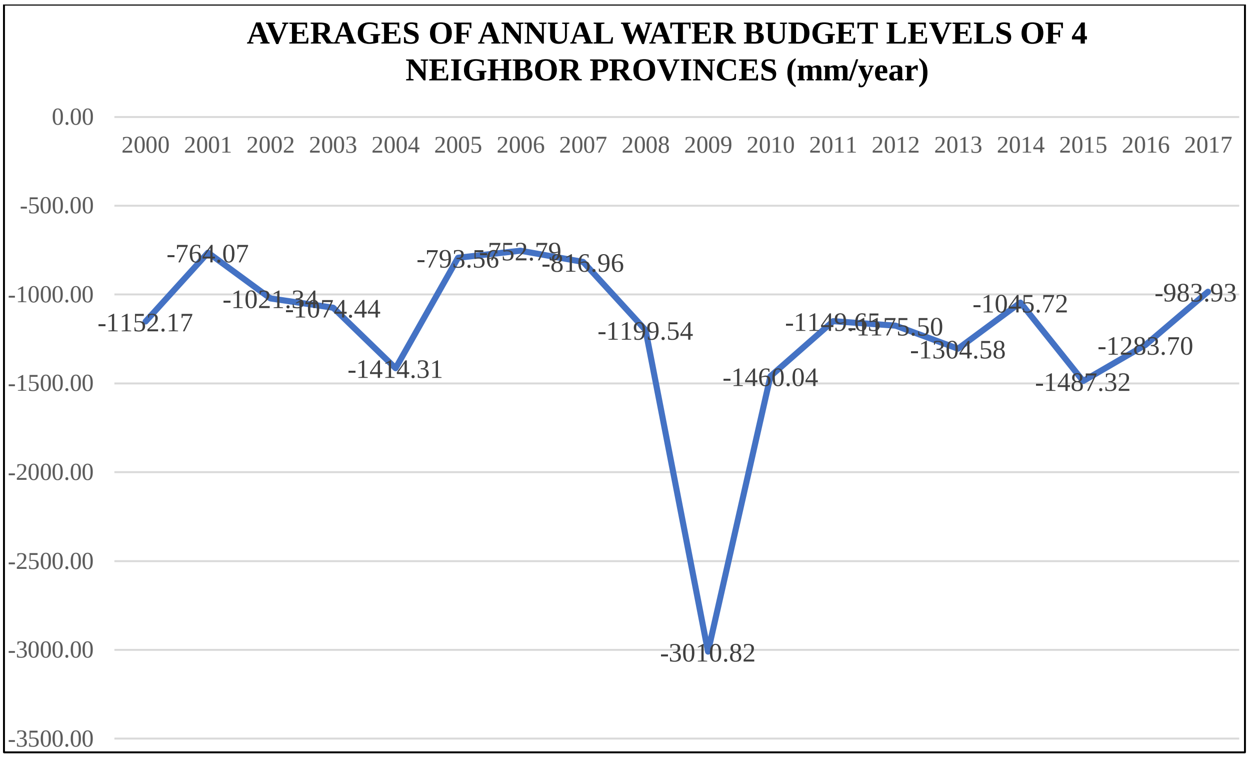

Figure 3.5. Averages of annual water budget levels of Aydın, Denizli, Muğla and Uşak (2000-2017).

3.4.2. Water Budget Scoring

Baseline year for the estimations was accepted as 2006 since it has the highest water budget level (still lower than 0). Percentage changes in water budget in each year relative to the baseline value were calculated and these values were normalized between -1 and 0, using the following formula:

$$\text{Normalized Value} = \left[\frac{x_i - x_{min}}{x_{max} - x_{min}}\right] \times 100 \times (-1) \tag{3.7}$$

and the scores shown in Table 3.5 were obtained for each year other than the baseline year.

Average of the scores shown in Table 3.5 gave the state variable score of the water budget indicator, which is – 0,21. State variable has a minus score since in all of the years, water budget values are below zero. This is because water stored in reservoirs and dams were not included in the calculations of this indicator. Reservoir capacities are included as a separate indicator of the resource sub-index, and its calculations will be discussed below.

Table 3.5. Annual water budget scores for the study region.

Sample Years	Annual Average Water Budget (mm/year)	Change (%)	Normalization*(-1)	State Scores
2006 (baseline=100)	-752,79	-	-	-
2000	-1152,17	-53,05	-17,27	-0,17
2001	-764,07	-1,50	0	0
2002	-1021,34	-35,67	-11,45	-0,11
2003	-1074,44	-42,73	-13,81	-0,14
2004	-1414,31	-87,87	-28,94	-0,29
2005	-793,56	-5,42	-1,31	-0,01
2007	-816,96	-8,52	-2,35	-0,02
2008	-1199,54	-59,35	-19,38	-0,19
2009	-3010,82	-299,95	-100	-1
2010	-1460,04	-93,95	-30,98	-0,31
2011	-1149,65	-52,72	-17,16	-0,17
2012	-1175,50	-56,15	-18,31	-0,18
2013	-1304,58	-73,30	-24,06	-0,24
2014	-1045,72	-38,91	-12,54	-0,13
2015	-1487,32	-97,57	-32,19	-0,32
2016	-1283,70	-70,53	-23,13	-0,23
2017	-983,93	-30,70	-9,79	-0,1
Sample Mean	-1216,14	Avg	-21,33	-0,21

Coefficient of variation, defined as the ratio of standard deviation to sample mean, demonstrates the extent of variability in relation to the long term average, and defines the pressure variable. Pressure variable’s score decreases as coefficient of variation increases, since a higher deviation from the sample mean implies a higher pressure on the environment. Table 3.5 shows the calculation process of the final water budget pressure score. First, mean values of the annual water budgets for the period 2000-2017 of each province (Aydın, Denizli, Muğla, Uşak) were calculated. Then, coefficient of variations of each sample were computed, according to the formula:

$$\text{Coefficient of Variation (\%)}=\frac{\text{Standard Deviation}}{\text{Sample Mean}} \times 100 \qquad (3.8)$$

Since all of the values in all samples were lower than zero, coefficient of variation values were also negative. So, absolute values of those negative numbers were taken before normalization. After the normalization process, pressure scores were given to each province as it is shown in Table 3.6. Final pressure variable result is the average of the pressure scores of four provinces, which is calculated as 0,5 (Table 3.6).

Table 3.6. Calculation of the water budget pressure score.

Pressure Variable Calculation	Aydın	Denizli	Muğla	Uşak
Sample Means	-1596,86	-1103,81	-562,12	-1498,70
Coefficient of Variation (%)	-60,84	-20,77	-45,84	-28,85
Absolute CV (%)	60,84	20,77	45,84	28,85
Normalization	100	0	62,57	20,15
Pressure Scores	0	1	0,25	0,75
Pressure Result	0,5			

Lastly, the response variable is calculated through measuring the percentage difference in water budget levels between the first (2000) and last year (2017) of the sample, in order to find the evolution of water budget within the period of study. However, since data points of the sample are unstable (i.e. there can be large differences between the water budget values of consecutive years, positively or negatively) directly measuring the percentage difference between the first value and the last value of the sample would have led to a misleading result. For instance, last data point can be higher than the first one, yet there can be a negative trend in the dataset. If the response value is directly measured by simply looking at the percentage difference between the values of the years 2000 and 2017, response score would be overestimated. So, a trend line was fitted into the distribution of water budget data points, which is presented in Figure 3.6. It can be seen in Figure 3.6 that distribution of data points has a fitted line equation of:

$$y = -18,665x + 36273 \qquad (3.9)$$

According to Equation (3.9), average of annual water budget level becomes -1057 mm/year in 2000, and -1374,305 mm/year in 2017. Thus, average annual water budget of the 4 neighbour provinces decreases by 30,02 % between these two years.

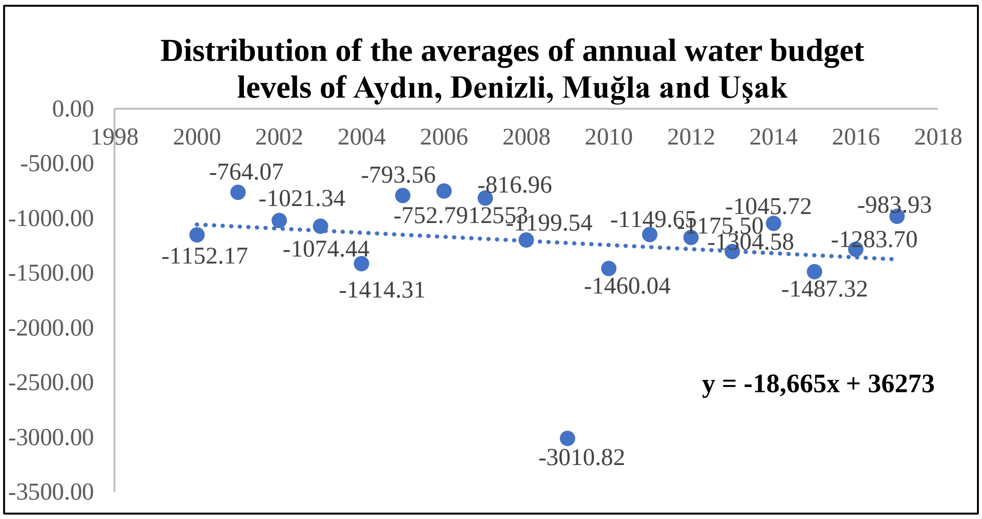

Figure 3.6. Distribution of the averages of annual water budget levels of Aydın, Denizli, Muğla and Uşak.

Consequently, the response variable of the water budget indicator gets a score of -0,25 since the response value is between – 20% and -40%. In this specific scoring case, the positive relation between scores and sub-ranges presented in Table 3.3 were considered as negative since annual water budget average of the 4 neighbour provinces had decreased within the period of interest from a negative value to even a lower value. By following the principles of the PSR method, overall water budget indicator is calculated by the arithmetic mean of the state, pressure and response variable grading results and gets the score of (-0,21+0,5-0,25)/3=0,013. According to Table 3.4, this number corresponds to "very poor conditions" of water budget within the study area.

3.4.3. Aridity Index

Measuring aridity is crucial for the evaluation of water security as that it gives provides insights about the study area's status of drought or water abundance. Most widely used Aridity Index (AI) in the previous works regarding climate change is the one that Barrow (1992) accepts:

$$AI=\frac{P}{PET} \tag{3.10}$$

where P is annual precipitation and PET is potential evapotranspiration. Gao and Giorgi (2008) use this index and divide the ranges for different values of AI (Table 3.7).

Table 3.7. AI ranges (Gao and Giorgi, 2008) and scores.

Ranges	Land Type	Scores
AI ≥ 1	Humid	1
0,65 ≤ AI < 1	Dry land	0,8
0,5 ≤ AI < 0,65	Dry sub-humid	0,6
0,2 ≤ AI < 0,5	Semi-arid	0,4
0,05 ≤ AI < 0,2	Arid	0,2
AI < 0,05	Hyper-arid	0

There are a number of methods to calculate potential evapotranspiration, and the most commonly used techniques are Penman's method (1948) and Thornthwaite method (1957). Thornthwaite's method is the most suitable one for this work, due to the data availability.

Karlsson and Pomade (2003) and Ferrer and Candela (2015) present the Thornthwaite method as follows:

$i = \left(\frac{t}{5}\right)^{1,5}$, where t is mean monthly temperature (3.11)

i : monthly heat index (n = 1,…..,12)

$I = \sum_{n=1}^{12} i$ (annual heat index) (3.12)

$PET = 16 \times (10 \times \frac{t}{I})^{\alpha}$ (monthly basis) (3.13)

where

$\alpha = 6,7 \times 10^{-7} \times I^3 - 7,7 \times 10^{-5} \times I^2 + 1,8 \times 10^{-2} \times I + 0,49$ (3.14)

Equations (3.10), (3.11), (3.12), (3.13) and (3.14) are used in the calculation of yearly Aridity Index values of the 4 neighbour cities. Monthly temperature and precipitation data at a provincial basis is obtained from the Turkish State Meteorological Service. State variable of the AI indicator is the long term average of AI values, pressure variable is the variation in AI values relative to the long term average, and the response variable is determined as the improvement in aridity of the region within the period of study.

3.4.4. Aridity Index Scoring

For the calculation of the aridity index, first PET values are calculated for each province and then the aridity index is calculated by following Thornthwaite method. According to these calculations, Aydın, Denizli, Muğla and Uşak has the following index values and relevant scores, as shown in Table 3.8.

Long term average of the Aridity Index values is counted as the state variable, with the variation in aridity values relative to long term average being the pressure variable, and percentage change in aridity during the period of study being the response variable attached to it. According to Table 3.8, Aydın, Denizli, Muğla and Uşak has the average scores of 0,72, 0,68, 0,98 and 0,79, respectively, for the period 2000-2017. Sample mean of these 4 numbers give us the final score of the AI for the overall study area, which is 0,79. Scores assigned to the state values are taken from Table 3.7. It is important here to also note that the original aridity index value (not the score) of the overall study area – which is the average of the mean aridity indices of the 4 provinces – was calculated as 0,893 (Table 3.8), which implicates the area of concern is in the category of a dry land.

Pressure values are calculated for each province, and gave the results of 24,39%, 19,48%, 22,52% and 21,71% for Aydın, Denizli, Muğla and Uşak accordingly, following Equation (3.8). Unlike the state variable, the higher the pressure value, the lower its score, since a greater deviation from the sample mean would indicate that dry and wet spells are experienced more intensely. In that sense, according to Table 3.3, Aydın, Muğla and Uşak get a pressure score of 0,75, while Denizli gets 1. Coefficient of variation percentages of the AI of each province and their relevant scores are introduced in Table 3.9. As a result, the final pressure score becomes 0,8125, which is the arithmetic mean of the pressure scores of Aydın, Denizli, Muğla and Uşak (Table 3.9).

Lastly, the response variable is calculated through measuring the percentage difference in AI levels between the first (2000) and last year (2017) of the sample, in order to find the evolution of aridity within the period of study. Since aridity index values tend to be unstable, it was plausible to fit a linear equation into the sample distribution and calculate the percentage difference.

The only difference here from the response variable of the water budget indicator is that trend line fitting process is applied to the datasets of each province because in this case, data availability allows enough sample years to make measurements for each province.

Table 3.8. Aridity Index values and state scores of Aydın, Denizli, Muğla and Uşak.

	Aridity Index (P/PET)				Scores			
Years	Aydın	Denizli	Muğla	Uşak	Aydın	Denizli	Muğla	Uşak
2000	0,64	0,75	1,27	-	0,6	0,8	1	-
2001	0,94	0,70	1,71	0,89	0,8	0,8	1	0,8
2002	0,90	0,67	1,56	0,71	0,8	0,8	1	0,8
2003	0,95	0,77	1,55	-	0,8	0,8	1	-
2004	0,66	0,62	1,31	0,69	0,8	0,6	1	0,8
2005	0,68	0,66	1,36	0,83	0,8	0,8	1	0,8
2006	0,57	0,60	1,28	0,53	0,6	0,6	1	0,6
2007	0,63	0,57	0,90	0,62	0,6	0,6	0,8	0,6
2008	0,46	0,37	0,76	0,52	0,4	0,4	0,8	0,6
2009	1,09	0,92	2,06	1,09	1	0,8	1	1
2010	0,72	0,60	1,23	0,74	0,8	0,6	1	0,8
2011	0,51	0,56	1,34	0,82	0,6	0,6	1	0,8
2012	0,75	0,76	1,70	-	0,8	0,8	1	-
2013	0,77	0,61	1,45	0,76	0,8	0,6	1	0,8
2014	0,77	0,62	1,85	1,02	0,8	0,6	1	1
2015	0,74	0,67	1,67	0,81	0,8	0,8	1	0,8
2016	0,44	0,42	1,19	0,67	0,4	0,4	1	0,8
2017	0,91	0,69	1,67	-	0,8	0,8	1	-
Average (Sample Mean)	0,73	0,64	1,44	0,76	0,72	0,68	0,98	0,79
Avg of sample mean values	0,893				Final State Score: 0,79			

Table 3.9. Pressure values and scores of each province for the AI indicator.

Provinces	Pressure Values (CV%)	Pressure Scores
Aydın	24,39	0,75
Denizli	19,49	1
Muğla	22,52	0,75
Uşak	21,71	0,75
	Pressure Variable Score	0,8125

Integration of the first (2000) and the last (2017) year into the linear equations presented in Figure 3.7 yielded the following results: while Aydın’s aridity index value decreased by 10,28% and Denizli’s value decreased by 13,62%, in Muğla and Uşak, aridity index values showed an increase by 12,61% and by 11,95%, respectively.

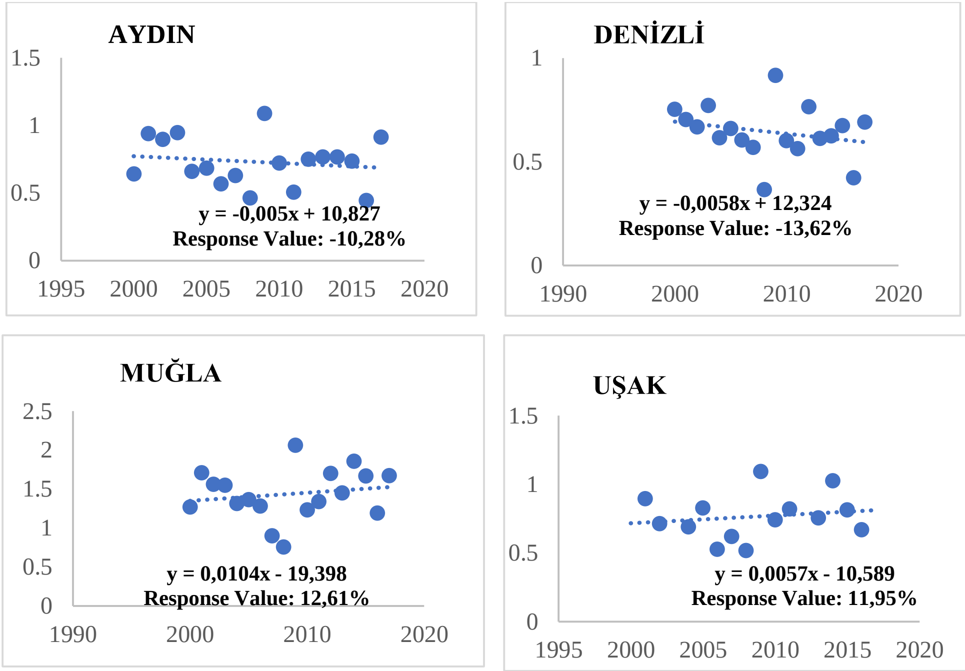

Figure 3.7. Aridity Index value distributions of Aydın, Denizli, Muğla and Uşak and reference fitted line equations.

Since none of the response values (-10,8% for Aydın, -13,62% for Denizli, 12,61% for Muğla and 11,95% for Uşak) showed a change in either directions above 20%, response of each province and thus, the overall response variable got a score of 0, according to Table 3.3. As a result, final indicator score of AI became (0,79+0,8125+0)/3 = 0,534, in accordance with Equation (3.2).

3.4.5. Water Quality

3.4.5.1. Water Contamination Sub-Indicator. The extensive industrial activity, especially the discharges of Uşak and Denizli Organized Industrial Sites' wastewater treatment plants (WWTPs), contaminate water bodies and adversely affect the aquatic habitats. Water quality deterioration, which is one of the most important problems in Büyük Menderes River Basin (Büke et al., 2013), is a great challenge for Aydın, Denizli, Muğla and Uşak. Chemical wastes are not the only source of pollution in the region. Unfortunately, in some parts of the region's ecosystem, the extremely hot wastewaters stemming from the textile and paint industries cause abrupt water temperature changes which jeopardizes the aquatic life in those discharge points (Büke et al., 2013).

Data availability was a great challenge for this sub-indicator, since the General Directorate of State Hydraulic Works of Turkey only shared the water quality station names and their relevant time periods of monitoring pollutants, but not the levels of contamination free of charge. Therefore, WWF's global water risk filter map was used to observe the risks regarding surface water contamination**.** Figure 3.8 shows WWF's risk estimations, where red dotted lines indicate the boundaries of the Büyük Menderes River Basin.

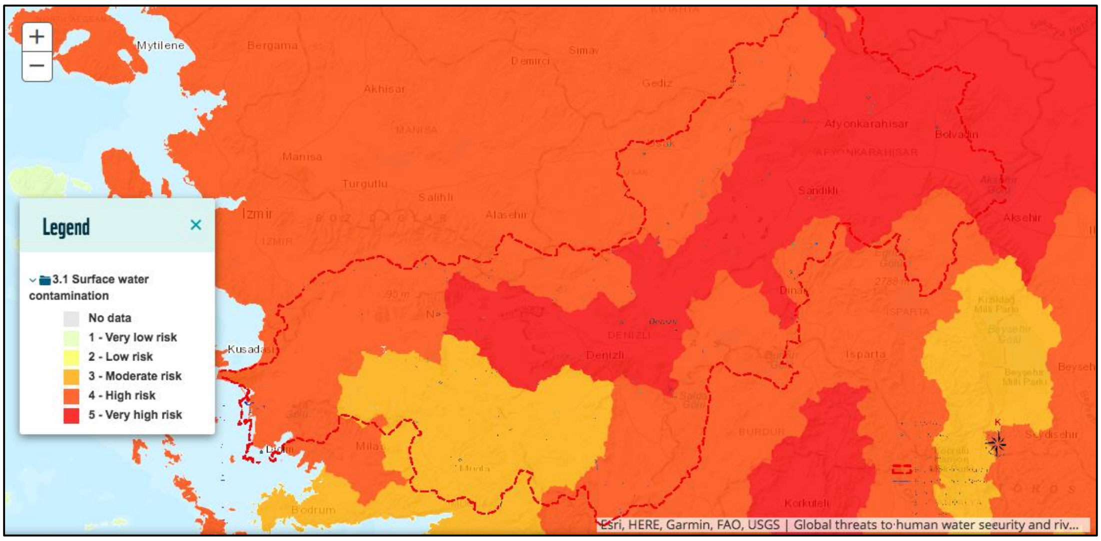

Figure 3.8. WWF surface water contamination risk estimations. (Source: waterriskfilter.panda.org/en/Explore/Map)

Calculations of the state variable score, which is determined as surface water contamination risk, is discussed below. Surface water contamination risk refers to the potential threats that the surface waters face, such as emerging pollutants resulting from unrestrained economic growth. Gavrilescu et al. (2015) represent emerging pollutants as a large spectrum of human-induced chemicals like pesticides, cosmetics, pharmaceuticals etc. However, due to lack of past data in WWF's risk filters, the pressure variable is the variation of nitrate levels in surface waters relative to long term average, which is the only data retrieved from provincial environmental status reports of Aydın and Denizli (Aydın Çevre ve Şehircilik İl Müdürlüğü, 2014, 2015, 2016, 2017; Denizli Çevre ve Şehircilik İl Müdürlüğü, 2012, 2016, 2017). Providing relevant background information about the international and national water quality standards would be useful at this point, as these standards were helpful for scoring. First of all, European Union, in its Nitrates Directive (1991), indicates that for groundwater resources, a nitrate concentration of 50 mg/L is the upper limit. OECD (2001) also defines 50 mg/L of nitrates as a threshold level for both surface water and groundwater resources, but assigns different threshold values to a list of Annex countries (Figure 3.9).

Annex Table 1. **Drinking water threshold values and trends in surface and groundwater quality in agricultural vulnerable areas**

	Drinking water threshold values			% of measurement points in agriculture vulnerable areas above drinking water threshold values					
	Surface water		Groundwater	Surface water				Groundwater	
	Nitrate NO_3 mg/l	Phosphorus P total mg/l	Nitrate NO_3 mg/l	Nitrate NO_3 mg/l		Phosphorus P mg/l		Nitrate NO_3 mg/l	
				Early 1990s	Late 1990s	Early 1990s	Late 1990s	Early 1990s	Late 1990s
Austria[1]	50	0.2	50	0	0	4	1	17	17
Canada	44	0.03[2]	44	..	..	..	..	..	..
Denmark	50	..	50	..	..	..	..	3[3]	..
Finland	25	0.1	25	..	..	..	..	..	..
France	50	50	..	..	..	..	..	..	..
Germany[4]	50	..	50	..	2	..	..	..	..
Japan[5]	44	..	44	..	..	..	..	13	..
Italy[6]	1.3-50	0.07-0.3	50	0 (83)	0 (82)	2 (10)	2 (7)	12	1
Korea[7]	..	..	20	..	..	..	..	14	24
Netherlands[8]	50	0.15	50	73	71	71	62	25	26
Norway	..	..	50	..	..	..	..	0	0
Poland[9]	< 6-> 60	< 0.1-< 0.4	..	..	..	..	..	..	..
Portugal	50	..	50	..	0	..	..	..	60
Spain	50	..	50	..	..	..	..	..	..
Sweden	44	0.025-0.1	44	..	..	..	..	..	..
Switzerland	25	..	25	..	..	..	..	..	..
United Kingdom[10]	50	..	50	3	3	..	..	..	7
United States	44	..	..	..	..	..	..	..	..
EU-15	50	..	50	..	..	..	..	..	..

Note: The following countries have not established national threshold values for nitrate: Iceland and Norway; for phosphorus: Iceland, Spain and the United Kingdom.

Figure 3.9. Surface and groundwater nutrient threshold values assigned by OECD.

In addition, according to OECD's global nutrient data (OECD, 2019) the nitrate surplus (inputs-outputs) in Turkey was 28,3 kg per hectare in 1990, while it has decreased to 23,3 kg per hectare in 2016. However, for the year 2015 the estimated nitrate surplus for EU was at 51,0 kg per hectare. European Environment Agency (2018) claims that even though the agricultural nitrogen surplus is going down in most of the member states of EU, nitrogen balance is still seen as intolerably high in some parts of Europe, especially in western regions and in some Mediterranean countries. In the same assessment report, it is said that regions with high nitrogen loadings may exist even in countries with low national averages of nitrogen surpluses, due to intense agriculture and livestock density.

Apart from those, it is alleged by the World Health Organization (WHO) (2011) that acceptable nitrate concentration in surface water is between 0 and 18 mg/L. It is also noted that groundwater resources have a time-lag in response to the changes in the soil, which means that the effects of increased use of nitrogen based fertilizers cannot yet be seen in some aquifers that are under risk. In addition to those, WHO specifies 10 mg/L of nitrates in drinking water as a potential health problem for infants. According to U.S. Water Research Center's official website (n.d.), the natural level of ammonia or nitrate in surface water is typically lower than 1 mg/L. Water Research Center (n.d.) also asserts that 10 mg/L of NO3-N (nitrate nitrogen) is equal to 44,3 mg/L of nitrate. This equality is very useful for this project since some of ad hoc data of the water quality indicator contain the annual contaminant levels as nitrate nitrogen, while some others are in the form of nitrate levels. It is also important to keep in mind that soluble nitrate may leach below the plant's root zone and reach groundwater with excess surface water application - resulting from rainfall or irrigation (Chen et al., 2016). The predominance of inefficient irrigation practices accompanied with the application of unnecessary amounts of water to the soil taking place in Büyük Menderes River Basin which Büke et al. (2013) points out may eventually cause nitrate contamination in groundwater resources of the region of study.

Eurostat (2018) mentions that maximum nitrate (NO3-) contamination level for groundwater is 50 mg/L, and 25 mg/L is a threshold level for concern. On the other hand, the river nitrate concentration limit is given as 11,3 mg N/L (which is equal to 50 mg NO3-/L), and 5,6 mg N/L is the level of concern. According to Eurostat, river nitrate levels are measured in N (nitrogen), whereas groundwater nitrate levels are quantified as NO3. Lastly, according to the water pollution control regulation tables published in the Official Gazette (2004) of Turkey, intra-continental water resources are given 4 grades (in the descending order, I, II, III and IV) according to different parameters (Table 3.10):

Table 3.10. Water pollution regulation tables of Turkey (SKKY, Resmi Gazete, 2004).

Parameter	I	II	III	IV
Ammonium nitrogen (mg NH_4^+-N/L)	0.2[c]	1[c]	2[c]	> 2
Nitrite nitrogen (mg NO_2^--N/L)	0.002	0.01	0.05	> 0.05
Nitrate nitrogen (mg NO_3^--N/L)	5	10	20	> 20
Biological oxygen demand (BOD)	4	8	20	> 20

(c) Free concentration of ammonium nitrogen should not exceed 0,02 mg NH_3^-N/L according to pH value

Unfortunately, the discrepancy of the data sources for state (surface water contamination risk) and pressure (variation of nitrate levels in surface waters relative to long term average) variables of this indicator may create inconsistent results. Response variable is chosen as the percentage increase in all waste water treatment plant (WWTP) capacities (including municipal and organized industrial site wastewater treatment plants). Data for response variable scoring is obtained from TÜİK database.

3.4.5.2. Scoring of Water Contamination Sub-Indicator. As it can be seen in Figure 3.8, 20% of the basin area is under moderate surface water contamination risk, while 40% of its surface water resources is under high contamination risk, and the remaining 40% of the area is under very high risk. The calculation of the state variable is made through taking the weighted average of these area proportions and the scores given to the levels of risks. Based on Table 3.4, very high risk indicates a score of 0, high risk means a score of 0,25, moderate risk is graded as 0,5, low risk gets the score 0,25, and very low risk gets 0. As a result, state variable's score becomes the weighted average of the surface water contamination risk zones: (0,2 x 0,5 + 0,4 x 0,25 + 0,4 x 0)/(0,2 + 0,4 + 0,4) = 0,2. For the state variable of the water contamination sub-indicator, the study area was accepted as the Büyük Menderes River Basin itself, due to the constraints in data availability.

Since higher scores of indicators indicate better conditions in this study, as shown in Table 3.4, some of the PSR variables' values and scores have inverse relationships because in that case, a higher value would mean a worse condition for the environment, and the score of that variable should be lower. So, during the scoring process of that variable, second column of Table 3.3 is implemented. Pressure variable (the coefficient of variation of nitrate levels in surface waters) values and scores have a negative relationship since more deviation from the long term mean of nitrate levels indicate a higher pressure on the environment. Response variable (percentage increase in all waste water treatment plant capacities) values and scores have a positive relation since as waste water treatment plant capacities increase, more pollutants will be eliminated. It is important here to remind here that, in the calculation process of the response values and scores, a fitted line equation (Section 3.4.2 and Section 3.4.4) for the distribution of annual WWTP capacity levels could not be used since there were not enough data years. Therefore, percentage difference between the first and last year of WWTP capacities was directly calculated in order to reach response values (Table 3.12). Consequently, pressure and response variables got the scores of 0,75 and 0,417, respectively. Calculation of pressure and response variable scores are shown in Table 3.11 and Table 3.12.

As a result of the calculations in this section, overall water contamination sub-indicator score becomes (0,2+0,75+0,417)/3 = 0,456, according to Equation (3.2).

3.4.5.3. Proportion of Wastewater Treatment Service. Proportion of municipal population receiving wastewater treatment service to total municipal population is related to water quality in the sense that municipal endeavors towards minimizing wastewater actually contribute to the quality of water resources.

Table 3.11. Calculation of pressure scores (coefficient of variation of nitrate levels in surface water).

Years	Aydın Surface Nitrate	Denizli Surface Nitrate
2012	-	7,47
2013	-	-
2014	4,41	-
2015	2,58	-
2016	2,28	3,74
2017	3,41	6,26
Sample Mean	3,17	5,82
Coefficient of Variation (%)	30,12	32,67
Pressure Scores	0,75	0,75
Pressure Variable Score	0,75	

Table 3.12. Calculation of response scores (percentage increase in all WWTP capacities).

Provinces	Municipal WWTP capacity increase	Organized Industrial Site WWTP
Aydın	64,73	196,26
Denizli	119,33	0
Muğla	63,12	-
Uşak	1,67	28,57
	Normalization	
Aydın	53,596	100
Denizli	100	0
Muğla	52,23	-
Uşak	0	14,56
	Scores	
Aydın	0,5	1
Denizli	1	0
Muğla	0,5	-
Uşak	0	0
Average	0,5	0,33
Response Score	0,417	

The state variable is the long term (2001-2016) average of the percentage of the municipal population receiving waste water treatment service, the pressure variable is the variation of the same sample relative to long term average, and the response variable is the percentage increase of the municipal waste water treatment plant capacities during the same period (the first column of Table 3.12). Data for the state and pressure variables is taken from TÜİK (Turkish Statistical Institution) database, and data for the response variable is taken from annual provincial environmental status reports of Aydın, Denizli, Muğla and Uşak. (Aydın Çevre ve Şehircilik İl Müdürlüğü, 2011, 2012, 2013, 2014, 2015, 2016, 2017; Denizli Çevre ve Şehircilik İl Müdürlüğü, 2011, 2012, 2014, 2015, 2016, 2017; Muğla Çevre ve Şehircilik İl Müdürlüğü, 2013, 2014, 2015, 2016, 2017; Uşak Çevre ve Şehircilik İl Müdürlüğü, 2012, 2013, 2014, 2015, 2016, 2017). Percentage of municipal population receiving wastewater treatment service data for the years 2001-2016 is presented in Table 3.13.

Table 3.13. Proportion of municipal population receiving wastewater treatment service (%) (2001-2016).

Proportion of municipal population receiving wastewater					
Years	Aydın	Denizli	Muğla	Uşak	Turkey
2001	47	0	16	0	35
2002	50	0	25	0	36
2003	50	0	32	0	38
2004	53	0	32	0	45
2006	33	0	37	28	51
2008	58	34	38	48	56
2010	60	63	43	42	62
2012	65	68	60	71	68
2014	88	65	55	69	68
2016	75	70	77	76	75
Average (State)	57,9	30	41,5	33,4	53,4
CV% (Pressure)	26,64	110,41	43,42	96,11	27,41

3.4.5.4. Scoring of Proportion of Wastewater Treatment Service. First of all, normalization for the state values before grading was not required since data was given in percentage, and the range of this data (0,100%) is divided into 5 equal sub-ranges in scoring (0-20% means a score of 0, 20-40% means a score of 0,25, 40-60% means 0,5, 60-80% is equivalent to 0,75, and 80-100% is corresponds to 1). As the value of the state variable (average of the sample mean) increases, so does the score attributed to it. In Aydın, on average 57,9% of the total population receives wastewater treatment service, while this number goes down to 30%, 41,5% and 33,4% in Denizli, Muğla and Uşak, respectively (Table 3.13). According to these percentages, Aydın and Muğla get a state variable score of 0,5, whereas both of Denizli and Uşak's state score gets 0,25 points (Table 3.14).

Pressure variable values (coefficient of variance percentages of the provincial samples) have an inverse relationship with their scores because more variation relative to the average means more pressure on the environment, thus lowering the score.

Table 3.14. Calculation of state and response scores of proportion of WW treatment service sub-indicator.

Proportion of WW treatment service	State Values (%)	State Scores	Pressure Values (%)	Pressure Normalized	Pressure Scores
Aydın	57,9	0,5	26,64	0	1
Denizli	30	0,25	110,41	100	0
Muğla	41,5	0,5	43,42	20,04	0,75
Uşak	33,4	0,25	96,11	82,93	0
Turkey	State Average	0,375	27,41	Pressure Average	0,4375

Pressure values were normalized before scoring since the absence of any wastewater treatment service in Denizli until the year 2008 pushed the province's coefficient of variation above 100%, because it is observed from the dataset of Denizli that the percentage of population receiving wastewater treatment service in the year 2016 had reached to 70%. Normalization process paves the way for the pressure variable values of 0, 100, 20,04 and 82,93 for Aydın, Denizli, Muğla and Uşak in the same order (Table 3.14). As a result, Aydın's pressure score becomes 1, while Denizli and Muğla's pressure variables both get 0 points, and Uşak gets 0,75 points (following Table 3.3). Lastly, a higher response value (percentage change in municipal WWTP capacities within the period of interest) indicates a higher score since an increase in wastewater treatment plant capacity implies a positive societal response and has a beneficial outcome for both the society and the environment. Details of response variable scoring is given in Table 3.12's second column. After the application of state pressure and response scores (0,375, 0,4375 and 0,5 respectively) into Equation (3.2), overall sub-indicator score becomes 0,4375.

After the calculation of these 2 sub-indicators of water quality (water contamination sub-indicator and proportion of waste water treatment service), the score of water quality indicator was found as (0,456+0,4375)/2 = 0,447.

3.4.6. Fertilizer Use

Excessive fertilizer use, which is a widespread global problem that causes water-pollution, is an indicator of the resource sub-index (Figure 3.3) because it has a delayed but direct impact on the study area's ecosystem. For instance, an excessive use of nitrogen based fertilizers will result in the leakage of the excess amount of nitrogen (in forms of nitrite or nitrate) from the soil to surface waters and aquifers, thus causing water pollution (WHO, 2011). For this study, monthly fertilizer use data (ton/year) for the period 2000-2018 was obtained from the Ministry of Food, Agriculture and Livestock of Turkey. Monthly values for each province (Aydın, Denizli, Muğla and Uşak) were summed in order to reach annual values (Table 3.15). State variable is determined as the long term average of fertilizer uses, pressure variable is the variation in fertilizer uses relative to long term average in percentage, and the response variable is the percentage difference in fertilizer use levels between 2000 and 2018.

3.4.7. Fertilizer Use Scoring

Firstly, in the grading of the state variable, normalized values of sample means of each province (Turkey's sample mean was incorporated into the normalization process of all PSR variables), by using Equation (3.1). An important remark for the state variable in this case is that as fertilizer use increases, its adverse effects on the environment and water security will accumulate, thus, the state variable has to get a lower score as fertilizer use goes up. Average annual fertilizer use levels in Aydın, Denizli, Muğla, Uşak and Turkey is 92520,32 tons/year, 76026,95 tons/year, 44201,05 tons/year, 45559 tons/year and 64844,43 tons/year, respectively (Table 3.15). According to these values, annual average fertilizer uses in Aydın and Denizli are above Turkey's average, while those in Muğla and Uşak are below the average fertilizer use level in Turkey.

Therefore, normalization process of sample means of the 4 provinces lead to state variable value (score) results of 100 (0) for Aydın, 65,82 (0,25) for Denizli and 0 (1) for Muğla and 2,8 (1) for Uşak, following Table 3.3. Hence, the state variable got the score of 0,5625, which is the arithmetic mean of the state scores of the 4 provinces (Table 3.16). Secondly, the pressure gauge is the coefficient of variation of fertilizer use amounts. So, pressure score decreases as coefficient of variation increases, since a higher deviation from the sample mean implies a higher pressure on the environment.

Normalization was not necessary for pressure variable scoring since all of the pressure values were in the range of (10%,20%), with the coefficient of variation values of Aydın, Denizli, Muğla, Uşak and Turkey are in the order of 13,41%, 13,25%, 15,97%, 13,69% and 1,85%. Therefore, each of the province get a pressure score of 1, according to Table 3.3, and the overall fertilizer use indicator pressure score results in 1.

Table 3.15. Annual uses of fertilizers in Aydın, Denizli, Muğla, Uşak and Turkey (2000-2018).

Annual Fertilizer Uses (ton/year)					
Years	Aydın	Denizli	Muğla	Uşak	Turkey
2000	81233	68034	47564	36799	63560,135
2001	76150	63499	43736	35033	52620
2002	90978	67257	45496	42579	55912
2003	72999	71513	68141	46275	63593
2004	94313	73775	44204	50871	63809
2005	100013	74035	49703	52556	64184
2006	98110	71739	47055	56436	65893
2007	90552	70226	42522	47311	63555
2008	74505	58677	39686	34368	50979
2009	78118	75454	41685	47040	65131
2010	86865	75052	41471	43278	61336
2011	93397	73113	37499	44200	58844
2012	88525	76249	39051	49100	65924
2013	98505	85825	41841	52143	71771
2014	98413	88694	37986	50080	67550
2015	99117	79977	37973	43911	67997
2016	116047	97144	48607	50459	83270
2017	114331	96397	48139	45789	78185
2018	105715	77852	37461	37393	66891
Average (State Values)	92520,32	76026,95	44201,05	45559,00	64884,43
CV% (Pressure Values)	13,41	13,25	15,97	13,69	11,85

Table 3.16. State variable score calculation of the fertilizer use indicator.

State Score Calculation	Aydın	Denizli	Muğla	Uşak	Turkey
Average (State values)	92520,32	76026,95	44201,05	45559	64884,43
Normalization	100	65,87	0	2,81	State Avg.
State Scores	0	0,25	1	1	0,5625

Thirdly, the response variable is the percentage change in fertilizer use between the first (2000) and the last year (2018) for measurement. Fitted line equation (Figure 3.10) results of provincial distributions of annual fertilizer uses, as well as the distribution of Turkey's annual fertilizer use for the period 2000-2018 indicate that fertilizer use increased 30,14% in Aydın, 14,43% in Denizli, 1,61% in Uşak and 2,34% in Turkey, while it decreased 21,24% in Muğla, between 2000 and 2018.

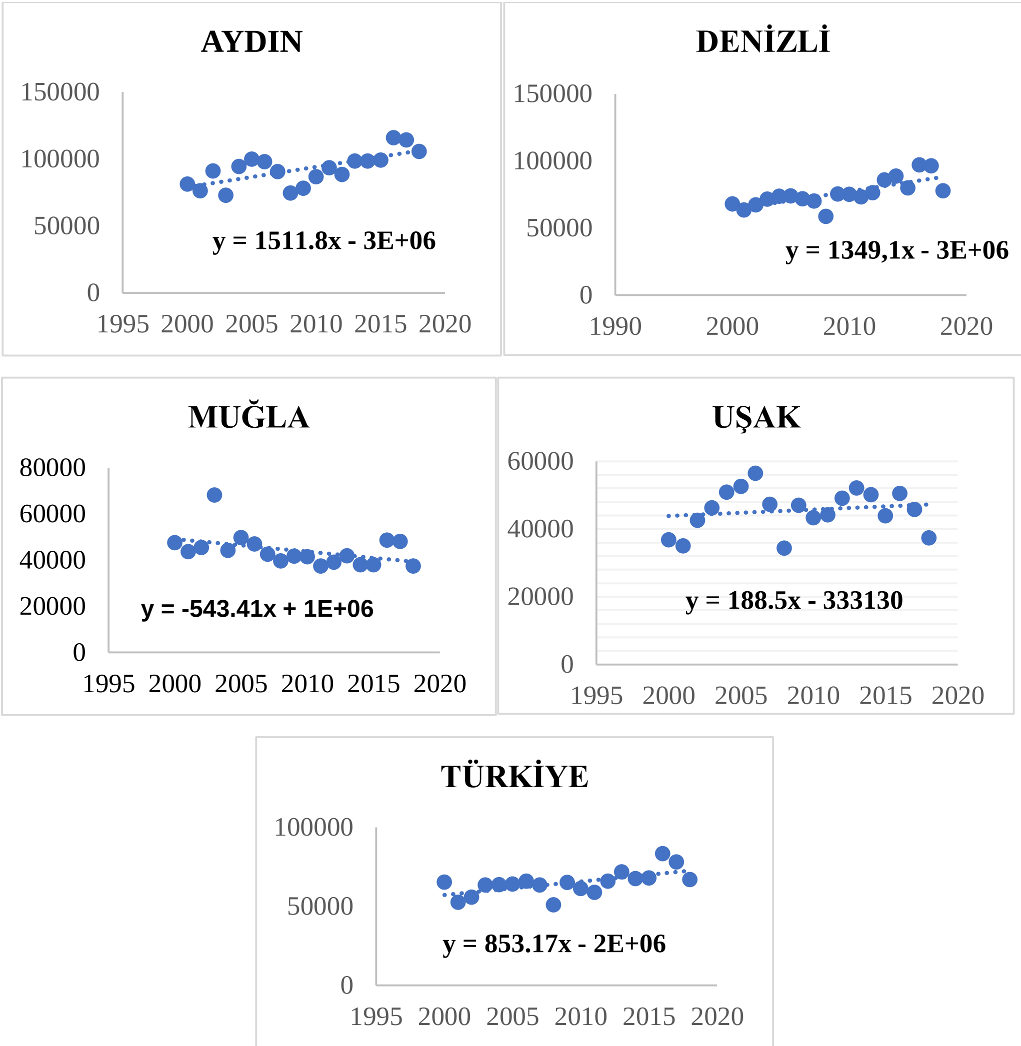

Figure 3.10. Fitted line equation results of provincial distributions of annual fertilizer uses (2000-2018).

Normalizing these values yields the results of 0, 0,25, 1 and 0,5 for Aydın, Denizli, Muğla and Uşak respectively, which makes the overall response score 0,4375 (arithmetic mean of the response scores of Aydın, Denizli, Muğla and Uşak). Scoring process of the response variable is shown in Table 3.17.

Normalized values and response scores of the fertilizer use indicator have an inverse relationship (Table 3.3), because an increase in fertilizer use would imply a negative outcome. Eventually, overall score of fertilizer use indicator becomes the arithmetic mean of pressure, state and response variables, which is (0,5625+1+0,4375)/3=0,67, following Equation (3.2).

Table 3.17. Scoring of the response variable of the fertilizer use indicator.

Response Score Calculation	Response Values (change in % 2000-2017)	Normalization	Response Scores
Aydın	30,14	100	0
Denizli	14,43	69,43	0,25
Muğla	-21,24	0	1
Uşak	1,61	44,48	0,5
Turkey	2,34	Response Avg.	0,4375

3.4.8. Reservoir Capacity

Reservoir capacity, which should have been originally included in the calculation of water budget, is a separate indicator of the resource sub-index here, due to the data availability. Water budget calculations were made in units of mm/month, but the General Directorate of State Hydraulic Works provides reservoir capacity data only in the form of percentage annual occupancy rates of each basin in Turkey. That is why this indicator's PSR variables reflect the reservoir capacities in Büyük Menderes River Basin, not Aydın, Denizli, Muğla and Uşak separately. Table 3.18 shows the occupancy rates of the dams of Büyük Menderes Basin.

In this case, the state variable is the average of annual occupancy rates of Büyük Menderes Basin shown in Table 3.18 the pressure variable is the sample variation relative to its mean, and the response variable is percentage change in occupancy rates in the sample period, which gives information about the improvement in dam occupancy rates in the period of interest. It can be seen from the values in Table 3.18 that the occupancy rates have fallen more than half between the first and the last year, which can be linked with temperature increases as a result of global warming and increase in evaporation rates.

Table 3.18. Büyük Menderes Basin dam occupancy rates (%).

Years	Büyük Menderes Basin occupancy rates (%)
2010	35,29
2011	56,92
2012	43,8
2013	44,8
2014	27,4
2015	50,1
2016	31,1
2017	17
Average	38,3
CV (%)	34,07

3.4.9. Reservoir Capacity Scoring

For the state variable, our sample mean is 38,3% (Table 3.18), which can be directly used in scoring since it is a percentage value. The idea behind the scoring here is to divide the range of occupancy rates (0-100%) into 5 equal sub-ranges and increase the score if the occupancy rate increases. So, our sample mean goes into the range where the score is 0,25 (Table 3.3). Pressure variable here is the variation in occupancy rates relative to long term average, which has a value of 34,07%, thus a score of 0,75 since a higher pressure means worse conditions for the environment, indicating a lower score, according to Table 3.3.

The response variable gets the score 0, since the occupancy rates between 2010 and 2017 went down approximately by 43,5%, according to the fitted line equation of occupancy rate distribution (Figure 3.11).

Consequently, overall score for the reservoir capacity becomes (0,25+0,75+0)/3=0,333, according to Equation (3.2).

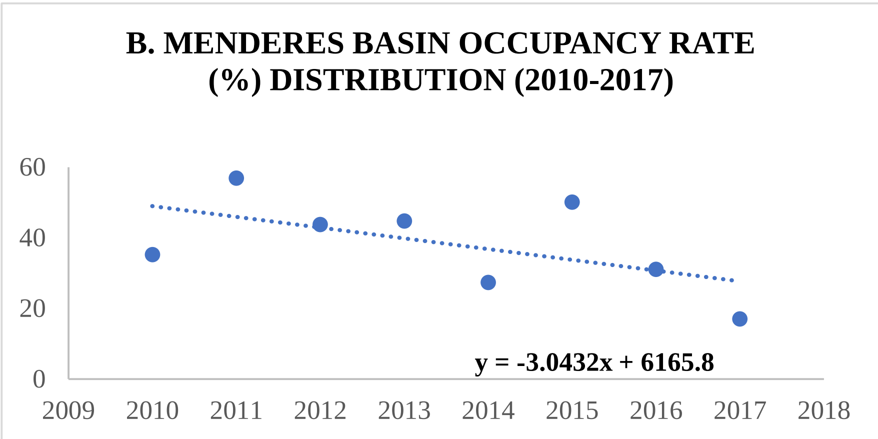

Figure 3.11. Fitted line equation result of occupancy rate distribution (2010-2017).

According to the calculations of Section 3.4., the overall resource sub-index baseline result, which is the arithmetic mean of the final scores of the 5 indicators became (0,013+0,5342+0,447+0,646+0,333)/5=0,399 (Table 3.19). Resource sub-index result reveals that the health of the 4 neighbour provinces' water resources as a whole is in "poor conditions" (Table 3.4).

Information about the incorporation of future climate data into water budget and aridity index indicators is given in Section 4, along with the comparison and analysis of the baseline and future scenarios.

Table 3.19. Baseline scenario resource sub-index results.

	Indicator Name	State	Pressure	Response	PSR indicator
Resource Sub-Index	Water Budget	-0,21	0,5	-0,25	0,013
	Aridity Index	0,79	0,8125	0	0,534
	Water Quality Sub-Indicator	0,2	0,75	0,417	0,456
	Proportion of municipal population	0,375	0,4375	0,5	0,4375
		WQ Indicator Average			0,447
	Fertilizer Use	0,5625	1	0,4375	0,667
	Reservoir Capacity	0,25	0,75	0	0,333
		Sub-Index Result			0,399

3.5. Access and Use Sub-Index

In UN's (2000) well accepted definition of water security, "sustainable access" to water is emphasized, and this is why the second sub-index is determined as "Access and Use". It has 4 indicators, including water use per capita, percentage of population that has access to clean water, cost to access (basically the price per unit of municipal water) and population density (Figure 3.12).

Population density is settled within this sub-index since it is directly related to water use. Besides, population growth is seen as a global environmental challenge along with climate change. Combination of these two challenges creates a larger pressure on environmental resources. That being said, future population data is incorporated into the population density indicator in order to find out the effects of population growth on the baseline value of the index, which is discussed in Section 4.

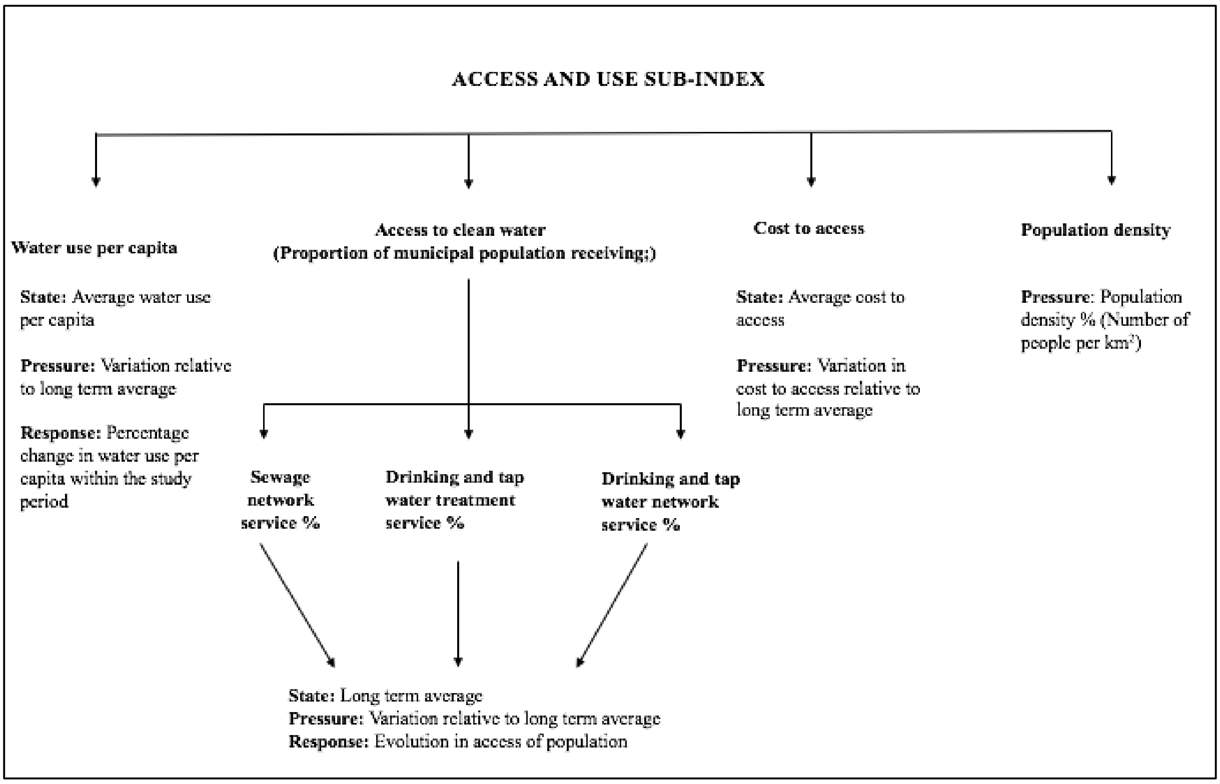

Figure 3.12. Indicators of the access and use sub-index and their relevant PSR variables.

3.5.1. Water Use Per Capita

Data required for this indicator is obtained from TÜİK (Turkish Statistical Institute) database. Daily water uses per capita (liter/person/day) between the years 2001 and 2016 were listed on a provincial basis including Turkey as a whole. State variable is the sample mean of water use per capita in all provinces, pressure variable is the variation of the sample relative to sample mean in percentage, and the response variable is the percentage change (or improvement in water use per capita) within the period of 2001-2016. Each of the state, pressure and response variable values of Aydın, Denizli, Muğla and Uşak are normalized against water use per capita levels of Turkey as a whole. Datasets of Aydın, Denizli, Muğla, Uşak and Turkey retrieved from TÜİK's database are presented in Table 3.20.

3.5.2. Water Use Per Capita Scoring

The value of the state variable (sample mean of water use per capita) has an inverse relationship with the state score, since environmental damage increases as individuals tend to use more water per day. Sample means show that in Aydın, an individual used an average of 263 liters of water per day. In Denizli, Muğla, Uşak and Turkey as a whole, average water use per capita (liters/day) within the same period was 237,4, 374,5, 196,7 and 233,3, respectively (Table 3.20).

Table 3.20. Water use per capita levels (2001-2016).

Water use per capita (liter/day)					
Years	Aydın	Denizli	Muğla	Uşak	Turkey
2001	294	236	411	176	252
2002	298	234	437	194	255
2003	311	250	452	197	259
2004	311	252	434	203	255
2006	292	268	365	217	245
2008	235	276	361	262	215
2010	188	207	364	183	216
2012	211	239	335	177	216
2014	257	180	347	177	203
2016	233	232	239	181	217

Table 3.21. Calculation of the state variable score of water use per capita indicator.

Provinces	State Values (Sample mean)	Normalized State Values	State Scores
Aydın	263	37,29	0,75
Denizli	237,4	22,89	0,75
Muğla	374,5	100	0
Uşak	196,7	0	1
Turkey	233,3	Average State Score	0,625

Aydın and Denizli's water use per capita levels are slightly above Turkey general. On the other hand, Muğla's water use per capita is way higher than Turkey's average, while in Uşak, water use per capita is much lower than the average of Turkey. It can be seen from Table 3.21 that the state variable has a score of 0,625, after the normalization process.

Pressure variable of this indicator is the coefficient of variation of Aydın, Denizli, Muğla and Uşak samples, normalized altogether with the Turkey sample. Again, a higher normalized value of the pressure variable indicates a more unstable effect on the environment, thus, lowering its score. By using this reasoning, final pressure score becomes 0,3125 (Table 3.22).

Table 3.22. Calculation of the pressure variable score of water use per capita indicator.

Provinces	Pressure Values (CV%)	Normalized Pressure Values	Pressure Scores
Aydın	16,85	100	0
Denizli	11,80	33,39	0,75
Muğla	16,85	99,96	0
Uşak	13,52	56,02	0,5
Turkey	14,55	Avg. Pressure Score	0,3125

Response variable is the percentage change in water use per capita within the period of interest (2001-2016). In order to observe the actual direction of change in water use per capita, a trend line was fitted into each sample distribution (Figure 3.13), and the percentage changes between the first (2001) and the last (2016) year of each sample was calculated to reach the response scores. Figure 3.13 shows that water uses in all of the provinces of our concern and Turkey in general decreased during the period 2001-2016.

Percentage differences between the water use per capita values between 2001 and 2016 calculated in accordance with the fitted line equations presented in Figure 3.13 show that water use per capita decreased by 30,834% in Aydın, by 14,175% in Denizli, by 36,224% in Muğla, by 7,604% in Uşak and by 21,467% in Turkey. Normalization process of these response values and their relevant response scores are shown in Table 3.23.

A bigger decrease in water use per capita values within the period of study decreases the pressure on water resources, so a higher response value indicates a higher response score. As a result, Aydın, Denizli, Muğla and Uşak were given the scores of 1, 0,25, 1 and 0, respectively (Table 3.3).

Therefore, the overall response score became (1+0,25+1+0)/4 = 0,5625, the arithmetic mean of the response scores of the 4 provinces. As a result, water use per capita indicator's score became the arithmetic average of the final state, pressure and response scores, (0,625+0,3125+0,5625)/3 = 0,5 (using Equation (3.2)).

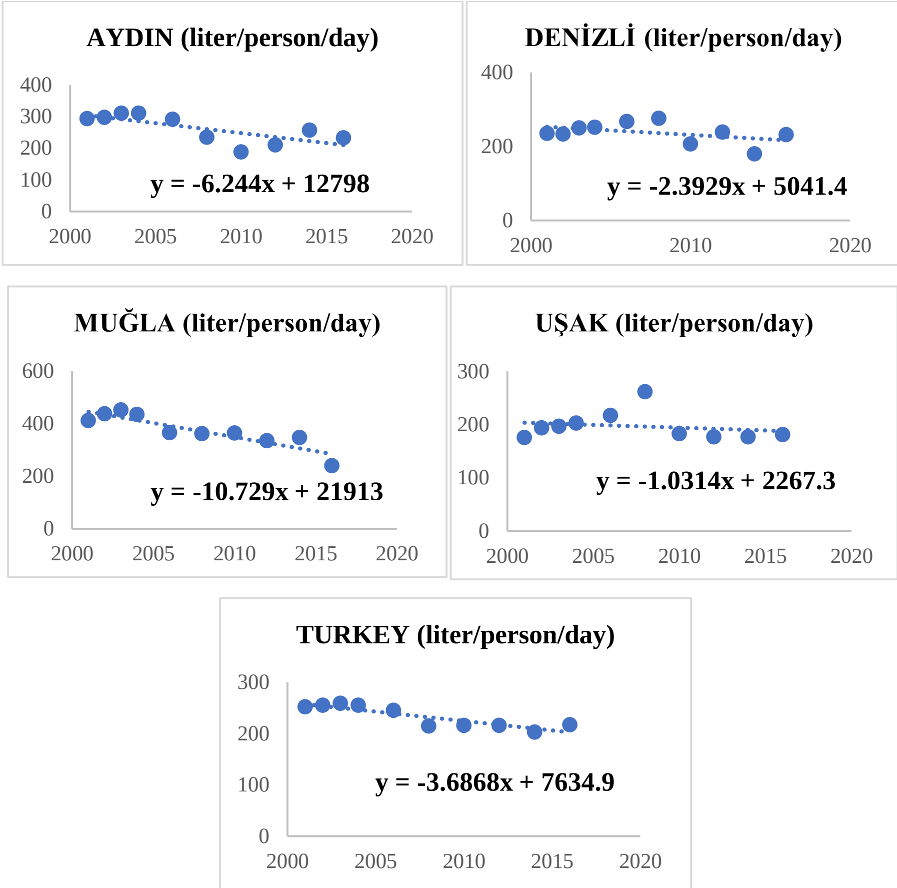

Figure 3.13. Fitted line equations of the water use per capita percentage distributions (2000-2016).

Table 3.23. Calculation of the response variable score of water use per capita indicator.

Provinces	Response Values (decrease in water use percentages)	Normalized Response Values	Response Scores
Aydın	30,84	81,19	1
Denizli	14,18	22,96	0,25
Muğla	36,224	100	1
Uşak	7,604	0	0
Turkey	21,467	Final Response Score:	0,5625

3.5.3. Access Percentage of Population to Clean Water

TÜİK (Turkish Statistical Institute) has listed 3 datasets (used as sub-indicators) with respect to this indicator, named as proportion of municipal population receiving sewage network service to total municipal population (%), proportion of municipal population receiving drinking and tap water treatment service to total municipal population (%) and proportion of municipal population receiving drinking and tap water network service to total municipal population (%), for the period between 2001 and 2016. Data for access percentages of Aydın, Denizli, Muğla, Uşak and Turkey is presented in Table 3.24.

State, pressure and response variables are again, long term average, variation relative to long term average, and improvement in access percentage of population, respectively. There was no need for normalization for the state variable since the datasets were given in percentage. Pressure and response values were normalized before scoring, with the inclusion of Turkey averages of the aforementioned 3 datasets. It is also important to note that missing values were accepted as 0.

3.5.4. Access Percentage of Population to Clean Water Scoring

For this indicator, state variable (sample mean of access of population) has a positive relationship with its score (a higher access percentage value indicates better conditions for the society).

Calculations show that Turkey's average population access to sewage network service in the period of 2001-2016 was 87%. The same percentage was 72,3 in Aydın, 83,1 in Denizli, 57,4 in Muğla and 90,6 in Uşak (Table 3.25). Measurements for the second sub-indicator reveal that on average, only 13,1% of Aydın's population, 0% of Denizli's population, 15,6% of Muğla's population and 12,4% of Uşak's population had access to drinking and tap water treatment service. Surprisingly, 47,8% of Turkey's population received this service within the period of interest. This may be the result of the assumption that missing data points were accepted as 0 for this indicator. In all of the 4 neighbour provinces and Turkey as a whole, average of the population proportion that received drinking and tap water network service was above 95%.

Pressure variable and the scores attached to it are inversely related (a higher coefficient of variation value means that the data points of the sample have deviated more from the sample mean, thus creating a bigger pressure on the society). The response variable (improvement in access, defined as the percentage difference between the first and the last year of the sample) also has a positive relationship with its score since almost in all provinces, access of population to sewage network service, access to drinking and tap water treatment service and access to drinking and tap water network service have increased between 2001 and 2016, which indicates that the society has responded to the limitations in infrastructure in a positive way. Otherwise, if a downward movement in access percentage of the 3 sub-indicators is observed between the first and the last year of the sample, response variable gets a score of 0. Linear line fitting into distribution of access percentage datasets did not work for the response variable values, since nearly in all of the datasets, values were quite close to the lower or upper limits of the access percentages (0% or 100%). That is to say, a fitted line equation may carry the value of the first or the last year which might be below 0% or above 100%. As these results would not be realistic, for this response variable fitted-line equation method is not implemented.

Table 3.24. Access percentages of Aydın, Denizli, Muğla, Uşak and Turkey to clean water.

Provinces	Years	Access % to sewage network service	Access % to drinking and tap water treatment service	Access % to drinking and tap water network service
Aydın	2001	60	11	97
	2002	63	6	97
	2003	66	7	96
	2004	69	8	98
	2006	69	17	99
	2008	73	12	99
	2010	77	13	99
	2012	81	24	99
	2014	90	14	90
	2016	75	19	97
Denizli	2001	76	0	94
	2002	82	0	98
	2003	83	0	98
	2004	84	0	99
	2006	88	0	100
	2008	89	0	99
	2010	89	0	99
	2012	90	0	99
	2014	80	0	100
	2016	70	0	99
Muğla	2001	44	6	93
	2002	46	5	93
	2003	48	6	95
	2004	50	16	97
	2006	51	14	98
	2008	56	12	97
	2010	60	15	94
	2012	72	18	95
	2014	70	26	96
	2016	77	38	100
Uşak	2001	83	0	98
	2002	85	0	100
	2003	87	0	100
	2004	87	0	100
	2006	94	0	98
	2008	94	4	99
	2010	93	6	100
	2012	96	32	95
	2014	91	44	95
	2016	96	38	96
Turkey	2001	81	35	95
	2002	83	36	97
	2003	85	39	97
	2004	86	42	99
	2006	87	49	98
	2008	88	50	99
	2010	88	54	99
	2012	92	56	98
	2014	90	58	97
	2016	90	59	98

Calculations of the state (sample mean of access of population), pressure (variation in access of population relative to sample mean) and response (percentage change in access during the period of study) variables regarding the access percentage of population to clean water indicator are shown in detail in Table 3.25.

According to Table 3.25, state scores of the 3 datasets regarding access percentages of population are 0,813, 0 and 1. Therefore, the final state variable score, which is the arithmetic mean of these 3 scores, becomes 0,604. Following the same logic, the final pressure and response variable scores become 0,5 and 0,521, respectively. Ultimately, the access percentage of population to clean water indicator gets the score of (0,604+0,5+0,521)/3 = 0,54, according to Equation (3.2).

3.5.5. Cost to Access

Data for this indicator is retrieved from local newspapers and the official websites of the municipalities of Aydın and Denizli (Aydın Su ve Kanalizasyon İdaresi, 2015, 2017, 2018; Denizli Su ve Kanalizasyon İdaresi, 2018). No past data could be found for Muğla and Uşak, therefore they were not included in the calculations. The state variable is simply the average of different monthly price levels of per unit water that households are charged for the years between 2014 and 2018. Pressure variable is the variation in unit water prices relative to the average provincial price. There is no response variable since a societal response would indicate a new economic policy regarding water prices, which is beyond this work’s scope.

3.5.6. Cost to Access Scoring

Both of the state and pressure values have negative relationships with their reference values because of the following reasons: first, a higher per unit water price is an undesirable scenario for the society, and second, more price hikes in the period of study result in a higher deviation of the data values from their sample mean, which is again, an additional pressure on the locals. In order to make a comparison between unit prices of water, historical water prices of 7 other large cities of Turkey (İstanbul, Ankara, İzmir, Adana, Antalya, Konya and Gaziantep) were included in the normalization process (Table 3.26).

Table 3.25. Calculation process of access % of population indicator.

Access to sewage network service	State Values (Sample Mean)	State Scores	Pressure Values (CV%)	Pressure Normalized	Pressure Scores	Response Values (% change)	Response Normalized	Response Scores
Aydın	72,3	0,75	12,35	50,72	0,5	15	53,85	0,5
Denizli	83,1	1	7,77	23,29	0,75	-6	0	0
Muğla	57,4	0,5	20,60	100	0	33	100	1
Uşak	90,6	1	5,23	8,16	1	13	48,72	0,5
	State Avg	0,813		Pressure Avg	0,5625		Response Avg	0,5
Access to drinking and tap water treatment service	State Values	State Scores	Pressure Values	Pressure Normalized	Pressure Scores	Response Values	Response Normalized	Response Scores
Aydın	13,1	0	43,25	29,78	0,75	8	21,05	0,25
Denizli	0	0	-	0	1	0	0	0
Muğla	15,6	0	65,11	44,83	0,5	32	84,21	1
Uşak	12,4	0	145,22	100	0	38	100	1
	State Avg	0		Pressure Avg	0,5626		Response Avg	0,5625
Access to drinking and tap water network service	State Values	State Scores	Pressure Values	Pressure Normalized	Pressure Scores	Response Values	Response Normalized	Response Scores
Aydın	97,1	1	2,81	100	0	0	22,22	0,25
Denizli	98,5	1	1,74	30,19	0,75	5	77,78	0,75
Muğla	95,8	1	2,35	69,99	0,25	7	100	1
Uşak	98,1	1	2,12	54,90	0,5	-2	0	0
	State Avg	1		Pressure Avg	0,375		Response Avg	0,5
Final Results	State Score	0,604		Pressure Score	0,5		Response Score	0,521

As a result of the normalization of the sample means and coefficient of variance percentages of unit water prices, Aydın gets a state value of 26,27 and a pressure value of 100, and Denizli's state and pressure values become 5,27 and 28,36, respectively (Table 3.27). Consequently, Aydın's state score comes out as 0,75 and its pressure score becomes 0. Denizli's state variable gets a score of 1, while its pressure score becomes 0,75. To this respect, state variable of cost to access indicator gets the score of 0,875 (arithmetic mean of Aydın and Denizli's state variable scores).

Table 3.26. Historical unit water prices of 9 big provinces of Turkey.

	Unit Water Prices (TL/cubic meter)							
Provinces	2014	2015	2016	2017	2018	2019	Sample Mean	CV%
Aydın	1,75	2,36	3,86	5,18	4,45	-	3,52	40,71
Denizli	-	2,16	2,70	3,13	3,38	3,38	2,95	17,72
İstanbul	4,29	4,21	4,36	4,79	5,13	-	4,55	8,62
Ankara	4,55	5,10	5,78	6,75	5,40	-	5,52	14,94
İzmir	-	-	3,60	4,16	4,58	-	4,11	11,95
Adana	3,00	3,27	3,50	3,91	4,94	-	3,72	20,33
Antalya	-	2,44	2,44	2,68	3,24	3,24	2,81	14,46
Konya	-	-	2,87	3,20	3,84	4,24	3,54	17,51
Gaziantep	3,64	3,89	4,16	4,65	5,07	-	4,28	13,50

Table 3.27. Normalized state and pressure values and relevant scores.

Province	Normalized State Values	State Scores	Normalized Pressure Values	Pressure Scores
Aydın	26,27	0,75	100	0
Denizli	5,27	1	28,36	0,75
	State Avg	0,875	Pressure Avg	0,375

Relatively high score of the state variable indicates that in both Aydın and Denizli, water prices are low relative to other large cities of Turkey. Pressure variable of cost to access indicator is 0,375 points (arithmetic mean of Aydın and Denizli's pressure variable scores). Therefore, the final indicator score becomes (0,875+0,375)/2 = 0,625 (the arithmetic mean of the state and pressure variables, since there is no response variable in this specific case).

3.5.7. Population Density

From the water security perspective, population increase is a challenging issue that is just as important as climate change. The consideration of water as a renewable resource has led to the exploitation of water resources by humans and created limits for water supply, and may even have prolonged its natural renewal process. For this reason, water must be considered as a finite resource in the face of quite high rates of population growth.

TÜİK (Turkish Statistical Institute) provides data regarding the number of people per km^2 for the period 2007-2017, on a provincial basis. Population density is the only pressure variable for this indicator, since it exerts a pressure on the environment and there is no response to it. A higher population density value means more pressure on the environment, so, the values and scores have inverse relationships. Numerical values obtained from TÜİK’s database were normalized in conjunction with Turkey’s population density values for the same period.

3.5.8. Population Density Scoring

Normalization process reveals that Aydın’s average population density (129,14 people per km^2) is much higher than the averages of the remaining neighbour provinces, which leads to a score of 0. Denizli gets 0,75 with a population density of 81,92 people per km^2, and Muğla and Uşak both get 1 with population densities of 66,5 people per km^2 and 64,63 people per km^2, respectively. Population density of Turkey as a whole is 98,33 people per km^2. Population densities of each province and Turkey in general are presented in Table 3.28, along with the normalized values and the pressure scores.

Table 3.28. Calculation phases of population density indicator.

Provinces	Average Population Density (person/km^2)	Normalization	Scores	Result
Aydın	129,14	100	0	0,6875
Denizli	81,92	26,81	0,75	
Muğla	66,49	2,89	1	
Uşak	64,63	0	1	
Turkey	98,33			

As a result, overall score for the population density indicator becomes 0,6875, which is the arithmetic mean of the scores of the 4 provinces.

According to the results of the 4 indicators of the access and use sub-index (water use per capita, access to clean water, cost to access and population density), the score is (0,5+0,54+0,625+0,6875)/4= 0,589 (Table 3.29). That is to say, access to clean water and water use statuses of the region are in medium conditions relative to Turkey as a whole, since the sub-index score is between 0,4 and 0,6, according to Table 3.4.

3.6. Capacity Sub-Index

Forouzani and Karami (2011) define capacity as a whole of knowledge, technological capacity (includes financial savings and investments) and capital (monetary and non-monetary). In this context, the capacity sub-index developed in this study demonstrates the capacity of society to take steps in favor of sustainable use of water resources. Education and income are considered as the two most important contributors to capacity here, since they both tend to increase the capacity of society to invest in, or stimulate the preference of environmental friendly practices as they permeate the society at all levels. In addition to education and income, current practices that the society applies in water-related sectors and the investments aimed for encouraging efficient water use are also important for the calculation of this sub-index since they express how income and educational levels are utilized. In this respect, the capacity sub-index has the highest number of indicators which can be listed as: percentage of efficient agricultural practice, household income, annual water investments, income from agricultural activities, number of locals employed and years of education (Figure 3.14).

3.6.1. Percentage of Efficient Agricultural Practice

Büke et al. (2013) refer to the intense prevalence of inefficient irrigation practices within the region surrounding Büyük Menderes River, which has been a very important problem for many years since it depends on excessive uses of water resources. According to the same study, the dominance of “surface irrigation” practice among farmers also increases the salinity of the soil and thus, decrease the soil quality, which in turn causes fertilizer use to rise. Moreover, Büke et al. (2013) refer to the warnings of officials from the irrigation unions of the region that the high pollution levels in the region cause the water-saving systems like the drip irrigation system to get blocked, and that is the main reason why most of the farmers do not want to switch to this technology. Most of the farmers want to maintain the low-cost surface irrigation practice even though the Ministry of Agriculture and Forestry has been granting investments in efficient irrigation systems since 2006. After evaluation of this information, the state, pressure and response variables were classified as the share of efficient agricultural practice in total irrigation area, ratio of the cost of the inefficient agricultural practice to the cost of switching to efficient agricultural practice, and frequency of policies supporting efficient water use in agriculture, respectively.

Table 3.29. Baseline scenario access and use sub-index results.

	Indicator Name	State Score	Pressure Score	Response Score	PSR indicator result (P+S+R)/3
Access and Use Sub-Index	Water use per capita	0,625	0,3125	0,5625	0,5
	Access to clean water (3 sub-indicators)				
	1) Proportion of population receiving sewage network service	0,8125	0,5625	0,5	0,625
	2) Proportion of population receiving drinking and tap water treatment service	0	0,5625	0,5625	0,375
	3) Proportion of municipal population receiving drinking and tap water network service	1	0,375	0,5	0,625
	Average	0,604	0,5	0,52	0,54
	Cost to access	0,875	0,375	-	0,625
	Population Density	-	0,6875	-	0,6875
				Sub-Index Result	0,589

3.6.2. Percentage of Efficient Agricultural Practice Scoring

Values for the state variable are retrieved from the yearly provincial environmental status reports for Aydın and Denizli only, because no data regarding the subject exists in the relevant reports for Muğla and Uşak (Aydın Çevre ve Şehircilik İl Müdürlüğü, 2017; Denizli Çevre ve Şehircilik İl Müdürlüğü, 2013, 2017). State score of this indicator is 0 since both in Aydın and Denizli, the percentage of areas in which drip irrigation or pressurized irrigation systems are applied are less than 1% of the total irrigation areas.

Environmental Status Report of 2017 for Aydın indicates that drip and sprinkler irrigation practices at total were used only in 131,027 ha of land in Aydın, while the total land used for irrigation was 216389 ha. Denizli's Environmental Status Report of 2017 indicates that. In 2013, the area of land in which pressurized irrigation practices were implemented was only 7,8 ha in Denizli (Denizli Çevre ve Şehircilik İl Müdürlüğü, 2013) and in 2017 (Denizli's Environmental Status Report) 21,859 ha of land implemented pressurized irrigation practices, while the total irrigation land covers 153359 ha in Denizli.

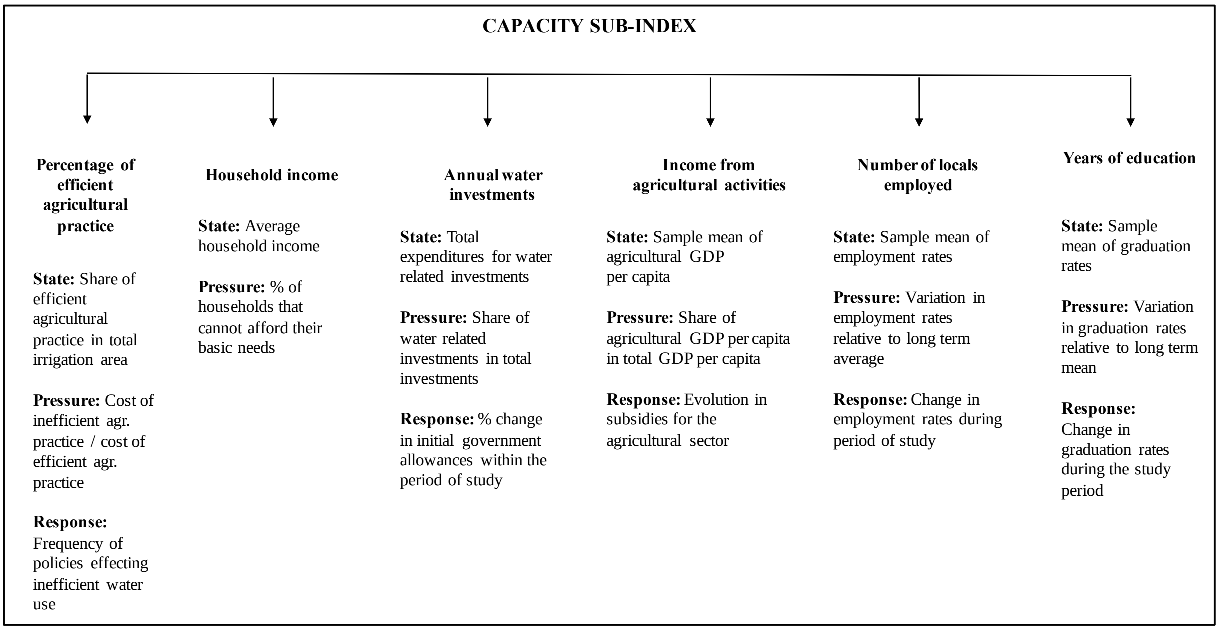

Figure 3.14. Indicators of the capacity sub-index and their relevant PSR variables.

Pressure variable is scored according to the ratio of the cost of the initial installment of surface irrigation system per decare to the cost of initial installment of water-efficient system (drip irrigation or pressurized irrigation). Information about the installment costs were gathered from the irrigation unions of Söke and Aydın through phone conversations. According to this information, the initial cost of surface irrigation system installment is about 55 liras per decare, while the initial cost of drip irrigation system installment is around 1500 liras per decare, and the cost of pressurized irrigation system is approximately 600 liras per decare. Therefore, the pressure variable is the ratio of the cost of surface irrigation over cost of drip irrigation and the value of the pressure variable is 3,67%, and the ratio of the cost of surface irrigation over cost of pressurized irrigation is 9,17%. These two ratios both reveal that surface irrigation is much cheaper than water-saving systems which also have high maintenance costs. So, for both ratios, the pressure score is 0 since they are both in the range 0-20% (Table 3.3). Apart from those, the response variable (frequency of policies supporting efficient water use) is calculated by looking at the study period and presence of incentives during the study period. In 2006, the Turkish government began to provide incentives for the use of efficient agricultural practices (Kırsal Kalkınma Destekleri Kapsamında Bireysel Sulama Sistemlerinin Desteklenmesi Hakkında Tebliğ, Resmi Gazete, 2017). This means that between 2000 and 2006, there were no incentives given, which corresponds to 38,9 % of our timeline (2000-2017). Hence, incentives were given 71,1 % of the study time, which is between the interval 60%-80%, and has an equivalent score of 0,75, according to Table 3.3. Ultimately, as state, pressure and response variables of this indicator get the scores of 0, 0 and 0,75, respectively, percentage of efficient agricultural practice indicator gets the score of (0+0+0,75)/3 = 0,25, according to Equation (3.2).

3.6.3. Household Income

For this indicator, yearly Gross Domestic Product (GDP) per capita data of Aydın, Denizli, Muğla and Uşak, as well as Turkey for the period 2004-2014 were retrieved from TÜİK database. Here, the state variable is the average household income, pressure variable is the percentage of households that cannot afford their basic needs, and there is no response variable since an increase in the average household income is dependent on the status of the Turkish economy, which is beyond the scope of this study.

3.6.4. Scoring of Household Income

A different methodology is pursued in the scoring of both the state and pressure variables for the calculation of this indicator. For the state variable, minimum and maximum levels of GDP per capita of Turkey for each year were retrieved from data that TÜİK provides on a provincial basis and then these values were averaged. Then, the average minimum-maximum range was divided into 5 equal sub-ranges for scoring. Minimum-maximum GDP per capita ranges of Turkey for the period 2004-2014 and the averages of those values are shown in Table 3.30.

After this process, average min-max GDP per capita range (5116,64 TL – 26785 TL) was divided into 5 equal sub-ranges for the purpose of fitting the scores of 0, 0,25, 0,5, 0,75 and 1 into this range. Scores assigned for each subrange are presented in Table 3.31.

Table 3.30. Minimum-maximum GDP per capita ranges of Turkey (2004-2014).

Annual GDP per capita (TL)		
Years	Turkey min	Turkey max
2004	2765	14656
2005	3164	16749
2006	3368	19368
2007	3662	21388
2008	3927	23852
2009	4210	23454
2010	5678	26253
2011	6111	31165
2012	7083	34637
2013	7829	39468
2014	8486	43645
Average	5116,64	26785

As GDP per capita gets higher, so does the score of the state variable since a higher GDP per capita is considered as an indicator of a society that is in better conditions. Average GDP per capita levels of Aydın, Denizli, Muğla and Uşak are calculated as 11819 TL, 14830 TL, 17074 TL and 12644 TL, respectively during 2004-2014.

Table 3.31. GDP per capita sub-ranges and relevant scores.

GDP per capita subrange (TL)	Scores
5116,64 – 9450,312	0
9450,312 – 13783,984	0,25
13783,984 – 18117,656	0,5
18117,656 – 22451,328	0,75
22451,328 – 26875	1

As a result, according to Table 3.31, Aydın and Uşak get a score of 0,25, whereas Denizli and Muğla get 0,5. That being said, final state score becomes 0,375, the arithmetic average of the scores of the 4 provinces. A similar technique was used for the scoring of the pressure variable. In this step, minimum and maximum levels of the percentages of households that cannot meet their basic needs in Turkey (32,8% and 75%, respectively) were extracted from TÜİK's provincial data, and this range was divided into 5 equal sub-ranges. Note that this division could only be made for the year 2015, due to data availability. Table 3.32 shows the percentages of households in Aydın, Denizli, Muğla and Uşak that cannot meet their basic needs and the calculation of the pressure scores. Pressure scores are assigned in accordance with the division of sub-ranges presented in Table 3.33.

Table 3.32. Calculation process of the pressure variable score of household income indicator.

Province	% of HHs that cannot meet their basic	Pressure	Final Pressure
Aydın	49,9	0,5	0,6875
Denizli	44,5	0,75	
Muğla	51,3	0,5	
Uşak	35,7	1	
Turkey Min	32,8		
Turkey	75		
Turkey Avg	51		

Table 3.33. Sub-ranges household percentages that cannot meet their basic needs and relevant scores.

Subranges of % of HHs that cannot meet their basic needs	Scores
32,8% - 41,24%	1
41,24% - 49,68%	0,75
49,68% - 58,12%	0,5
58,12% - 66,56%	0,25
66,56% - 75%	0

The only difference here is that as the percentage value of the pressure variable increase, score for that province decreases since a higher value implies that more people living under the poverty line. According to TÜİK's data for the year 2015, 51% of the households in Turkey have declared that their basic needs cannot be met. Moreover, Uşak has the lowest percentage of households that cannot afford their basic needs within the area of study, with 35,7%. This proportion is 49,9% in Aydın, 44,5% in Denizli, and 51,3% in Muğla. Thereby, Aydın and Muğla get a pressure score of 0,5, while Denizli gets 0,75 and Uşak gets 1 according to Table 3.3. So, the ultimate pressure variable score becomes (0,5+0,75+0,5+1)/4 = 0,6875. The ultimate score of household income is calculated as (0,375+0,6875)/2 = 0,53, which is the arithmetic mean of the state and pressure variable scores of the household income indicator.

3.6.5. Annual Water Investments

Investment data for all the sectors of Turkey for the period 1999-2018 used in the calculation of state and pressure variables were obtained from the official website of the Presidency of Strategy and Budget. Data required for the response variable, which is the percentage change in the government allowances for each province from 2000 to 2017, was obtained from TÜİK database. State variable is the total expenditures for water-related investments, and the pressure variable is the share of water related investments in total investments. Lastly, the response variable is the percentage change in initial government allowances on a yearly basis within the period 2000-2017. TÜİK provides the data required for the calculation of response variable on a provincial basis.

3.6.6. Scoring of Annual Water Investments

For the state variable (total expenditures for water-related investments), water-related investments and their relative total expenditures for the period 1999-2018 were gathered in one cluster. Water-related investments include the sectors of agriculture, vegetative production, livestock, forestry, water products, irrigation, environment, drinking water and sewage. Values of total expenditures on these sectors were normalized along with the total expenditure values of the remaining 64 sectors that are unrelated to water management such as mining, energy, tourism, housing, etc. As the amount of the expenditure on water-related projects increases, so does the score of the state variable because it means that the government is taking steps in line with the promotion of sustainable use of water resources. Normalized values and the related state scores of total expenditures on water-related sectors are presented in Table 3.34. State variable scores are assigned according to Table 3.3.

As seen in Table 3.34, overall state score (which is the average of the scores of 9 water-related sectors) was calculated as 0,083. For the pressure variable (percentage of water related projects as a share of total investments), total number of projects conducted in water-related sectors were divided by the total number of projects in order to get a percentage. Same process was followed for the 64 other sectors that are not related to water, such as mining, housing, energy, manufacturing, tourism, etc., to normalize the percentage share value of water-related projects in total projects.

Table 3.34. Total expenditures on water related sectors, their normalized values and state variable scores.

Water related sectors	Total expenditures (1000 TL) (1999-2018)	Normalized Value	State Score
Agriculture	26459137	39,28	0,25
Vegetative Production	7698664	11,43	0
Livestock	890452	1,32	0
Forestry	6192042	9,19	0
Water products	490630	0,73	0
Irrigation	31809389	47,22	0,5
Environment	674717	1	0
Drinking water	12924902	19,19	0
Sewage	3361079	4,99	0
		Average	0,083

It is important to note that the pressure variable in this case does not have an inverse relationship with its score, since investment in water-related projects tend to improve the level of water saving within the region of interest. Infrastructural capacity also increases with more money spent on water related projects. Therefore, pressure score increases as the normalized pressure value goes up. Sectoral project percentages and relevant normalized values for each sector are shown in Table 3.35.

According to Table 3.35, water related projects constituted a share of 14,95% of the total projects between 1999 and 2018. This percentage has a normalized value of 47,14, which is in the subrange (40, 60) according to Table 3.3, and thus, has a pressure score of 0,5.

As mentioned above, response values of each province were obtained from directly calculating the percentage change between the first and last yearly value of initial government allowances took effect in between 2000 and 2017. Linear fitted line equation method was not used for calculation, since the government allowance values showed an exponential increase in all provinces within the period of interest, so a fitted line equation would underestimate the response value of 2017. Furthermore, nearly all of the data points of all provinces follow each other in an incremental way, so a direct comparison between the first and last value of each sample is adequate. Normalization of the obtained response values was necessary since an increase larger than 100% in initial government allowances from 2000 to 2017 is observed in all provinces. Response values and relevant scores have a positive relationship since more allowance from the government means that there will be more money spent on sectoral projects and the infrastructural capacity of the study area will be enhanced.

Table 3.35. Project percentages of each sector and their normalized values.

Sectoral Projects	Project Percentages	Normalized Values	Pressure Score
Water related projects/Total projects	14,95	47,14	0,5
Mining projects/Total projects	1,96	1,37	
Manufacturing projects/Total projects	4,06	8,76	
Energy projects/Total projects	4,10	8,90	
Transportation projects/ Total projects	13,32	41,40	
Tourism projects/ Total projects	1,87	1,05	
Housing projects/ Total projects	1,57	0	
Education projects/ Total projects	29,94	100	
Healthcare projects/ Total projects	7,99	22,62	
Financial projects/ Total projects	5,83	15,01	
Social projects/ Total projects	14,40	45,22	
Total	100		

Percentage change in government allowance amounts between 2000 and 2017, as well as the normalized response values and relevant scores of those for Aydın, Denizli, Muğla and Uşak are presented in Table 3.36.

Table 3.36. Scoring process of the percentage change in initial government allowances (2000-2017) for Aydın, Denizli, Muğla and Uşak.

Provinces	% change between 2000-2017	Normalization	Scores
Aydın	1183,49	4,37	0
Denizli	1326,79	4,98	0
Muğla	348,16	0,88	0
Uşak	2775,94	11,05	0

In all of the provinces of interest (Aydın, Denizli, Muğla and Uşak), the normalized value of percentage change in government allowances from 2000 to 2017 is lower than 20%, which leads to scores of 0 for all, following Table 3.3. Although all of the percentage increases in initial allowances within the period of interest are above 100%, all of the 4 neighbour provinces lagged behind other provinces of Turkey. For instance, the initial government allowances increased by 24070,6% in Aksaray, by 17219,6% in Mardin and by 14177,7% in Bayburt. After the calculation of all the PSR variables of the annual water investments indicator, final score for the water investment indicator is found to be (0,083+0,5+0)/3=0,194.

3.6.7. Income from Agricultural Activities

Agricultural GDP per capita values obtained from TÜİK's database for the period 2007-2017 were used in the calculation of this indicator. State variable is the sample mean of agricultural GDP per capita values, pressure variable is agricultural GDP per capita's share in total GDP per capita, and the response variable is evolution of subsidies for the agricultural sector, measured by the percentage change in the real value index of allocated funds from budget to agricultural producers between 2004 and 2015 (Çakmak and Kasnakoğlu, 2016). Çakmak and Kasnakoğlu (2016) state that allocated funds from budget to agricultural producers included subsidies such as wheat, corn, sunflower, cotton, forage crops, tea and fertilizer payments, as well as water product, drought and rural development supports direct income support.

3.6.8. Income from Agricultural Activities Scoring

The PSR scores are directly related to their reference values, since higher incomes from agricultural activities indicate better-off levels for producers (state), a higher proportion of agricultural GDP per capita in total GDP per capita means less pressure on the capacity of the agricultural sector, meaning that it will have a higher score. Higher levels of subsidies allocated to the agricultural sector also has a positive economic effect on the industry. Agricultural GDP per capita levels of Aydın, Denizli, Muğla, Uşak and Turkey for the period 2007-2017 are shown in Table 3.37. Averages of each sample were normalized (also presented in Table 3.37) in order to reach the final state variable score.

After normalizing agricultural GDP per capita averages (Equation (3.1)), Aydın, Denizli, Muğla and Uşak got the normalized state values of 73,17, 54,87, 69,12 and 100, which led to the state scores of 0,75, 0,5, 0,75 and 1, respectively (Table 3.3). As a result, overall state score became (0,75+0,5+0,75+1)/4 = 0,75. Pressure values were calculated for each province by simply dividing the agricultural GDP per capita of that province to total GDP per capita of the same province. Then, the obtained ratio was multiplied by 100 in order to convert into percentage, for the years between 2007 and 2014.

Table 3.37. Agricultural GDP per capita levels of Aydın, Denizli, Muğla, Uşak and Turkey (2000-2017).

Agricultural GDP per capita (TL)	Aydın	Denizli	Muğla	Uşak	Turkey
2007	2324	1921	2318	2199	1479
2008	2774	2268	2560	2560	1613
2009	2668	2384	2816	2546	1696
2010	3685	3125	3752	3913	2239
2011	3783	3588	3824	4002	2565
2012	3638	3813	4020	4322	2655
2013	3582	3550	3663	4283	2486
2014	3845	3751	3603	4347	2639
2015	4194	3653	4207	4945	3161
2016	4555	4442	4426	5749	3399
2017	5837	5151	4979	6766	4005
Average	3716,82	3422,36	3651,64	4148,36	2539,73
Normalized Values	73,17	54,87	69,12	100	0
State Scores	0,75	0,5	0,75	1	
Final State Score	0,75				

2007-2014 timeline is the intersection period of two different datasets since GDP per capita data is available for the period 2004-2014 (Section 3.6.4), while data for agricultural GDP per capita involves the years between 2007 and 2017. Then, pressure values of each province and Turkey were averaged for normalization. After the normalization process, pressure scores were assigned to each city according to Table 3.3. Calculation stages of the final pressure score are presented in Table 3.38.

It can be seen from Table 3.38 that the average share of agricultural GDP per capita in total GDP per capita was the highest in Aydın with 25,36%, followed by Uşak (24,47%), both of which are quite above Turkey's average (12,06%), within the period 2007-2014. In Denizli (18,51%) and Muğla (17,54%), average shares of agricultural GDP per capita were slightly above Turkey's average (12,06%). As a result, the pressure scores of Aydın and Uşak are 1, while Denizli and Muğla both get 0,5 points. Therefore, final pressure score - the arithmetic means of the pressure scores of each province - is calculated as 0,75. Lastly, as mentioned above, response variable is the percentage change in the real value index of allocated funds from national budget to agricultural producers between 2004 and 2015, which is calculated as 36,67% (Figure 3.15).

Table 3.38. Agricultural/total GDP per capita share of each province and the calculation of final pressure variable score.

Agr./Total GDP per capita share (%)	Aydın	Denizli	Muğla	Uşak	Turkey
2007	25,14	16,30	17,03	24,96	11,78
2008	27,13	17,84	17,25	24,36	11,52
2009	26,44	19,72	19,00	23,79	12,23
2010	31,47	22,01	21,60	30,83	14,12
2011	27,77	20,78	18,84	25,64	13,65
2012	23,81	19,99	18,24	24,68	12,72
2013	20,98	16,27	15,04	21,70	10,46
2014	20,11	15,14	13,31	19,83	9,96
Average	25,36	18,51	17,54	24,47	12,06
Normalization	100	48,51	41,23	93,38	0
Pressure Scores	1	0,5	0,5	1	
Final Pressure Score	0,75				

Real value index of allocated funds from the national budget to agricultural producers is a gauge of government subsidies for the agricultural sector, and "real value index" means that the calculations of this index are made without considering the effects of inflation (i.e. the effects of increasing prices are subtracted from the actual subsidy levels). So, the real index values in Figure 3.15 give an insight about the actual amounts of subsidies allocated for the agricultural sector. In 2004, the real value index of allocated funds from budget to agricultural producers had a value of 90, while this value has increased to 123 in 2015 (or by 36,67% between 2004 and 2015). As a result, the response variable gets the score of 0,25, according to Table 3.3.

PSR variable scores of the income from agricultural activities indicator has led to the final indicator result of (0,75+0,75+0,25)/3 = 0,583.

3.6.9. Number of Locals Employed

Employment rates of the population older than 15 for the years between 2004 and 2017 (source: TÜİK database) were used as the main measurement for the PSR variables of this indicator. TÜİK provides employment data on a regional basis.

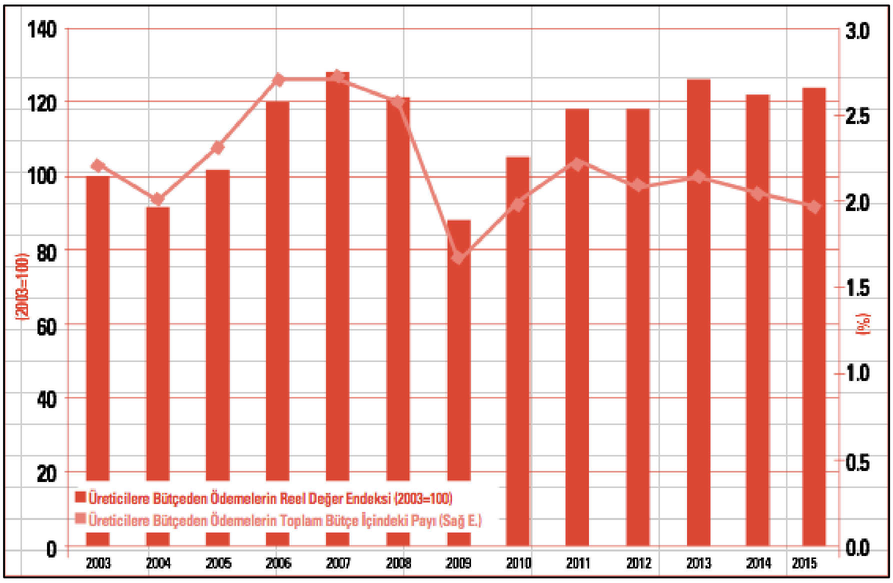

Figure 3.15. Real value index of allocated funds from national budget to agricultural producers (Çakmak and Kasnakoğlu, 2016).

Employment rate data of only TR32 region were included in the calculations since this region embodies the provinces of Aydın, Denizli and Muğla. TÜİK categorized Uşak under another region coded as TR33, which includes other provinces that are outside the borders of the study area of this work, so, employment rates of Uşak could not be included in the calculations. State variable is the sample mean, pressure is variation relative to long term average (coefficient of variation in percentage), and response is the percentage difference between the first and the last value of the sample. Pressure and response values of Aydın, Denizli, Muğla, Uşak and Turkey were normalized before scoring. There was no need for normalization for the state values since they were given in percentage.

3.6.10. Scoring of Number of Locals Employed

The higher the state and the normalized response values, the higher the corresponding score because higher employment rates depict a better status of the society. However, this relationship is reversed when it comes to the pressure variable, because more deviation from the mean indicates more socioeconomic pressure and results in a lower score. Employment rates of population older than 15 within TR32 region for the period 2004-2017 are given in Table 3.39.

Table 3.39. 15+ employment rates in TR32 region (2004-2017).

Year	Region Code	Provinces	15+ Employment Rate (%)
2004	TR32	Aydın, Denizli, Muğla	51,1
2005	TR32	Aydın, Denizli, Muğla	48,2
2006	TR32	Aydın, Denizli, Muğla	46
2007	TR32	Aydın, Denizli, Muğla	44,3
2008	TR32	Aydın, Denizli, Muğla	44,6
2009	TR32	Aydın, Denizli, Muğla	46,3
2010	TR32	Aydın, Denizli, Muğla	48,3
2011	TR32	Aydın, Denizli, Muğla	49,8
2012	TR32	Aydın, Denizli, Muğla	52,2
2013	TR32	Aydın, Denizli, Muğla	52,3
2014	TR32	Aydın, Denizli, Muğla	50,1
2015	TR32	Aydın, Denizli, Muğla	50,3
2016	TR32	Aydın, Denizli, Muğla	50,3
2017	TR32	Aydın, Denizli, Muğla	51,5
		Average	48,95
		Coeff. Of Variation (%)	5,55

State variable, which is the average of the sample, has a value of 48,95%. Nearly half of the population older than 15 on average had a job in the period between 2004 and 2017. According to Table 3.3, the state score becomes 0,5, since it is in the range of (40, 60). Pressure variable is determined as the variation relative to long term average (or the coefficient of variation), which is calculated as 5,55% for TR32 region (Table 3.39). The normalization of this value as against all the other regions of Turkey leads to a normalized pressure value of 24,77 (Table 3.40). Since the pressure value has an inverse relationship with its score, the pressure score becomes 0,75, following Table 3.3. Response variable calculation involves trendvline fitting into employment rate distributions of each region. Employment rate distribution of TR32 region and the relevant linear fitted line equation is presented in Figure 3.16.

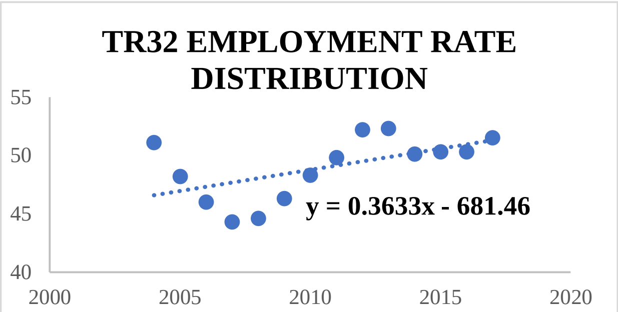

Figure 3.16. Employment rate distribution and fitted line equation of TR32 region.

According to the fitted line equation of TR32 region, employment rate has increased by 10,14% from 2004 to 2017. After the same procedure is applied to each region, response value of TR32 (10,14%) was subject to normalization against all of the other regions' response values (which cannot be presented here since there are a total of 26 regions).

Table 3.40. Calculation of pressure and response scores for the number of locals employed indicator.

Regions	Pressure Values (CV%)	Normalization of Pressure Value	Pressure Result	Response Values from fitted line equations (%)	Normalization of Response Value	Response Result
TR32	5,55	24,77	0,75	10,14	48,23	0,5
TR33	9,77			27,09		
TR10	8,13			26,166		
TR21	4,39			9,54		
TR22	2,62			0,37		
TR31	8,38			27,526		
TR41	3,53			2,43		
TR42	10,51			35,92		
TR51	8,48			29,55		
TR52	9,75			27,63		
TR61	3,09			2,58		
TR63	7,37			8,403		
TR71	8,45			21,59		
TR72	12,29			37,93		
TR81	6,96			7,77		
TR82	14,12			33,98		
TR83	3,80			-6,47		
TR90	7,29			-17,7		
TRA1	6,61			-7,67		
TRA2	6,15			12,34		
TRB1	12,00			40,02		
TRB2	8,05			18,93		
TRC1	7,04			18,84		
TRC2	14,45			36,71		
TRC3	10,76			-3,93		
TR62	7,99			24,27		

As a result, normalized response value of TR32 region was found as 48,23. So, the response score becomes 0,5, and the final indicator result is (0,5+0,75+0,5)/3 = 0,583, according to Equation (3.2).

3.6.11. Years of Education

8 sub-indicators (illiteracy rate, percentage of literates that did not finish any school, primary school graduates, secondary school graduates, high school graduates, college graduates, postgraduates and percentage of people who has a PhD) were used altogether in the calculation process of this indicator. Data regarding these 8 sub-indicators are provided by TÜİK, for the period 2008-2017. State variable is the sample mean of graduation rates, pressure variable is the variation in graduation rates relative to long term mean, and response variable is the percentage change in

graduation rates from the first to the last year of the sample. All of the PSR variable values were normalized as against rest of Turkey before scoring.

3.6.12. Scoring of Years of Education

The relationship between the state variable values and scores of illiteracy rates and the percentage of literates that did not finish any school sub-indicators are inverse since a higher illiterate rate or a higher proportion of population that did not finish any formal education is a barrier against social development, and indicate that the society is in worse conditions. Pressure variable values and scores for the 2 sub-indicators (illiteracy rate and percentage of literates that did not finish any school) are also inversely related because a higher deviation from the sample mean would point out that the society has an educational gap, thus a higher level of social pressure exists on sustainable resource usage. On the other hand, these 2 sub-indicators' response variable values have negative relationships with their scores since an increase in both of the illiterate rates and the number of literates that did not finish any school would be a negative response and worsen social capacity. Remaining 6 sub-indicators' (primary school graduates, secondary school graduates, high school graduates, college graduates, postgraduates and percentage of people who has a PhD) state and response values and scores have positive relationships, since graduation from any kind of school impacts social development in a positive way. Pressure values and scores of these remaining 6 sub-indicators are inversely related because of the same reason mentioned above: a higher deviation from the sample mean would create more pressure on society.

State and pressure values (i.e., averages and coefficient of variations of Aydın, Denizli, Muğla and Uşak's samples regarding the 8 sub-indicators), as well as their normalized values are shown in Table 3.41 and Table 3.42.

State and pressure scores of the 8 sub-indicators of education for each province as well as the final state and pressure variable scores are presented in Table 3.43.

Table 3.41. State and pressure values of 8 sub-indicators of education for each province.

Averages (%) (State Values)	**Aydın**	**Denizli**	**Muğla**	**Uşak**
Illiteracy rates	4,67	3,73	3,00	4,94
% of literates that did not finish any school	5,95	5,33	3,65	6,21
Primary school graduates	34,77	34,05	34,61	33,31
Secondary school graduates	15,75	16,43	14,03	18,01
High school graduates	18,61	19,93	21,19	19,10
College graduates	10,72	10,51	12,60	9,33
Postgraduates	0,56	0,58	0,72	0,51
% of people who has a PhD	0,17	0,19	0,20	0,14
CV (%) (Pressure Values)	**Aydın**	**Denizli**	**Muğla**	**Uşak**
Illiteracy rates	56,29	67,13	38,74	58,77
% of literates that did not finish any school	12,23	17,31	12,01	15,80
Primary school graduates	12,80	15,61	14,67	16,33
Secondary school graduates	45,05	44,02	40,76	40,07
High school graduates	9,17	9,93	7,35	8,04
College graduates	26,00	25,28	26,49	24,92
Postgraduates	44,57	46,04	41,01	43,41
% of people who has a PhD	31,63	29,71	35,06	49,25

According to Table 3.43, Aydın, Denizli, Muğla and Uşak's average state scores are 0,44, 0,47, 0,5 and 0,41, in the same order. Therefore, overall state variable score becomes (0,4375+0,4675+0,5+0,40625)/4 = 0,45. It is also seen in Table 3.43 that the average pressure scores are calculated as 0,59, 0,44, 0,69 and 0,47 for Aydın, Denizli, Muğla and Uşak, respectively. As a result, overall pressure variable score becomes the arithmetic mean of these 4 scores, 0,55.

Table 3.42. Normalized state and pressure values of the 8 sub-indicators of education.

Normalized State Values	**Aydın**	**Denizli**	**Muğla**	**Uşak**
Illiteracy rates	15,31	8,54	3,32	17,24
% of literates that did not finish any school	20,59	16,60	5,66	22,33
Primary school graduates	31,35	37,47	15,90	51,73
Secondary school graduates	23,21	36,45	31,63	38,37
High school graduates	45,59	53,68	61,46	48,60
College graduates	43,66	42,06	58,28	32,86
Postgraduates	17,46	18,42	26,60	14,67
% of people who has a PhD	20,96	23,85	25,66	15,93
Normalized Pressure Values	**Aydın**	**Denizli**	**Muğla**	**Uşak**
Illiteracy rates	77,25	97,28	41,31	81,39
% of literates that did not finish any school	33,67	66,61	32,29	56,81
Primary school graduates	48,21	86,95	40,79	86,62
Secondary school graduates	23,89	22,36	17,53	16,50
High school graduates	50,92	56,11	38,57	43,27
College graduates	28,60	25,76	30,49	24,38
Postgraduates	56,65	61,33	45,34	52,95
% of people who has a PhD	22,57	19,29	28,42	52,66

Table 3.43. Years of education indicator state and pressure scores.

State Scores	**Aydın**	**Denizli**	**Muğla**	**Uşak**
Illiteracy rates	1	1	1	1
% of literates that did not finish any school	0,75	1	1	0,75
Primary school graduates	0,25	0,25	0	0,5
Secondary school graduates	0,25	0,25	0,25	0,25
High school graduates	0,5	0,5	0,75	0,5
College graduates	0,5	0,5	0,5	0,25
Postgraduates	0	0	0,25	0
% of people who has a PhD	0,25	0,25	0,25	0
Avg. State Scores	0,44	0,47	0,50	0,41
Final State Score	0,45			
Pressure Scores	**Aydın**	**Denizli**	**Muğla**	**Uşak**
Illiteracy rates	0,25	0	0,5	0
% of literates that did not finish any school	0,75	0,25	0,75	0,5
Primary school graduates	0,5	0	0,5	0
Secondary school graduates	0,75	0,75	1	1
High school graduates	0,5	0,5	0,75	0,5
College graduates	0,75	0,75	0,75	0,75
Postgraduates	0,5	0,25	0,5	0,5
% of people who has a PhD	0,75	1	0,75	0,5
Avg. Pressure Scores	0,59	0,44	0,69	0,47
Final Pressure Score	0,55			

Lastly, as mentioned above, response values are determined as the percentage change between the first (2008) and the last (2017) year of each sample for the 8 sub-indicators. First 2 sub-indicator response values (illiteracy rate and percentage of literates that did not finish any school) have inverse relationships with their scores, whereas the remaining 6 indicator response values and relevant scores are positively related because of the reasons explained above. In order to calculate response values for each sub-indicator of each province, a linear equation was fitted into the distribution of each sample, and the percentage difference between the first and last year's value of the sample was estimated according to that fitted line equation. Response values of each province are shown in Table 3.44.

Last column of Table 3.44 represents the average response values of the other provinces of Turkey, excluding Aydın, Denizli, Muğla and Uşak. This method was followed in order to enable the normalization of the response values of 4 neighbour provinces against the rest of Turkey. It is also seen in Table 3.44 that illiteracy rates and primary school graduates had a downward movement in all provinces between 2008 and 2017. Since illiteracy rate sub-indicator's response values are inversely related to their scores, these values were accepted as positive in the normalization process, and a higher value was associated with a higher score. On the other hand, since primary school graduates sub-indicator response values are directly related to their scores, the negative numbers were accepted as positive, and a lower score was assigned to a higher score. Table 3.45 represents normalized response values of each province and their relevant response scores.

Table 3.44. Sub-indicator response values of each province and Turkey.

Sub-indicator name	**Aydın**	**Denizli**	**Muğla**	**Uşak**	**Turkey**
Illiteracy rates	-87,17	-94,44	-69,87	-87,45	-61,47
% of literates that did not finish any school	5,13	20,17	-28,54	13,05	-15,24
Primary school graduates	-30,62	-35,85	-34,72	-36,01	-28,5
Secondary school graduates	19,25	23,81	16,71	32,54	8,28
High school graduates	30,54	33,64	23,9	25,81	24,64
College graduates	126,28	121,17	126,97	116,32	157,34
Postgraduates	378,95	397,83	415,38	337,97	245,24
% of people who has a PhD	243,17	228,1	256,54	602,59	248,98

Arithmetic mean of the response scores of Aydın, Denizli, Muğla and Uşak lead to the final response score of 0,43. According to Equation (3.2), the overall years of education indicator result becomes (0,45+0,55+0,43)/3 = 0,477.

Table 3.45. Normalized response values of the 8 sub-indicators of years of education indicator and their relevant scores.

	Normalized Response Values			
Sub-indicator name	**Aydın**	**Denizli**	**Muğla**	**Uşak**
Illiteracy rates	77,95	100	25,48	78,80
% of literates that did not finish any school	69,12	100	0	85,38
Primary school graduates	28,23	97,87	82,82	100
Secondary school graduates	45,22	64,01	34,75	100
High school graduates	68,17	100	0	19,61
College graduates	24,28	11,82	25,96	0
Postgraduates	78,59	89,68	100	54,50
% of people who has a PhD	4,02	0	7,59	100
	Response Scores			
Illiteracy rates	0,75	1	0,25	0,75
% of literates that did not finish any school	0,27	0	1	0
Primary school graduates	0,75	0	0	0
Secondary school graduates	0,5	0,75	0,25	1
High school graduates	0,75	1	0	0
College graduates	0,25	0	0,25	0
Postgraduates	0,75	1	1	0,5
% of people who has a PhD	0	0	0	1
Average	0,5	0,47	0,34	0,41
Final Response Score	0,43			

According to the arithmetic mean of the final results of the 6 capacity indicators (percentage of efficient agricultural practice, household income, annual water investments, income from agricultural activities, number of locals employed and years of education), this sub-index gets a score of 0,436 (Table 3.46), meaning that the societal capacity of the region of study to take steps towards sustainable water use is in “medium conditions” (Table 3.4).

3.7. Sustainability Sub-Index

The last sub-index of the water security index is sustainability, since a water secure environment necessitates sustainable use of environmental resources. Factors that affect sustainability in Aydın, Denizli, Muğla and Uşak are chosen in compliance with the major problems of the region, which can be listed as land cover change (change in the percentage of green areas), treatment plant wastewater discharges and the percentage of clean production in the industrial sector (Erdoğan, 2012; Büke et al., 2013). Erdoğan (2012) emphasizes that population increase stimulates the unidirectional change in land use and intensifies the impacts of especially erosion, fires and decrease in productivity of the soil. Büke et al. (2013) mention that extremely dirty production of the industrial sector is one of the biggest problems of the region, and they underline that the outputs of leather and textile factories in Denizli and Uşak have been threatening the aquatic habitats and in some parts of the region, water resources have become unusable as a result. At the same time, region’s economy is also heavily dependent on these 2 industries, which is a controversial topic that is included in the discussion part (Section 5). However, the last sustainability indicator (percentage of clean production in the industrial sector) could not be included in the calculations since there is no data regarding this subject. Figure 3.17 shows the indicators of the sustainability sub-index and their relevant PSR variables.

Table 3.46. Baseline calculation results of the capacity sub-index.

	Indicator Name	State Score	Pressure Score	Response Score	PSR indicator result (P+S+R)/3
Capacity Sub-Index	Efficient agricultural practice (%)	0	0	0,75	0,25
	HH income	0,375	0,6875	-	0,531
	Annual water investments	0,083	0,5	0	0,194
	Income from agricultural activities	0,75	0,75	0,25	0,583
	Number of locals	0,5	0,75	0,5	0,583
	Years of education	0,453	0,547	0,430	0,477
				Sub-Index Result	0,436

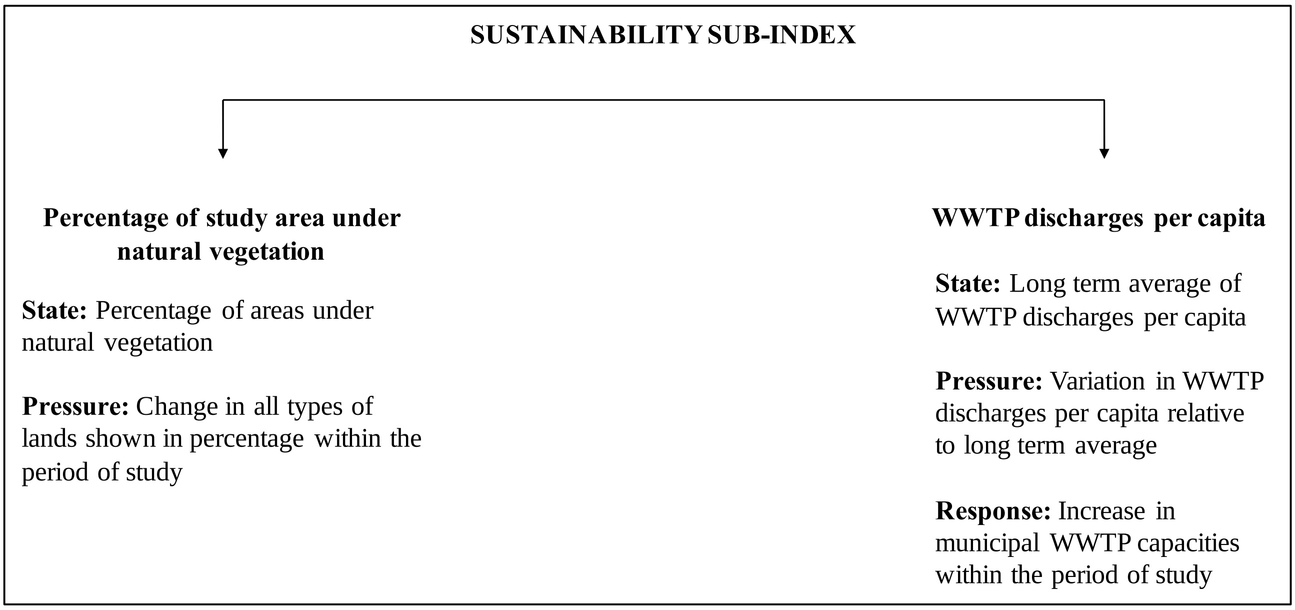

Figure 3.17. Indicators of the sustainability sub-index and their relevant PSR variables.

3.7.1. Percentage of Study Area under Natural Vegetation

In the provincial environmental status reports of Aydın, Muğla, Denizli and Uşak, land use data for the period 1990-2012 were presented (Aydın Çevre ve Şehircilik İl Müdürlüğü, 2017; Denizli Çevre ve Şehircilik İl Müdürlüğü, 2017; Muğla Çevre ve Şehircilik İl Müdürlüğü, 2017; Uşak Çevre ve Şehircilik İl Müdürlüğü, 2017). According to these reports, total land is divided into 5 categories: artificial lands, agricultural lands, forests and semi-natural lands, wetlands and water bodies. For the calculation of this indicator, data for artificial lands, agricultural lands and forests and semi-natural lands were adequate, since the change in green areas is investigated. State variable is the percentage of the study area under natural vegetation, and the pressure variable is the increase/decrease percentages of all types of lands (artificial lands, agricultural lands and forests and semi-natural lands) between 1990 and 2012. Response variable could not be generated due to data availability regarding the improvement in conservation areas within the period studied.

3.7.2. Percentage of Study Area Under Natural Vegetation Scoring

As mentioned above, the state variable is chosen as the percentage of area under natural vegetation. In line with data provided in provincial environmental status reports, forests and semi-natural lands are associated with lands with natural vegetation. Agricultural lands were not included in the calculation of the state values because of the assumption that they are converted to fields from forests, or lands with natural vegetation. State values and their relevant scores have a positive relationship, since an increase in natural vegetation area percentage is beneficial for the environment. Scores are given for the state values of each data year (1990, 2000, 2006 and 2012), and the average scores for each year are calculated in order to reach final scores for each province. Then, the average of those scores for each province is taken to calculate the ultimate state score. Calculation details of the final state score are shown in Table 3.47.

It is seen in Table 3.47 that in all of the sample years, the percentage of study area under natural vegetation was between 40% and 60% in Aydın, thus leading to a state score of 0,5 for each year, according to Table 3.3. As a result, Aydın gets a state score of 0,5, the arithmetic mean of the yearly state scores. Following the same logic, Denizli and Uşak's state scores are also 0,5, and Muğla gets 0,75 points. Taking the arithmetic mean of the provincial state scores leads to the ultimate state variable score of 0,5625.

Table 3.47. State values and scores of the percentage of study area under natural vegetation indicator.

	State Values (% of basin area under natural vegetation)				
Province	State (1990)	State (2000)	State (2006)	State (2012)	State Scores
Aydın	49,51	49,33	47,83	47,67	0,5
Denizli	56,51	56,4	54,46	54,41	0,5
Muğla	73,41	73,12	73,49	73,35	0,75
Uşak	48,41	48,26	42,24	42,18	0,5
				Average	0,5625

Pressure variable here is the percentage change in all land types, so according to each type of land, the technique of grading changes. A decrease in the areas of agricultural lands, forests and semi-natural lands, wetlands and water bodies all have negative outcomes, so, a contraction in these types of lands is associated with a lower pressure score. On the other hand, a decrease in the area of artificial lands has a positive meaning, so a higher pressure score is assigned to a lower pressure value for this type of land. Fitted line equation method could not be used in the calculation of percentage changes between the first and the last values of each sample here, since the number of data years is not adequate to apply this technique. Table 3.48 shows the pressure values, normalized pressure values and their relevant scores.

As it is shown in Table 3.48, in all provinces, there is a decrease in forests and semi-natural land areas between 1990 and 2012. So, in the normalization process of the pressure values of this type of land, negative percentages were accepted as positive numbers, and the highest number (-13,46%) got the lowest score (0), and vice versa (Table 3.3). As a result of the pressure score calculations shown in Table 3.48, the overall pressure score of the percentage of study area under natural vegetation variable becomes (0,4375+0,5+0,6875+0,5+0,25)/5 = 0,475. Thus, the indicator score was calculated as (0,5625+0,475)/2 = 0,529, which is the average of state and pressure scores.

Table 3.48. Increase and decrease percentages in all types of lands (1990-2012) and the calculation of pressure scores.

	Pressure Values (Land Cover Change % between 1990-2012)				
Provinces	**Artificial Lands**	**Agricultural Lands**	**Forests and Semi-Natural Lands**	**Wetlands**	**Water Bodies**
Aydın	40,43	3,58	-2,09	-18,80	15,07
Denizli	25,96	4,77	-3,57	8,31	62,81
Muğla	65,33	-3,25	-0,02	-7,49	-8,05
Uşak	-4,08	11,37	-13,46	-	979,56
	Normalized Pressure Values				
Aydın	64,12	46,69	15,40	0	2,34
Denizli	43,28	54,80	26,46	100	7,18
Muğla	100	0	0	41,72	0
Uşak	0	100	100	-	100
	Pressure Scores				
	Artificial Lands	**Agricultural Lands**	**Forests and Semi-Natural Lands**	**Wetlands**	**Water Bodies**
Aydın	0,25	0,5	1	0	0
Denizli	0,5	0,5	0,75	1	0
Muğla	0	0	1	0,5	0
Uşak	1	1	0	-	1
Averages	0,4375	0,5	0,6875	0,5	0,25
Pressure Result	0,475				

3.7.3. Treatment Plant Wastewater Discharges Per Capita

Data in relation to the daily municipal wastewater discharge levels per capita (liter/day) for the period 2001-2016 is taken from TÜİK database. State (long term average of discharges per capita), pressure (variation relative to the long-term average) and response (increase in municipal wastewater treatment plant capacities) were all normalized before scoring. Since this indicator is related to wastewater, which has negative effects on the environment as its discharge increases, all variable scores except the response variable scores have negative relationships with their reference values.

According to daily municipal wastewater discharge levels per capita data (given in liter/day) retrieved from TÜİK database (Table 3.49), in Aydın, an average 201 liters of wastewater per capita was discharged in a day, for the period 2001-2016. This number was 146,6 in Denizli, 396,8 in Muğla, 129,3 Uşak and 173,8 in Turkey as a whole. Normalization process of these 5 values yielded the normalized state values of 26,8, 6,47, 100 and 0 for Aydın, Denizli, Muğla and Uşak, respectively.

Since the state values have negative relationships with their scores, Aydın gets a score of 0,75, Denizli gets 1, Muğla gets 0 and Uşak gets 1 according to Table 3.3. As a result, the overall state score becomes 0,6875. Table 3.50 shows the calculation stages for the state and pressure variables.

3.7.4. Treatment Plant Wastewater Discharges Per Capita Scoring

Table 3.49. Daily municipal wastewater discharge levels per capita (2000-2016).

	Daily municipal wastewater discharge levels per capita (liter/day)				
Years	Aydın	Denizli	Muğla	Uşak	Turkey
2001	167	118	253	101	147
2002	172	116	398	105	154
2003	178	120	436	115	173
2004	181	121	452	117	174
2006	292	143	486	122	181
2008	206	150	446	141	173
2010	183	163	402	166	182
2012	205	156	480	144	190
2014	181	198	361	148	181
2016	245	181	254	134	183

Table 3.50. Calculation of final PSR scores of the WWTP discharges per capita indicator.

Discharge per capita (liter/day)		State Values (Sample Mean)				
		Aydın	Denizli	Muğla	Uşak	Turkey
		201	146,6	396,8	129,3	173,8
		Normalized State Values				
		26,80	6,47	100	0	State Result
	State Scores	0,75	1	0	1	0,6875
		Pressure (CV%)				
		Aydın	Denizli	Muğla	Uşak	Turkey
		19,56	19,46	21,30	16,04	7,74
		Normalized Pressure Values				
		87,18	86,45	100	61,236	Pressure Result
	Pressure Scores	0	0	0	0,25	0,0625

Pressure values, determined as the coefficient of variation of each sample (Aydın, Denizli, Muğla, Uşak and Turkey), lead to the pressure scores of 0 for Aydın, Denizli and Muğla, and 0,25 for Uşak, after the normalization process. Therefore, the final pressure variable score becomes 0,0625 (Table 3.50).

Lastly, as it is mentioned above, response variable is defined as the percentage increase in municipal wastewater treatment plant capacities. Calculation process of the response variable (which is determined as the same response variable for proportion of wastewater treatment service in Section 3.4.5.4) is shown in Table 3.12, so, overall response score is 0,5. Ultimately, overall indicator score is calculated as (0,6875+0,0625+0,5)/3 = 0,417.

According to the results of sustainability indicators, this sub-index gets a score of (0,519+0,417)/2=0,468 by taking the arithmetic mean of percentage of study area under natural vegetation and treatment plant wastewater discharges per capita indicators (Table 3.51).

Table 3.51. Baseline calculation results of the sustainability sub-index.

	Indicator Name	State Score	Pressure Score	Response Score	PSR indicator result (P+S+R)/3
Sustainability Sub-Index	% of study area under natural vegetation	0,5626	0,475	No Data	0,519
	Treatment plant wastewater discharges per capita	0,6875	0,0625	0,5	0,417
			Sub-Index Result		0,468

The numerical value of 0,468 implies that the sustainable use of resources within the region is in "medium conditions", however, since the clean production indicator could not be incorporated into the estimations, this sub-index might have been overestimated. This situation is a good example of weak environmental monitoring and data storage practices in Turkey interfering with proper estimations, which will be discussed in Section 5.

3.8. Baseline Calculation of the Water Security Index

The overall value of water security index of Aydın, Denizli, Muğla and Uşak is the arithmetic average of the 4 sub-indices (resource, access and use, capacity, and sustainability), since they are all assumed to have equal importance in the face of water security, thus given equal weights in the final calculation. As a result, the baseline index value becomes (0,399+0,589+0,436+0,468)/4 = 0,473 (Table 3.52).

Overall water security index result (0,473) falls into the range of "medium conditions" (Table 3.4), implying that there is a medium level of water security within the region, according to past data. In the following section, future climate and population data are incorporated in the calculations, and the results will be compared against the baseline values.

Table 3.52. Water security index results under baseline scenario.

	Indicator Name	State Score	Pressure Score	Response Score	PSR indicator result (P+S+R)/3
Resource Sub-Index	Water Budget	-0,21	0,5	-0,25	0,013
	Aridity Index	0,79	0,8125	0	0,534
	Water Quality Sub-Indicator	0,2	0,75	0,417	0,456
	Proportion of municipal population receiving ww treatment service (%)	0,375	0,4375	0,5	0,4375
		WQ Indicator Average	0,447		
	Fertilizer Use	0,5625	1	0,4375	0,667
	Reservoir Capacity	0,25	0,75	0	0,333
		Sub-Index Result		0,399	
Access and Use Sub-Index	Indicator Name	State Score	Pressure Score	Response Score	PSR indicator result (P+S+R)/3
	Water use per capita	0,625	0,3125	0,5625	0,5
	Access to clean water (3 sub-indicators)				
	1) Proportion of population receiving sewage network service	0,8125	0,5625	0,5	0,625
	2) Proportion of population receiving drinking and tap water treatment service	0	0,5625	0,5625	0,375
	3) Proportion of municipal population receiving drinking and tap water network service	1	0,375	0,5	0,625
	Average	0,604	0,5	0,52	0,54
	Cost to access	0,875	0,375	-	0,625
	Population Density	-	0,6875	-	0,6875
		Sub-Index Result		0,589	
Capacity Sub-Index	Indicator Name	State Score	Pressure Score	Response Score	PSR indicator result (P+S+R)/3
	Efficient agricultural practice	0	0	0,75	0,25
	HH income	0,375	0,6875	-	0,531
	Annual water investments	0,083	0,5	0	0,194
	Income from agricultural activities	0,75	0,75	0,25	0,583
	Number of locals employed	0,5	0,75	0,5	0,583
	Years of education	0,453	0,547	0,430	0,477
		Sub-Index Result		0,436	
Sustainability Sub-Index	Indicator Name	State Score	Pressure Score	Response Score	PSR indicator result (P+S+R)/3
	% of study area under natural vegetation	0,5626	0,475	No Data	0,519
	Treatment plant wastewater discharges per capita	0,6875	0,0625	0,5	0,417
		Sub-Index Result		0,468	
		Water Security Index Result		0,473	

Data collection was the most challenging part of this work. As practices of monitoring and data collection regarding environmental indicators are not consistent and practiced for a long time in Turkey, it is even more challenging to aggregate the existing data with different time scales. For example, historical data for precipitation and evaporation is needed for the baseline calculation of water budget and the aridity index and acquired from Turkish State Meteorological Service in two different formats: first, daily precipitation data for the period 2005-2018 which was measured by automatic meteorological observation stations, and the second dataset, daily precipitation data for the period 2000-2005 which was measured manually with many missing values. To overcome this problem, daily rainfall values for 2000-2004 were replaced with the historical simulation data obtained from U.S.'s National Center for Environmental Prediction (NCEP) database. Historical daily totals of open surface evaporation obtained from Turkish State Meteorological Service had many missing months for all of the provinces for 2005-2018, thus, those missing values were filled with the simulation data obtained from Boğaziçi University's Center for Climate Change and Policy Studies.

Another issue of missing data arose in the calculation process of future population density indicator. Population projections for Turkey, obtained from TURKSTAT contains the projections until the year 2080, whereas provincial population projections taken from the same source only has projections until the year 2025. This contradiction between two different time scales was solved with the "linear regression straight line method", which provided the extension of the missing data from 2025 to 2080, which is discussed in more detail in Section 4.3.1.

4. FUTURE SCENARIO DEVELOPMENT

It is now a significant challenge for water planners to predict future water supply levels because the unstable weather conditions make it harder to estimate future water quantities. It will be a much challenging problem to access clean water for the future generations, since they will live in a more densely populated world where the finite water resources will be exploited even more. These are the reasons why it is now compulsory to develop future scenarios in the evaluation of water related risks. Even if water resources of a region are not under the risk of scarcity right now, it is not guaranteed that the region will be water-secure in the future. So, development of future scenarios was necessary for this work in order to analyse the effects of climate change and population increase on the water security of the 4 neighbour provinces in the Aegean region. Schulze's work (2000) can be given as an example for such evaluations as he attempts to measure the sensitivity of Southern Africa's certain hydrological variables against changes in precipitation levels, in order to analyse the exacerbations that climate change create on the fluctuations of the Southern African hydrological regime. In another work which is more related to this one due to the adoption of Pressure-State-Response methodology, Chaves and Alipaz (2007) advocate that the impacts of climate change/variability on water availability in watersheds can be evaluated through incorporation into the hydrologic pressure parameters. Yet, in this work, future data is incorporated into all of the pressure, state and response variables, if they exist for the reference indicator. There are some other studies that examine the potential effects of future developments on: domestic water demand from an economic point of view (Neverre and Dumas, 2015), global water stress and water withdrawals through a dynamic global vegetation model (Murray et al., 2012). Another important work in which the impacts of climate change and population increase on water scarcity is assessed at the global level is that of Gosling and Arnell's (2016). In their work, they assess the impact of a range of possible future climate scenarios by a variety of global climate models, which makes their project comprehensive in water scarcity literature. In their analysis, they use 2 indices, named as Water Crowding Index (WCI) and Water Stress Index (WSI), which are gauges of total annual water resources per capita (emphasizes population size) and the ratio of water withdrawals to resources (highlights water use in agriculture), respectively. Similar kinds of these measures are used here in this study as a part of the water security index of the 4 neighbour provinces, which will be discussed below in more detail. Again, based on Gosling and Arnell's (2016) four metrics that isolate the sole impact of future climate change and the combined effects of future climate change, population and/or withdrawals pressure on water scarcity, 3 different schemes are integrated to the current (baseline) value of the water security index in this work: sole effect of climate change, sole effect of population increase, and the combined effects of these two dynamics on water security of the study area. Analysis of the effects of climate change on the water resources and water security of the region of interest involves two different Representative Concentration Pathway (RCP) scenarios.

The purpose of RCPs is to project future trends of greenhouse gas concentrations and emissions, and have an influence on policy makers. Moss et al. (2010) introduce RCP scenarios as pioneers in next stages of researches in relation to climate change modelling, and they mention that there are 4 different RCPs (RCP2.6, RCP4.5, RCP6.0 and RCP8.5). Wayne (2013) informs that these 4 different scenarios represent different alternatives for potential future greenhouse gas concentration trajectories and the numerical values 2.6, 4.5, 6.0 and 8.5 of the four scenarios refer to the radiative forcings in watts /m^2 (global energy imbalances) in the year 2100. Therefore, RCP2.6 scenario is the lowest greenhouse gas concentration projection scenario, while RCP8.5 is the scenario with highest emissions. Australian National Climate Change Adaptation Research Facility (NCCARF, n.d.) warns that the current emission levels are tracking close to the RCP8.5 pathway, in which the efforts to curb greenhouse gas emissions is the lowest and the consequent global temperature increases are the highest.

In this study, future climate data extracted from RCP4.5 and RCP8.5 scenarios provided by Boğaziçi University’s Center for Climate Change and Policy Studies are used. For the development of RCP4.5 and RCP8.5 scenarios, Boğaziçi University’s Center for Climate Change and Policy Studies used MPI-M-MPI-ESM-MR (global climate model of Max Planck Institute for Meteorology) data as the Global Climate Model (GCM) input, and the projections of future climate conditions until the year 2100 for the Middle East North Africa (MENA) Coordinated Regional Climate Downscaling Experiment (CORDEX) domain are modelled by forcing Regional Climate Model RegCM4.4-v5 of the International Centre for Theoretical Physics (ICTP), following Öztürk et al. (2018). Coordinates of the future climate data are the same as the geographic location of the historical climate data obtained from the observation stations of Turkish State Meteorological Service (Figure 3.4).

The use of future data from two different RCP models enables a comparison between the impacts of different climate scenarios with different levels of effort on reducing emissions and adds flexibility to this thesis project. Calculation of the future scores in compliance with the incorporation of RCP8.5 and RCP4.5 simulations into water budget and aridity index indicators of the resource sub-index is explained in Section 4.1, with a detailed analysis of the observed changes between the baseline and future values of the resource sub-index and the overall water security index.

4.1. RCP8.5 (High Emission) Climate Change Scenario

In this section, the sole effect of RCP8.5 climate change scenario on the water security level (which was estimated as in the range of "medium conditions" under baseline conditions) of the study region is investigated. Future precipitation, average temperature and evapotranspiration data required for the calculation of future water budget and aridity index scores are retrieved from Boğaziçi University's Center for Climate Change and Policy Studies, for the period 2018-2100.

4.1.1. Calculation of Future Water Budget and Its PSR Variable Scores under RCP8.5 Scenario

The units of future precipitation and evapotranspiration data obtained were both in $kg/m^2/day$, which is simply the same as mm/day, so no changes in units were necessary. However, future streamflow data was absent, so, the "runoff coefficient method", which is well-accepted in literature is used to estimate future runoff levels. Critchley et al. (1991) introduce the unitless runoff coefficient (K) in its rainfall-runoff analysis chapter as a certain fraction of total rainfall in mm:

$$K=\frac{\text{Monthly total runoff (mm)}}{\text{Total rainfall (mm)}} \tag{4.1}$$

and they give Finkel's (1987) correlation between rainfall and runoff factor in percentage for Kenya's Baringo region as an example, shown in Figure 4.1:

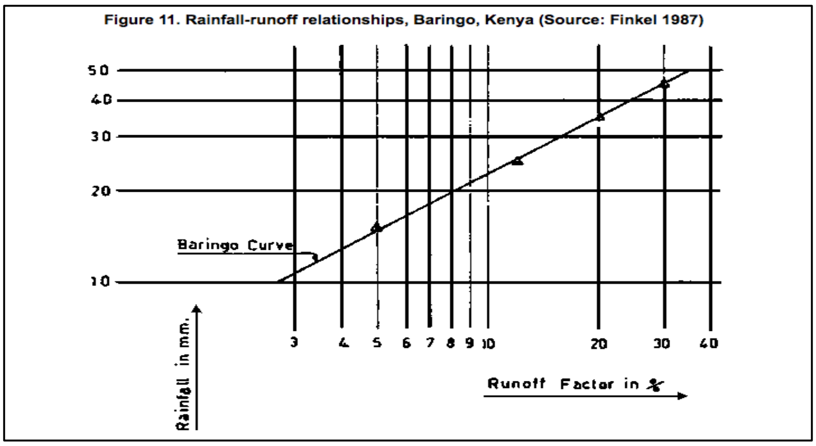

Figure 4.1. Finkel's correlation between rainfall and runoff factor in percentage.

However, Finkel (1987) also argue that if soil moisture and rainstorm duration are known along with the level of rainfall, the relationship between the runoff factor and precipitation would be much better. In another work, Shanan and Tadmor (1979) suggest that there is a requirement of at least 2-year data of rainfall and runoff, to reach a correlation between these two variables.

In a previous thesis project carried out by Acınan (2008), runoff coefficients of all basins in Turkey, including the Büyük Menderes River Basin, were calculated by the help of Geographic Information Systems Software. According to this study, monthly runoff coefficient values for 8 different locations in Aydın, Denizli, Muğla and Uşak are calculated as in Table 4.1:

Table 4.1. Monthly runoff coefficients of 8 different locations in Aydın, Denizli, Muğla and Uşak (Acınan, 2008).

Province	Name of Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Aydın	Aydın Köprüsü	0,12	0,16	0,14	0,14	0,11	0,17	0,29	0,45	0,22	0,09	0,06	0,08
Aydın	Çakırbeyli	0,19	0,29	0,26	0,26	0,16	0,17	0,14	0,23	0,07	0,04	0,04	0,09
Denizli	Çalıköy	0,11	0,13	0,09	0,11	0,09	0,16	0,44	0,57	0,23	0,06	0,03	0,05
Muğla	Yemişendere	0,49	0,55	0,54	0,5	0,32	0,32	0,72	0,51	0,45	0,16	0,16	0,41
Denizli	Akhan	0,49	0,55	0,5	0,57	0,6	0,91	0,78	1,14	1,04	0,72	0,37	0,39
Denizli	Çıtak Köprüsü	0,06	0,09	0,09	0,13	0,15	0,26	0,69	1,15	0,53	0,08	0,05	0,04
Aydın	Güney Burhaniye	0,07	0,1	0,08	0,11	0,11	0,23	0,52	0,77	0,5	0,08	0,04	0,05
Uşak	Azizler	0,14	0,26	0,25	0,3	0,17	0,18	0,03	0,01	0,02	0,02	0,04	0,08

After the multiplication of monthly precipitation values with the monthly average runoff coefficients of each province, future runoff values were estimated for each city in units of mm/month. Then, the same water budget equation (Equation 3.3) was used in the baseline calculations again. Monthly values of each province were summed up in order to reach the provincial annual water budget numbers. In the last step, values obtained for each city were averaged for each year (2018-2100), and final annual average water budget values for the same timeline were calculated for the region of interest as a whole (Figure 4.2).

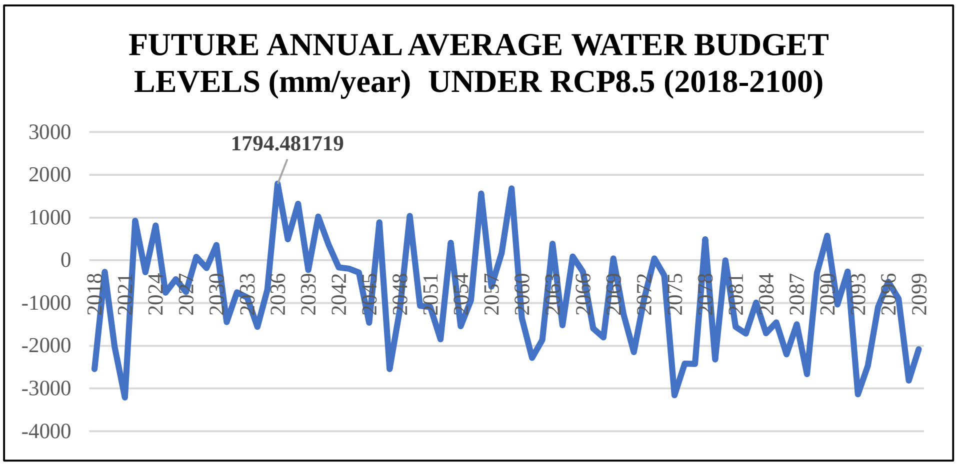

Figure 4.2. Annual average water budget levels (2008-2100) of the study area (RCP8.5).

According to Figure 4.2, the highest annual water budget average (1794,48 mm/year) within the region will occur in the year 2036. Scoring method is exactly the same as in the baseline scenario. First, the year 2036 is given the value 100, and the percentage changes between 2036 and each other year of the sample were calculated to obtain state variable values. Since these values are all negative (2036 is the year with the highest average water budget), normalization is done using Equation (3.7), and those normalized state values were averaged to reach the final state score (Table 4.2).

According to Table 4.2, state variable score (which is the average of the water budget scores between 2018 and 2100) is -0,521. Pressure variable gets the score 0, since the variation of water budget relative to its mean has a value of 144,36% (bigger than 100%), and the response variable score is -1, since a downward movement by -683,654% was observed in the fitted line equation of the distribution of annual average water budget data points for the period 2018-2100 (Figure 4.3).

Thereby, overall future water budget indicator is (-0,521+0-1)/3=-0,507. This number shows that the score of water budget has decreased by 0,52 when the future climate data is integrated into the calculations, which is a significant amount.

Figure 4.3. Distribution of the averages of annual water budget levels under RCP8.5.

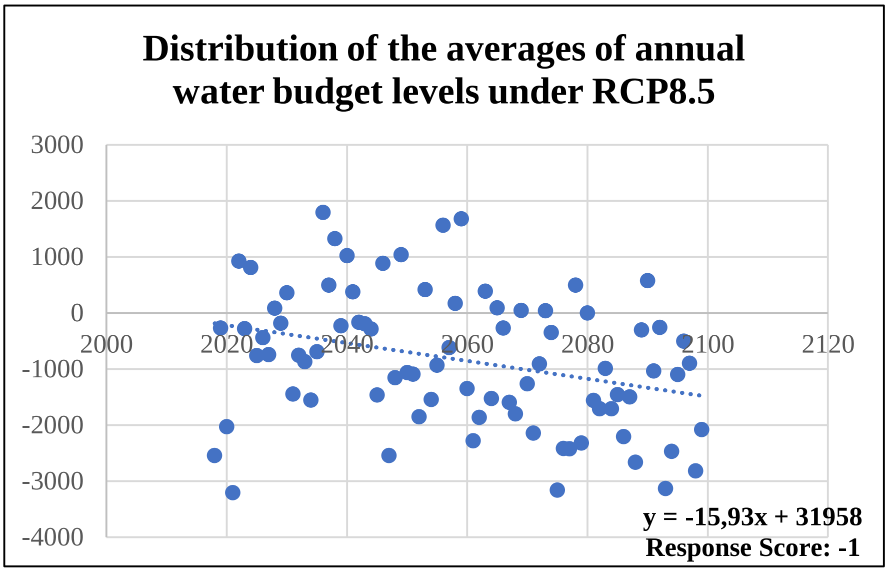

Table 4.2. State score calculation for the future water budget indicator (RCP8.5).

Years	Annual Average Water Budget (mm/year)	Values	Change (%)	Absolute value of change %	Normalization	SCORES = Normalization*-1	SCORES
2036 (baseline year)	1794,48	100	-	-	-	-	-
2018	-2543,24	-141,73	-241,73	241,73	0,86	-0,86	-0,86
2019	-269,14	-15,00	-115,00	115,00	0,40	-0,40	-0,40
2020	-2028,99	-113,07	-213,07	213,07	0,76	-0,76	-0,76
2021	-3209,24	-178,84	-278,84	278,84	1,00	-1,00	-1,00
2022	923,64	51,47	-48,53	48,53	0,15	-0,15	-0,15
2023	-278,85	-15,54	-115,54	115,54	0,40	-0,40	-0,40
2024	811,14	45,20	-54,80	54,80	0,18	-0,18	-0,18
2025	-758,65	-42,28	-142,28	142,28	0,50	-0,50	-0,50
2026	-443,63	-24,72	-124,72	124,72	0,43	-0,43	-0,43
2027	-742,83	-41,39	-141,39	141,39	0,50	-0,50	-0,50
2028	84,69	4,72	-95,28	95,28	0,33	-0,33	-0,33
2029	-182,74	-10,18	-110,18	110,18	0,38	-0,38	-0,38
2030	359,33	20,02	-79,98	79,98	0,27	-0,27	-0,27
2031	-1446,84	-80,63	-180,63	180,63	0,64	-0,64	-0,64
2032	-753,23	-41,97	-141,97	141,97	0,50	-0,50	-0,50
2033	-868,26	-48,39	-148,39	148,39	0,52	-0,52	-0,52
2034	-1555,23	-86,67	-186,67	186,67	0,66	-0,66	-0,66
2035	-692,05	-38,57	-138,57	138,57	0,49	-0,49	-0,49
2037	496,17	27,65	-72,35	72,35	0,24	-0,24	-0,24
2038	1323,05	73,73	-26,27	26,27	0,07	-0,07	-0,07
2039	-227,33	-12,67	-112,67	112,67	0,39	-0,39	-0,39
2040	1021,98	56,95	-43,05	43,05	0,13	-0,13	-0,13
2041	376,19	20,96	-79,04	79,04	0,27	-0,27	-0,27
2042	-168,74	-9,40	-109,40	109,40	0,33	-0,33	-0,38
2043	-194,10	-10,82	-110,82	110,82	0,33	-0,33	-0,38
2044	-287,64	-16,03	-116,03	116,03	0,36	-0,36	-0,40
2045	-1462,94	-81,52	-181,52	181,52	0,61	-0,61	-0,64

Years	Annual Average Water Budget (mm/year)	Values	Change (%)	Absolute value of change %	Normalization	SCORES = Normalization*-1	SCORES
2046	886,19	49,38	-50,62	50,62	0,10	-0,10	-0,16
2047	-2542,28	-141,67	-241,67	241,67	0,85	-0,85	-0,86
2048	-1156,90	-64,47	-164,47	164,47	0,55	-0,55	-0,58
2049	1040,75	58,00	-42,00	42,00	0,06	-0,06	-0,13
2050	-1063,72	-59,28	-159,28	159,28	0,53	-0,53	-0,56
2051	-1094,68	-61,00	-161,00	161,00	0,53	-0,53	-0,57
2052	-1850,18	-103,10	-203,10	203,10	0,70	-0,70	-0,72
2053	413,96	23,07	-76,93	76,93	0,20	-0,20	-0,26
2054	-1546,00	-86,15	-186,15	186,15	0,63	-0,63	-0,66
2055	-934,80	-52,09	-152,09	152,09	0,50	-0,50	-0,53
2056	1562,99	87,10	-12,90	12,90	-0,05	0,05	-0,02
2057	-618,44	-34,46	-134,46	134,46	0,43	-0,43	-0,47
2058	171,51	9,56	-90,44	90,44	0,25	-0,25	-0,31
2059	1681,62	93,71	-6,29	6,29	-0,08	0,08	0,00
2060	-1349,94	-75,23	-175,23	175,23	0,59	-0,59	-0,62
2061	-2281,53	-127,14	-227,14	227,14	0,80	-0,80	-0,81
2062	-1866,64	-104,02	-204,02	204,02	0,70	-0,70	-0,73
2063	387,91	21,62	-78,38	78,38	0,21	-0,21	-0,26
2064	-1523,84	-84,92	-184,92	184,92	0,63	-0,63	-0,66
2065	90,83	5,06	-94,94	94,94	0,27	-0,27	-0,33
2066	-271,94	-15,15	-115,15	115,15	0,35	-0,35	-0,40
2067	-1593,30	-88,79	-188,79	188,79	0,64	-0,64	-0,67
2068	-1801,57	-100,39	-200,39	200,39	0,69	-0,69	-0,71
2069	42,25	2,35	-97,65	97,65	0,28	-0,28	-0,34
2070	-1263,02	-70,38	-170,38	170,38	0,57	-0,57	-0,60
2071	-2146,33	-119,61	-219,61	219,61	0,78	-0,78	-0,78
2072	-909,94	-50,71	-150,71	150,71	0,53	-0,53	-0,53
2073	41,79	2,33	-97,67	97,67	0,34	-0,34	-0,34
2074	-352,34	-19,63	-119,63	119,63	0,42	-0,42	-0,42
2075	-3158,79	-176,03	-276,03	276,03	0,99	-0,99	-0,99
2076	-2417,08	-134,69	-234,69	234,69	0,84	-0,84	-0,84
2077	-2425,58	-135,17	-235,17	235,17	0,84	-0,84	-0,84
2078	494,21	27,54	-72,46	72,46	0,24	-0,24	-0,24
2079	-2320,43	-129,31	-229,31	229,31	0,82	-0,82	-0,82
2080	-3,56	-0,20	-100,20	100,20	0,34	-0,34	-0,34
2081	-1558,55	-86,85	-186,85	186,85	0,66	-0,66	-0,66
2082	-1711,59	-95,38	-195,38	195,38	0,69	-0,69	-0,69
2083	-988,99	-55,11	-155,11	155,11	0,55	-0,55	-0,55
2084	-1706,77	-95,11	-195,11	195,11	0,69	-0,69	-0,69
2085	-1455,83	-81,13	-181,13	181,13	0,64	-0,64	-0,64
2086	-2204,47	-122,85	-222,85	222,85	0,79	-0,79	-0,79
2087	-1500,16	-83,60	-183,60	183,60	0,65	-0,65	-0,65
2088	-2665,54	-148,54	-248,54	248,54	0,89	-0,89	-0,89
2089	-302,54	-16,86	-116,86	116,86	0,41	-0,41	-0,41
2090	578,21	32,22	-67,78	67,78	0,23	-0,23	-0,23
2091	-1032,98	-57,56	-157,56	157,56	0,56	-0,56	-0,56
2092	-260,17	-14,50	-114,50	114,50	0,40	-0,40	-0,40
2093	-3133,10	-174,60	-274,60	274,60	0,98	-0,98	-0,98
2094	-2467,76	-137,52	-237,52	237,52	0,85	-0,85	-0,85
2095	-1097,04	-61,13	-161,13	161,13	0,57	-0,57	-0,57
2096	-504,59	-28,12	-128,12	128,12	0,45	-0,45	-0,45
2097	-899,71	-50,14	-150,14	150,14	0,53	-0,53	-0,53
2098	-2817,03	-156,98	-256,98	256,98	0,92	-0,92	-0,92
2099	-2079,98	-115,91	-215,91	215,91	0,77	-0,77	-0,77
CV%	144,36					**STATE RESULT**	-0,521

4.1.2. Calculation of Future Aridity Index and Its PSR Variable Scores under RCP8.5 Scenario

As we know from Section (3.4.3), for the calculation of the aridity index indicator, Thornthwaite's method adopted in this study demands numerical values of mean monthly temperatures and annual precipitation levels which both exist in the climate datasets for the period 2018-2100 that Boğaziçi University's Center for Climate Change and Policy Studies has provided. The only difference here was that the RCP8.5 temperature data was in the form of Kelvin (K), which in turn was converted to Celcius (C), by simply subtracting 273,15 from all mean temperature values. Calculation processes of potential evapotranspiration and the overall indicator values, as well as the PSR variables and the scoring methods of those are exactly the same as in the baseline scenario. Provincial state variable scores, which is the average of the aridity index scores for each year between 2018 and 2100, is calculated as 0,595 for Aydın, 0,557 for Denizli, 0,973 for Muğla and 0,4425 for Uşak. The average of these 4 numbers yielded the final RCP8.5 scenario aridity index indicator state variable result of 0,642 (Table 4.3). It is also important to note that the future aridity index value (not the score) of the study area as a whole– which is the average of the future aridity indices of the 4 provinces – was calculated as 0,769 (also shown in Table 4.3), which implicates the area of concern will remain in the category of "dry land" within the period until 2100.

Pressure variable values that are determined by coefficient of variation percentages are as follows for each province: 31,95% for Aydın, 31,72% for Denizli, 32,2% for Muğla and 32,84% for Uşak (Table 4.3). Therefore, each province gets a pressure score of 0,75 according to Table 3.3, since a higher coefficient of variation percentage indicates more pressure on the environment, and gets a lower score. Hereby, the ultimate pressure variable score of RCP8.5 scenario's aridity index indicator becomes 0,75, the arithmetic mean of the pressure scores of the 4 provinces. Once again, for the calculation of the response score, which gauges the evolution in aridity levels of the 4 neighbour provinces within the period 2018-2100, a linear equation was fitted into the distribution of annual aridity index estimations for each province (Figure 4.4). Percentage difference between the first and last year of the sample according to the fitted line equations (Figure 4.4) determines the response values of each province.

Response values for Aydın, Denizli, Muğla and Uşak were calculated as -40,84%, -37,64%, -46,33% and -31,47%, respectively, according to the fitted line equations shown in Figure 4.4.

Main reason behind these negative scores is that in RCP8.5 model's AI estimations, a downward movement between the years 2018 and 2100 is observed in all provinces. A lower AI value indicates more dryness, which gets a lower score since it is a negative outcome for the water resources, according to Table 3.7.

Table 4.3. State and pressure variable results of future aridity index indicator (RCP8.5).

Aridity Index (P/PET)	**AYDIN**	**DENİZLİ**	**MUĞLA**	**UŞAK**	**SCORES**	**AYDIN**	**DENİZLİ**	**MUĞLA**	**UŞAK**
2018	0,34	0,40	1,24	0,22	**2018**	0,4	0,4	1	0,4
2019	0,93	0,75	2,13	0,66	**2019**	0,8	0,8	1	0,8
2020	0,51	0,51	1,49	0,38	**2020**	0,6	0,6	1	0,4
2021	0,22		1,05	0,19	**2021**	0,4	-	1	0,2
2022	0,81	0,84	2,19	0,47	**2022**	0,8	0,8	1	0,4
2023	0,75	0,60	2,02	0,47	**2023**	0,8	0,6	1	0,4
2024	0,84	0,69	2,55	0,52	**2024**	0,8	0,8	1	0,6
2025	0,62	0,62	1,63	0,51	**2025**	0,6	0,6	1	0,6
2026	0,73	0,52	2,16	0,24	**2026**	0,8	0,6	1	0,4
2027	0,53	0,47	1,81	0,36	**2027**	0,6	0,4	1	0,4
2028	0,71	0,59	1,96	0,37	**2028**	0,8	0,6	1	0,4
2029	0,76	0,63	1,84	0,45	**2029**	0,8	0,6	1	0,4
2030	0,89	0,79	1,98	0,53	**2030**	0,8	0,8	1	0,6
2031	0,52	0,59	1,66	0,50	**2031**	0,6	0,6	1	0,4
2032	0,55	0,53	1,89	0,28	**2032**	0,6	0,6	1	0,4
2033	0,52	-	1,72	-	**2033**	0,6	-	1	-
2034	0,42	0,44	1,26	0,39	**2034**	0,4	0,4	1	0,4
2035	0,55	0,53	1,89	0,51	**2035**	0,6	0,6	1	0,6
2036	1,02	0,89	2,36	0,62	**2036**	1	0,8	1	0,6
2037	0,75	0,78	2,19	0,57	**2037**	0,8	0,8	1	0,6
2038	0,79	0,80	2,24	0,60	**2038**	0,8	0,8	1	0,6
2039	0,68	0,53	2,10	0,42	**2039**	0,8	0,6	1	0,4
2040	0,84	0,88	2,20	0,57	**2040**	0,8	0,8	1	0,6
2041	0,81	0,73	2,08	0,62	**2041**	0,8	0,8	1	0,6
2042	0,73	0,59	1,88	0,48	**2042**	0,8	0,6	1	0,4
2043	0,85	0,75	1,78	0,59	**2043**	0,8	0,8	1	0,6
2044	0,75	0,66	1,80	0,52	**2044**	0,8	0,8	1	0,6
2045	0,40	0,37	1,51	0,25	**2045**	0,4	0,4	1	0,4
2046	0,92	0,80	2,08	0,59	**2046**	0,8	0,8	1	0,6
2047	0,41	0,44	1,23	0,38	**2047**	0,4	0,4	1	0,4
2048	0,65	0,51	1,23	0,39	**2048**	0,6	0,6	1	0,4
2049	0,89	0,64	1,71	0,60	**2049**	0,8	0,6	1	0,6
2050	0,49	0,52	1,69	0,44	**2050**	0,4	0,6	1	0,4
2051	0,64	-	1,53	-	**2051**	0,6	-	1	-
2052	0,41	0,28	1,23	0,23	**2052**	0,4	0,4	1	0,4
2053	0,76	0,75	1,89	0,49	**2053**	0,8	0,8	1	0,4
2054	0,43	0,33	1,34	0,29	**2054**	0,4	0,4	1	0,4
2055	0,66	0,47	1,37	0,45	**2055**	0,8	0,4	1	0,4
2056	0,88	0,87	2,78	0,66	**2056**	0,8	0,8	1	0,8
2057	0,59	0,63	1,74	0,45	**2057**	0,6	0,6	1	0,4
2058	0,67	0,46	2,06	0,36	**2058**	0,8	0,4	1	0,4
2059	0,96	0,90	3,42	0,83	**2059**	0,8	0,8	1	0,8
2060	0,48	0,42	1,35	0,31	**2060**	0,4	0,4	1	0,4
2061	0,39	0,33	0,83	0,21	**2061**	0,4	0,4	0,8	0,4
2062	0,39	0,30	1,14	0,28	**2062**	0,4	0,4	1	0,4
2063	0,63	0,52	1,63	0,43	**2063**	0,6	0,6	1	0,4
2064	0,48	0,31	1,56	0,29	**2064**	0,4	0,4	1	0,4
2065	0,70	0,60	2,10	0,38	**2065**	0,8	0,6	1	0,4
2066	0,67	0,65	1,57	0,39	**2066**	0,8	0,8	1	0,4
2067	0,49	0,44	1,12	0,31	**2067**	0,4	0,4	1	0,4

Aridity Index (P/PET)	AYDIN	DENİZLİ	MUĞLA	UŞAK	SCORES	AYDIN	DENİZLİ	MUĞLA	UŞAK
2068	0,54	0,42	1,14	0,42	**2068**	0,6	0,4	1	0,4
2069	0,70	0,52	1,89	0,45	**2069**	0,8	0,6	1	0,4
2070	0,51	0,38	1,28	0,34	**2070**	0,6	0,4	1	0,4
2071	0,41	0,33	1,09	0,32	**2071**	0,4	0,4	1	0,4
2072	0,51	0,51	1,32	0,42	**2072**	0,6	0,6	1	0,4
2073	0,60	0,51	1,35	0,37	**2073**	0,6	0,6	1	0,4
2074	0,58	0,64	1,54	0,48	**2074**	0,6	0,6	1	0,4
2075	0,22	0,28	0,75	0,19	**2075**	0,4	0,4	0,8	0,2
2076	0,37	0,35	0,96	0,24	**2076**	0,4	0,4	0,8	0,4
2077	0,36	0,31	0,84	0,30	**2077**	0,4	0,4	0,8	0,4
2078	0,81	0,51	1,98	0,44	**2078**	0,8	0,6	1	0,4
2079	0,41	0,41	1,05	0,28	**2079**	0,4	0,4	1	0,4
2080	0,57	0,54	2,12	0,32	**2080**	0,6	0,6	1	0,4
2081	0,45	0,40	1,04	0,32	**2081**	0,4	0,4	1	0,4
2082	0,46	0,45	1,46	0,44	**2082**	0,4	0,4	1	0,4
2083	0,53	0,45	1,53	0,29	**2083**	0,6	0,4	1	0,4
2084	0,43	0,33	1,02	0,29	**2084**	0,4	0,4	1	0,4
2085	0,49	0,34	0,97	0,28	**2085**	0,4	0,4	0,8	0,4
2086	0,36	0,34	0,96	0,24	**2086**	0,4	0,4	0,8	0,4
2087	0,41	0,51	1,29	0,37	**2087**	0,4	0,6	1	0,4
2088	0,39	0,45	1,08	0,38	**2088**	0,4	0,4	1	0,4
2089	0,58	0,48	1,25	0,37	**2089**	0,6	0,4	1	0,4
2090	0,62	0,46	1,47	0,29	**2090**	0,6	0,4	1	0,4
2091	0,45	0,52	1,28	0,52	**2091**	0,4	0,6	1	0,6
2092	0,58	0,65	1,54	0,48	**2092**	0,6	0,8	1	0,4
2093	0,38	0,29	0,80	0,23	**2093**	0,4	0,4	0,8	0,4
2094	0,32	0,34	0,94	0,19	**2094**	0,4	0,4	0,8	0,2
2095	0,62	0,67	1,37	0,41	**2095**	0,6	0,8	1	0,4
2096	0,56	0,51	1,63	0,31	**2096**	0,6	0,6	1	0,4
2097	0,35	0,35	0,84	0,26	**2097**	0,4	0,4	0,8	0,4
2098	0,28	0,35	0,91	0,34	**2098**	0,4	0,4	0,8	0,4
2099	0,38	0,28	0,82	0,27	**2099**	0,4	0,4	0,8	0,4
Average	0,58	0,53	1,57	0,40	**Average**	0,595	0,557	0,973	0,4425
Average State Value	0,769				**Average State Score**	0,642			
Pressure (CV%)	31,95	31,72	32,20	32,84	**Pressure Variable Score**	0,75			

Eventually, future aridity index (AI) indicator under RCP8.5 scenario gets the result of (0,642+0,75-0,375)/3 = 0,339, the arithmetic mean of future water budget indicator's PSR variables. At this point, it is observed that overall future aridity index indicator score is approximately 0,195 points below the baseline score (0,534).

4.1.3. Analysis of The Effects of Climate Change under RCP8.5 on Water Security of the Study Area

Summary of the integration of future climate values under RCP8.5 to both of the water budget and aridity index indicators are shown in Table 4.4.

According to Table 4.4, future precipitation, evapotranspiration and temperature levels until the year 2100 under RCP8.5 scenario have a negative pressure on the 4 neighbour provinces' water budget and aridity scores, thus decreasing the overall resource sub-index value by approximately 0,143 points.

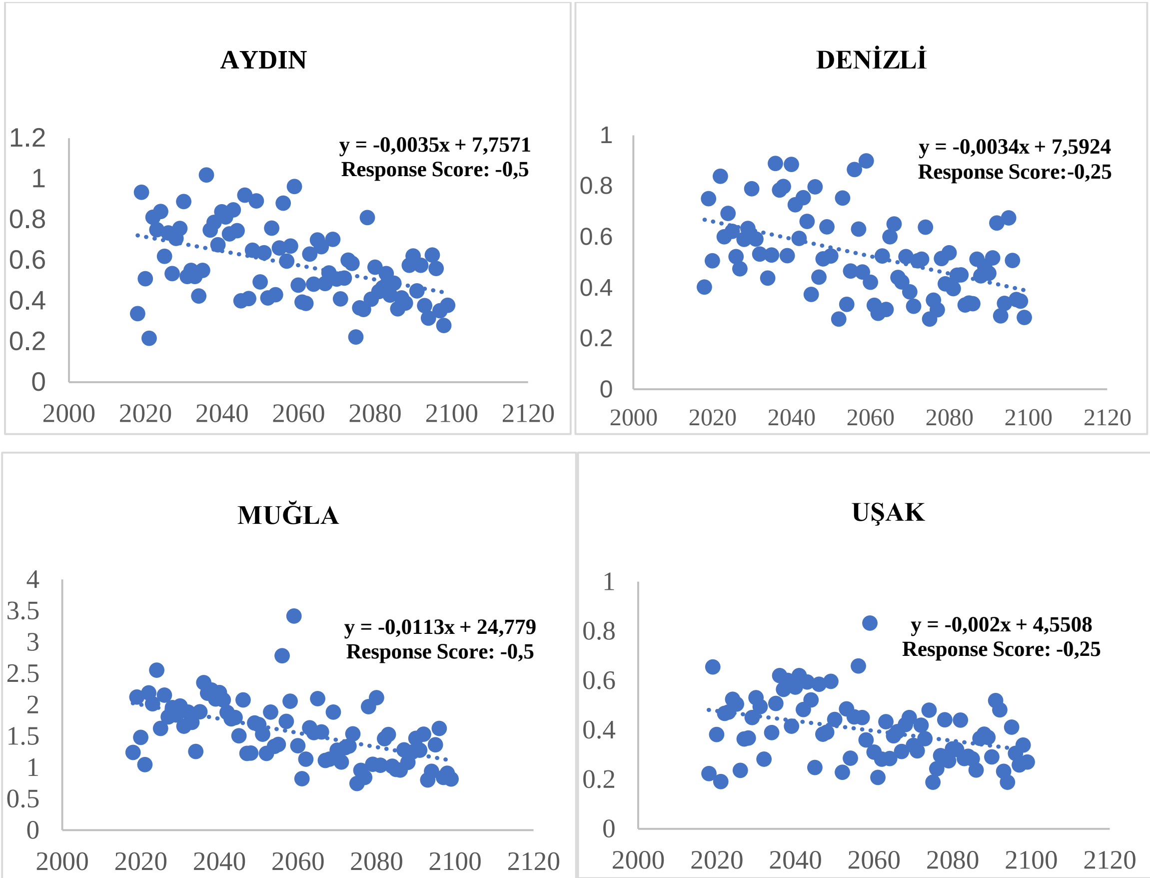

Figure 4.4. Distributions of AI estimations under RCP8.5 scenario and reference fitted line equations.

As it was mentioned in Section 3.4, the resource sub-index in the baseline scenario has already showed "poor conditions" in the region's water resources. After the integration of future climate data, the resource sub-index fell towards the lower threshold value (0,2) of "poor conditions", which buoys the idea that there is no guarantee that the study area's water resources (quantities and qualities of those as a whole) will not drop into the range of "very poor conditions" under RCP8.5 scenario.

Consequently, after the integration of RCP8.5 climate change scenario into the resource sub-index, the final value of the water security index diminishes from 0,473 to 0,437 (Table 4.5 and Table 4.6).

It is important here to keep in mind that there is a total of 17 indicators settled within the overall index, each having an equal weight in the calculation process. From this point of view, the 0,036 points of decrease caused by the climate forecasts is non-negligible. Still, regardless of this downward movement towards the "poor conditions" range (0,2-0,4), overall water security conditions of the 4 neighbour provinces will stay in "medium conditions", according to Table 3.4.

Table 4.4. Resource sub-index values under baseline and RCP8.5 scenarios.

	Indicator Name	State Score	Pressure Score	Response Score	PSR indicator result (P+S+R)/3
Resource Sub-Index	Water Budget	-0,21	0,5	-0,25	0,013
	Aridity Index	0,79	0,8125	0	0,534
	Water Quality Sub-Indicator	0,2	0,75	0,417	0,456
	Proportion of municipal population receiving ww treatment service (%)	0,375	0,4375	0,5	0,4375
		WQ Indicator Average	0,447		
	Fertilizer Use	0,5625	1	0,4375	0,667
	Reservoir Capacity	0,25	0,75	0	0,333
Baseline Scenario		**Sub-Index Result**		0,399	
	Indicator Name	State Score	Pressure Score	Response Score	PSR indicator result (P+S+R)/3
Resource Sub-Index	Water Budget	-0,521	0	-1	-0,507
	Aridity Index	0,642	0,75	-0,375	0,339
	Water Quality Sub-Indicator	0,2	0,75	0,417	0,456
	Proportion of municipal population receiving ww treatment service (%)	0,375	0,4375	0,5	0,4375
		WQ Indicator Average	0,447		
	Fertilizer Use	0,5625	1	0,4375	0,667
	Reservoir Capacity	0,25	0,75	0	0,333
Climate Change Scenario (RCP8.5)		**Sub-Index Result**		0,256	

4.2. RCP4.5 (Low Emission) Climate Change Scenario

Future precipitation, temperature and evapotranspiration data obtained from Boğaziçi University's Center for Climate Change and Policy Studies for the years between 2018 and 2100 under RCP4.5 scenario (the scenario in which the greenhouse gas emissions are relatively lower than the RCP8.5 scenario) was used to evaluate the effects of climate change on the water security level in the region of interest. However, future streamflow data required for the calculation of future water budget indicator was not available, so, the monthly runoff coefficients are calculated by using the method explained in Acınan (2008).

Table 4.5. Water security index calculations under baseline scenario.

	Indicator Name	State Score	Pressure Score	Response Score	PSR indicator result (P+S+R)/3
Resource Sub-Index	Water Budget	-0,21	0,5	-0,25	0,013
	Aridity Index	0,79	0,8125	0	0,534
	Water Quality Sub-Indicator	0,2	0,75	0,417	0,456
	Proportion of municipal population receiving ww treatment service (%)	0,375	0,4375	0,5	0,4375
		WQ Indicator Average	0,447		
	Fertilizer Use	0,5625	1	0,4375	0,667
	Reservoir Capacity	0,25	0,75	0	0,333
		Sub-Index Result		0,399	
Access and Use Sub-Index	Indicator Name	State Score	Pressure Score	Response Score	PSR indicator result (P+S+R)/3
	Water use per capita	0,625	0,3125	0,5625	0,5
	Access to clean water (3 sub-indicators)				
	1) Proportion of population receiving sewage network service	0,8125	0,5625	0,5	0,625
	2) Proportion of population receiving drinking and tap water treatment service	0	0,5625	0,5625	0,375
	3) Proportion of municipal population receiving drinking and tap water network service	1	0,375	0,5	0,625
	Average	0,604	0,5	0,52	0,54
	Cost to access	0,875	0,375	-	0,625
	Population Density	-	0,6875	-	0,6875
		Sub-Index Result		0,589	
Capacity Sub-Index	Indicator Name	State Score	Pressure Score	Response Score	PSR indicator result (P+S+R)/3
	Efficient agricultural practice	0	0	0,75	0,25
	HH income	0,375	0,6875	-	0,531
	Annual water investments	0,083	0,5	0	0,194
	Income from agricultural activities	0,75	0,75	0,25	0,583
	Number of locals employed	0,5	0,75	0,5	0,583
	Years of education	0,453	0,547	0,430	0,477
		Sub-Index Result		0,436	
Sustainability Sub-Index	Indicator Name	State Score	Pressure Score	Response Score	PSR indicator result (P+S+R)/3
	% of study area under natural vegetation	0,5626	0,475	No Data	0,519
	Treatment plant wastewater discharges per capita	0,6875	0,0625	0,5	0,417
		Sub-Index Result		0,468	
		Water Security Index Result		0,473	

Table 4.6. Water security index calculations under RCP8.5 climate change scenario.

	Indicator Name	State Score	Pressure Score	Response Score	PSR indicator result (P+S+R)/3
Resource Sub-Index	Water Budget	-0,521	0	-1	-0,507
	Aridity Index	0,642	0,75	-0,375	0,339
	Water Quality Sub-Indicator	0,2	0,75	0,417	0,456
	Proportion of municipal population receiving ww treatment service (%)	0,375	0,4375	0,5	0,4375
		WQ Indicator Average	0,447		
	Fertilizer Use	0,5625	1	0,4375	0,667
	Reservoir Capacity	0,25	0,75	0	0,333
		Sub-Index Result		**0,256**	
Access and Use Sub-Index	Indicator Name	State Score	Pressure Score	Response Score	PSR indicator result (P+S+R)/3
	Water use per capita	0,625	0,3125	0,5625	0,5
	Access to clean water (3 sub-indicators)				
	1) Proportion of population receiving sewage network service	0,8125	0,5625	0,5	0,625
	2) Proportion of population receiving drinking and tap water treatment service	0	0,5625	0,5625	0,375
	3) Proportion of municipal population receiving drinking and tap water network service	1	0,375	0,5	0,625
	Average	0,604	0,5	0,52	0,54
	Cost to access	0,875	0,375	-	0,625
	Population Density	-	0,6875	-	0,6875
		Sub-Index Result		0,589	
Capacity Sub-Index	Indicator Name	State Score	Pressure Score	Response Score	PSR indicator result (P+S+R)/3
	Efficient agricultural practice	0	0	0,75	0,25
	HH income	0,375	0,6875	-	0,531
	Annual water investments	0,083	0,5	0	0,194
	Income from agricultural activities	0,75	0,75	0,25	0,583
	Number of locals employed	0,5	0,75	0,5	0,583
	Years of education	0,453	0,547	0,430	0,477
		Sub-Index Result		0,436	
Sustainability Sub-Index	Indicator Name	State Score	Pressure Score	Response Score	PSR indicator result (P+S+R)/3
	% of study area under natural vegetation	0,5626	0,475	No Data	0,519
	Treatment plant wastewater discharges per capita	0,6875	0,0625	0,5	0,417
		Sub-Index Result		0,468	
		Water Security Index Result		**0,437**	

4.2.1. Calculation of Future Water Budget and Its PSR Variable Scores under RCP4.5 Scenario

Methods used in Section 3.4.1., Section 3.4.2 and Section 4.1.1 for the calculation of future water budget indicator's PSR values and scores are repeated here. Figure 4.5 shows the future annual average water budget levels of Aydın, Denizli, Muğla and Uşak under RCP4.5 scenario for the period 2018-2100.

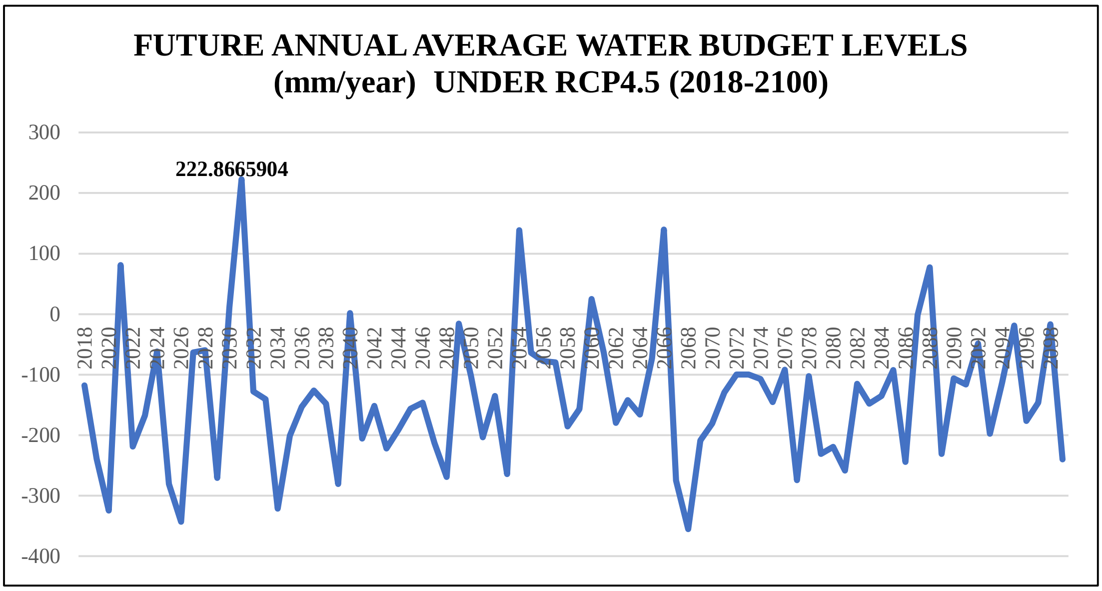

Figure 4.5. Future annual average water budget levels of Aydın, Denizli, Muğla and Uşak under RCP4.5 scenario.

According to Figure 4.5, the highest annual water budget average (222,86 mm/year) within the region will occur in the year 2031. Scoring method is exactly the same as in the baseline scenario.

First, the year 2031 is given the value 100, and the percentage changes between 2036 and each other year of the sample were calculated to obtain state variable values. Since these values are all negative (2031 is the year with the highest average water budget), normalization is done using Equation (3.7), and those normalized state values were averaged to reach the final state score (Table 4.7).

Table 4.7. State variable score calculation for the future water budget indicator (RCP4.5).

Years	Annual Average Water Budget (mm/year)	Values	Change %	Absolute value of change %	Normalization	SCORES = Normalization*-1
2031 (baseline year)	222,87	100	-	-	-	-
2018	-118,07	-52,98	-152,98	152,98	0,52	-0,52
2019	-239,11	-107,29	-207,29	207,29	0,76	-0,76
2020	-324,32	-145,52	-245,52	245,52	0,94	-0,94
2021	81,27	36,47	-63,53	63,53	0,12	-0,12
2022	-218,84	-98,19	-198,19	198,19	0,72	-0,72
2023	-167,48	-75,15	-175,15	175,15	0,62	-0,62
2024	-61,88	-27,76	-127,76	127,76	0,41	-0,41
2025	-280,56	-125,89	-225,89	225,89	0,85	-0,85
2026	-343,25	-154,02	-254,02	254,02	0,98	-0,98
2027	-63,43	-28,46	-128,46	128,46	0,41	-0,41
2028	-59,89	-26,87	-126,87	126,87	0,40	-0,40
2029	-270,84	-121,53	-221,53	221,53	0,83	-0,83
2030	11,00	4,93	-95,07	95,07	0,26	-0,26
2032	-127,95	-57,41	-157,41	157,41	0,54	-0,54
2033	-140,47	-63,03	-163,03	163,03	0,57	-0,57
2034	-321,62	-144,31	-244,31	244,31	0,93	-0,93
2035	-200,89	-90,14	-190,14	190,14	0,69	-0,69
2036	-153,29	-68,78	-168,78	168,78	0,59	-0,59
2037	-126,48	-56,75	-156,75	156,75	0,54	-0,54
2038	-147,73	-66,29	-166,29	166,29	0,58	-0,58
2039	-280,88	-126,03	-226,03	226,03	0,85	-0,85
2040	1,74	0,78	-99,22	99,22	0,28	-0,28
2041	-205,55	-92,23	-192,23	192,23	0,70	-0,70
2042	-151,67	-68,05	-168,05	168,05	0,59	-0,59
2043	-222,21	-99,71	-199,71	199,71	0,73	-0,73
2044	-191,58	-85,96	-185,96	185,96	0,67	-0,67
2045	-156,39	-70,17	-170,17	170,17	0,60	-0,60
2046	-146,15	-65,58	-165,58	165,58	0,58	-0,58
2047	-212,88	-95,52	-195,52	195,52	0,71	-0,71
2048	-268,95	-120,68	-220,68	220,68	0,83	-0,83
2049	-15,94	-7,15	-107,15	107,15	0,31	-0,31
2050	-101,75	-45,66	-145,66	145,66	0,49	-0,49
2051	-203,58	-91,35	-191,35	191,35	0,69	-0,69
2052	-135,44	-60,77	-160,77	160,77	0,56	-0,56
2053	-264,50	-118,68	-218,68	218,68	0,82	-0,82
2054	138,86	62,31	-37,69	37,69	0,00	0,00
2055	-63,88	-28,66	-128,66	128,66	0,41	-0,41
2056	-77,54	-34,79	-134,79	134,79	0,44	-0,44
2057	-79,57	-35,70	-135,70	135,70	0,44	-0,44
2058	-185,37	-83,17	-183,17	183,17	0,66	-0,66
2059	-157,15	-70,51	-170,51	170,51	0,60	-0,60
2060	24,70	11,08	-88,92	88,92	0,23	-0,23
2061	-63,10	-28,31	-128,31	128,31	0,41	-0,41
2062	-179,62	-80,60	-180,60	180,60	0,64	-0,64
2063	-142,09	-63,76	-163,76	163,76	0,57	-0,57
2064	-165,86	-74,42	-174,42	174,42	0,62	-0,62
2065	-72,80	-32,67	-132,67	132,67	0,43	-0,43
2066	139,52	62,60	-37,40	37,40	0,00	0,00
2067	-274,77	-123,29	-223,29	223,29	0,84	-0,84

Years	Annual Average Water Budget	Values	Change (%)	Absolute value of change (%)	Normalization	SCORES = Normalization*-1
2068	-355,49	-159,51	-259,51	259,51	1	-1
2069	-208,76	-93,67	-193,67	193,67	0,70	-0,70
2070	-181,00	-81,21	-181,21	181,21	0,65	-0,65
2071	-129,53	-58,12	-158,12	158,12	0,54	-0,54
2072	-99,78	-44,77	-144,77	144,77	0,48	-0,48
2073	-99,86	-44,81	-144,81	144,81	0,48	-0,48
2074	-107,24	-48,12	-148,12	148,12	0,50	-0,50
2075	-145,39	-65,24	-165,24	165,24	0,58	-0,58
2076	-92,15	-41,35	-141,35	141,35	0,47	-0,47
2077	-274,41	-123,13	-223,13	223,13	0,84	-0,84
2078	-102,28	-45,89	-145,89	145,89	0,49	-0,49
2079	-231,06	-103,68	-203,68	203,68	0,75	-0,75
2080	-219,59	-98,53	-198,53	198,53	0,73	-0,73
2081	-258,30	-115,90	-215,90	215,90	0,80	-0,80
2082	-115,38	-51,77	-151,77	151,77	0,51	-0,51
2083	-147,98	-66,40	-166,40	166,40	0,58	-0,58
2084	-135,01	-60,58	-160,58	160,58	0,55	-0,55
2085	-92,18	-41,36	-141,36	141,36	0,47	-0,47
2086	-243,98	-109,47	-209,47	209,47	0,77	-0,77
2087	-1,35	-0,61	-100,61	100,61	0,28	-0,28
2088	77,10	34,60	-65,40	65,40	0,13	-0,13
2089	-230,93	-103,62	-203,62	203,62	0,75	-0,75
2090	-106,27	-47,68	-147,68	147,68	0,50	-0,50
2091	-116,12	-52,10	-152,10	152,10	0,52	-0,52
2092	-48,79	-21,89	-121,89	121,89	0,38	-0,38
2093	-197,62	-88,67	-188,67	188,67	0,68	-0,68
2094	-113,80	-51,06	-151,06	151,06	0,51	-0,51
2095	-18,88	-8,47	-108,47	108,47	0,32	-0,32
2096	-176,64	-79,26	-179,26	179,26	0,64	-0,64
2097	-146,15	-65,58	-165,58	165,58	0,58	-0,58
2098	-16,84	-7,56	-107,56	107,56	0,32	-0,32
2099	-240,14	-107,75	-207,75	207,75	0,77	-0,77
CV%	-79,60				**State Result**	-0,57
Pressure Result	0,25					

According to Table 4.7, state variable score (which is the average of the water budget scores between 2018 and 2100) is -0,57. Pressure variable gets the score 0,25 according to Table 3.3, since the variation of water budget relative to its mean has a value of 79,6%. The response variable score is 0 according to Table 3.3, since an upward movement by 17,862% was observed in the fitted line equation of the distribution of annual average water budget data points for the period 2018-2100 (Figure 4.6).

Eventually, future water budget indicator of the RCP4.5 scenario was estimated as (-0,57+0,25+0)/3=-0,107. This number indicates that the score of water budget has decreased by 0,12 when the future climate data is integrated into the calculations, which is a non-negligible amount. The incorporation of RCP8.5 scenario into water budget indicator has an effect of 0,52 points of decrease on the baseline water budget indicator score, as shown in Section 4.1.1. The gap of 0,4 points between the effects of two different RCP scenarios is not surprising. As a high emission scenario with more elevated estimations of greenhouse gas concentrations, RCP8.5 should have a greater impact on the water resources and water security level of the study area than RCP4.5 scenario.

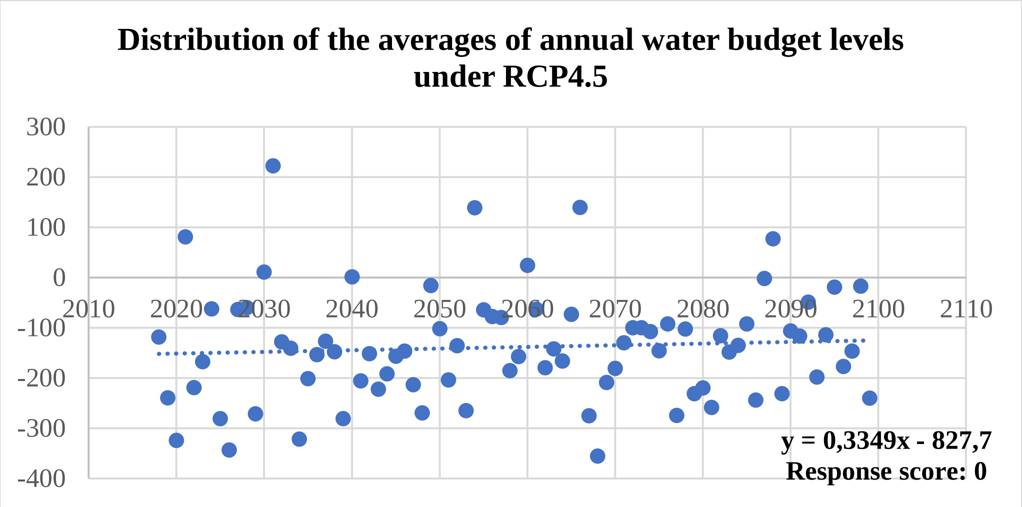

Figure 4.6. Distribution of the averages of annual water budget levels under RCP4.5.

4.2.2. Calculation of Future Aridity Index and Its PSR Variable Scores under RCP4.5 Scenario

Calculation processes of Section 3.4.3, Section 3.4.4 and Section 4.1.2 are repeated here. Provincial state variable scores, which is the average of the aridity index scores for each year between 2018 and 2100, are calculated as 0,878 for Aydın, 0,773 for Denizli, 0,985 for Muğla and 0,668 for Uşak. The average of these 4 numbers yielded the final RCP8.5 scenario aridity index indicator state variable result of 0,83, which is the arithmetic mean of the AI state scores of each province (Table 4.8).

Table 4.8 also shows the future aridity index value (not the score) of the study area as a whole – which is the average of the future aridity index values of the 4 provinces – is calculated as 0,98, which implicates that the area of concern will remain in the category of "dry land" within the period until 2100 in RCP4.5 scenario. Pressure variable values (coefficient of variation percentages) are determined as 21,77%, 24,15%, 23,51% and 23,89% for Aydın, Denizli, Muğla and Uşak, respectively. Therefore, each province gets a pressure score of 0,75 according to Table 3.3, and the final pressure variable score of RCP4.5 scenario's aridity index indicator becomes 0,75. Lastly, all of the fitted line equations of the distribution of annual aridity index estimations for the period 2018-2100 are almost flat (Figure 4.7). This means that the percentage differences between the first and last year are very close to 0% for all provinces. As a result, the ultimate response score becomes 0 under RCP4.5 scenario.

Eventually, future aridity index (AI) indicator under RCP4.5 scenario gets the result of (0,83+0,75+0)/3 = 0,525. At this point, it is observed that overall future aridity index indicator score is nearly the same as the baseline score (0,534), just 0,009 points below it.

4.2.3. Analysis of The Effects of Climate Change under RCP4.5 on Water Security of the Study Area

Summary of the integration of future climate values under RCP4.5 to both of the water budget and aridity index indicators is shown in Table 4.9.

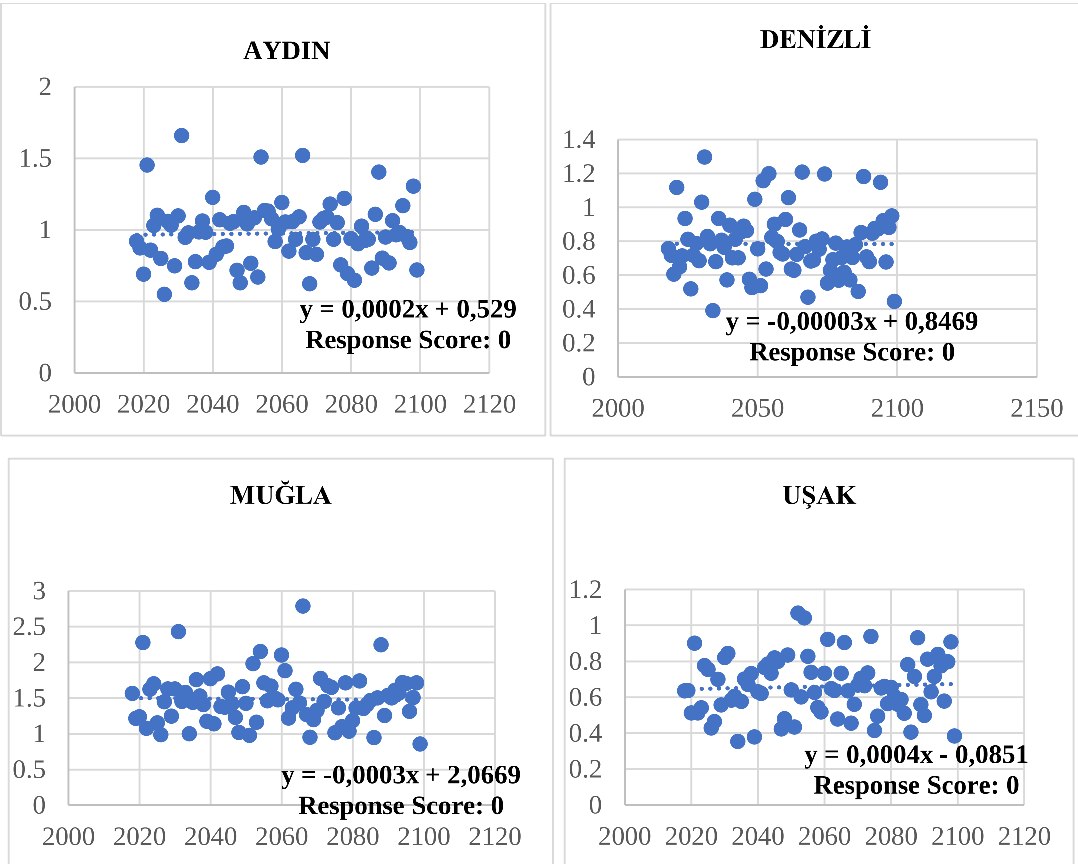

Figure 4.7. Distributions of AI estimations under RCP4.5 scenario and reference fitted line equations.

According to Table 4.9, RCP4.5's negative pressure on the study area's water budget and aridity scores is much lower than in RCP8.5 scenario. Overall resource sub-index value has decreased by approximately 0,026 points with the integration of RCP4.5 scenario. In addition, the final value of the water security index decreases by about 0,007 points (from 0,473 to 0,466) with the incorporation of RCP4.5 projections (Table 4.10 and Table 4.11) and stays in "medium conditions", following Table 3.4.

Table 4.8. State and pressure variable results of future aridity index indicator (RCP4.5).

Aridity Index (P/PET)	AYDIN	DENİZLİ	MUĞLA	UŞAK	SCORES	AYDIN	DENİZLİ	MUĞLA	UŞAK
2018	0,92	0,76	1,56	0,64	**2018**	0,8	0,8	1	0,6
2019	0,87	0,72	1,22	0,64	**2019**	0,8	0,8	1	0,6
2020	0,69	0,61	1,24	0,51	**2020**	0,8	0,6	1	0,6
2021	1,45	1,12	2,28	0,90	**2021**	1	1	1	0,8
2022	0,86	0,65	1,07	0,51	**2022**	0,8	0,6	1	0,6
2023	1,03	0,71	1,62	0,54	**2023**	1	0,8	1	0,6
2024	1,10	0,93	1,70	0,78	**2024**	1	0,8	1	0,8
2025	0,80	0,81	1,15	0,75	**2025**	0,8	0,8	1	0,8
2026	0,55	0,52	0,98	0,43	**2026**	0,6	0,6	0,8	0,4
2027	1,06	0,72	1,45	0,46	**2027**	1	0,8	1	0,4
2028	1,03	0,79	1,63	0,70	**2028**	1	0,8	1	0,8
2029	0,75	0,69	1,24	0,56	**2029**	0,8	0,8	1	0,6
2030	1,10	1,03	1,63	0,82	**2030**	1	1	1	0,8
2031	1,66	1,30	2,43	0,84	**2031**	1	1	1	0,8
2032	0,95	0,83	1,45	0,58	**2032**	0,8	0,8	1	0,6
2033	0,98	0,79	1,58	0,61	**2033**	0,8	0,8	1	0,6
2034	0,63	0,39	1,00	0,35	**2034**	0,6	0,4	0,8	0,4
2035	0,78	0,68	1,44	0,58	**2035**	0,8	0,8	1	0,6
2036	0,99	0,93	1,75	0,70	**2036**	0,8	0,8	1	0,8
2037	1,06	0,81	1,53	0,67	**2037**	1	0,8	1	0,8
2038	0,98	0,76	1,41	0,73	**2038**	0,8	0,8	1	0,8
2039	0,77	0,57	1,18	0,38	**2039**	0,8	0,6	1	0,4
2040	1,23	0,89	1,77	0,63	**2040**	1	0,8	1	0,6
2041	0,83	0,70	1,14	0,62	**2041**	0,8	0,8	1	0,6
2042	1,07	0,81	1,84	0,77	**2042**	1	0,8	1	0,8
2043	0,88	0,70	1,38	0,78	**2043**	0,8	0,8	1	0,8
2044	0,89	0,86	1,37	0,73	**2044**	0,8	0,8	1	0,8
2045	1,05	0,89	1,58	0,82	**2045**	1	0,8	1	0,8
2046	1,06	0,86	1,42	0,80	**2046**	1	0,8	1	0,8
2047	0,72	0,58	1,23	0,42	**2047**	0,8	0,6	1	0,4
2048	0,63	0,53	1,02	0,48	**2048**	0,6	0,6	1	0,4
2049	1,12	1,05	1,66	0,84	**2049**	1	1	1	0,8
2050	1,04	0,75	1,43	0,64	**2050**	1	0,8	1	0,6
2051	0,77	0,54	0,98	0,43	**2051**	0,8	0,6	0,8	0,4
2052	1,08	1,16	1,98	1,07	**2052**	1	1	1	1
2053	0,67	0,64	1,16	0,60	**2053**	0,8	0,6	1	0,6
2054	1,51	1,20	2,15	1,04	**2054**	1	1	1	1
2055	1,13	0,82	1,71	0,83	**2055**	1	0,8	1	0,8
2056	1,13	0,90	1,46	0,74	**2056**	1	0,8	1	0,8
2057	1,08	0,80	1,67	0,63	**2057**	1	0,8	1	0,6
2058	0,92	0,73	1,50	0,54	**2058**	0,8	0,8	1	0,6
2059	1,01	0,73	1,47	0,52	**2059**	1	0,8	1	0,6
2060	1,19	0,93	2,10	0,73	**2060**	1	0,8	1	0,8
2061	1,05	1,06	1,88	0,92	**2061**	1	1	1	0,8
2062	0,85	0,64	1,22	0,65	**2062**	0,8	0,6	1	0,6
2063	1,06	0,63	1,36	0,64	**2063**	1	0,6	1	0,6
2064	0,93	0,72	1,62	0,48	**2064**	0,8	0,8	1	0,4
2065	1,09	0,87	1,43	0,73	**2065**	1	0,8	1	0,8
2066	1,52	1,21	2,79	0,90	**2066**	1	1	1	0,8
2067	0,84	0,77	1,27	0,64	**2067**	0,8	0,8	1	0,6
2068	0,62	0,47	0,95	0,46	**2068**	0,6	0,4	0,8	0,4
2069	0,93	0,68	1,20	0,56	**2069**	0,8	0,8	1	0,6
2070	0,83	0,69	1,32	0,67	**2070**	0,8	0,8	1	0,8
2071	1,06	0,80	1,78	0,70	**2071**	1	0,8	1	0,8
2072	1,08	0,75	1,45	0,66	**2072**	1	0,8	1	0,8
2073	1,09	0,81	1,67	0,74	**2073**	1	0,8	1	0,8
2074	1,18	1,20	1,65	0,94	**2074**	1	1	1	0,8
2075	0,93	0,55	1,01	0,41	**2075**	0,8	0,6	1	0,4
2076	1,05	0,63	1,36	0,49	**2076**	1	0,6	1	0,4
2077	0,75	0,69	1,10	0,65	**2077**	0,8	0,8	1	0,8
2078	1,22	0,79	1,71	0,66	**2078**	1	0,8	1	0,8
2079	0,69	0,57	1,04	0,56	**2079**	0,8	0,6	1	0,6
2080	0,94	0,70	1,18	0,65	**2080**	0,8	0,8	1	0,8
2081	0,65	0,62	1,36	0,61	**2081**	0,6	0,6	1	0,6
2082	0,90	0,77	1,74	0,56	**2082**	0,8	0,8	1	0,6
2083	1,02	0,57	1,35	0,59	**2083**	1	0,6	1	0,6
2084	0,92	0,70	1,41	0,51	**2084**	0,8	0,8	1	0,6
2085	0,93	0,78	1,47	0,78	**2085**	0,8	0,8	1	0,8
2086	0,73	0,50	0,95	0,40	**2086**	0,8	0,6	0,8	0,4
2087	1,11	0,85	1,50	0,72	**2087**	1	0,8	1	0,8
2088	1,40	1,18	2,25	0,93	**2088**	1	1	1	0,8

Aridity Index (P/PET)	AYDIN	DENİZLİ	MUĞLA	UŞAK	SCORES	AYDIN	DENİZLİ	MUĞLA	UŞAK
2089	0,80	0,71	1,25	0,56	**2089**	0,8	0,8	1	0,6
2090	0,95	0,68	1,54	0,50	**2090**	0,8	0,8	1	0,4
2091	0,77	0,85	1,50	0,81	**2091**	0,8	0,8	1	0,8
2092	1,06	0,88	1,61	0,63	**2092**	1	0,8	1	0,6
2093	0,97	0,87	1,57	0,72	**2093**	0,8	0,8	1	0,8
2094	0,98	1,15	1,71	0,84	**2094**	0,8	1	1	0,8
2095	1,17	0,92	1,70	0,77	**2095**	1	0,8	1	0,8
2096	0,95	0,68	1,31	0,58	**2096**	0,8	0,8	1	0,6
2097	0,91	0,88	1,50	0,80	**2097**	0,8	0,8	1	0,8
2098	1,30	0,95	1,71	0,91	**2098**	1	0,8	1	0,8
2099	0,72	0,45	0,86	0,38	**2099**	0,8	0,4	0,8	0,4
Average	0,98	0,78	1,49	0,66	**Average**	0,88	0,77	0,99	0,67
Average State Value	0,98				**Average State Score**	0,83			
Pressure (CV%)	21,77	24,15	23,51	23,89	**Pressure Variable Score**	0,75			

Table 4.9. Resource sub-index values with and without RCP4.5 scenario integration.

	Indicator Name	State Score	Pressure Score	Response Score	PSR indicator result (P+S+R)/3
Resource Sub-Index	Water Budget	-0,21	0,5	-0,25	0,013
	Aridity Index	0,79	0,8125	0	0,534
	Water Quality Sub-Indicator	0,2	0,75	0,417	0,456
	Proportion of municipal population receiving ww treatment service (%)	0,375	0,4375	0,5	0,4375
		WQ Indicator Average	0,447		
	Fertilizer Use	0,5625	1	0,4375	0,667
	Reservoir Capacity	0,25	0,75	0	0,333
Baseline Scenario		**Sub-Index Result**		0,399	
Resource Sub-Index	Indicator Name	State Score	Pressure Score	Response Score	PSR indicator result (P+S+R)/3
	Water Budget	-0,57	0,25	0	-0,107
	Aridity Index	0,826	0,75	0	0,525
	Water Quality Sub-Indicator	0,2	0,75	0,417	0,456
	Proportion of municipal population receiving ww treatment service (%)	0,375	0,4375	0,5	0,4375
		WQ Indicator Average	0,447		
	Fertilizer Use	0,5625	1	0,4375	0,667
	Reservoir Capacity	0,25	0,75	0	0,333
Climate Change Scenario (RCP4.5)		**Sub-Index Result**		0,373	

The minor effect of RCP4.5 integration on water resources and water security of the study area is due to the fact that in this scenario, efforts to curb emissions are relatively higher than RCP8.5, and a moderate increase will be observed in extreme weather events until the year 2100 (NCCARF, n.d.).

Table 4.10. Water security index calculations under baseline scenario.

	Indicator Name	State Score	Pressure Score	Response Score	PSR indicator result (P+S+R)/3
Resource Sub-Index	Water Budget	-0,21	0,5	-0,25	0,013
	Aridity Index	0,79	0,8125	0	0,534
	Water Quality Sub-Indicator	0,2	0,75	0,417	0,456
	Proportion of municipal population receiving ww treatment service (%)	0,375	0,4375	0,5	0,4375
		WQ Indicator Average	0,447		
	Fertilizer Use	0,5625	1	0,4375	0,667
	Reservoir Capacity	0,25	0,75	0	0,333
		Sub-Index Result		0,399	
Access and Use Sub-Index	Indicator Name	State Score	Pressure Score	Response Score	PSR indicator result (P+S+R)/3
	Water use per capita	0,625	0,3125	0,5625	0,5
	Access to clean water (3 sub-indicators)				
	1) Proportion of population receiving sewage network service	0,8125	0,5625	0,5	0,625
	2) Proportion of population receiving drinking and tap water treatment service	0	0,5625	0,5625	0,375
	3) Proportion of municipal population receiving drinking and tap water network service	1	0,375	0,5	0,625
	Average	0,604	0,5	0,52	0,54
	Cost to access	0,875	0,375	-	0,625
	Population Density	-	0,6875	-	0,6875
		Sub-Index Result		0,589	
Capacity Sub-Index	Indicator Name	State Score	Pressure Score	Response Score	PSR indicator result (P+S+R)/3
	Efficient agricultural practice	0	0	0,75	0,25
	HH income	0,375	0,6875	-	0,531
	Annual water investments	0,083	0,5	0	0,194
	Income from agricultural activities	0,75	0,75	0,25	0,583
	Number of locals employed	0,5	0,75	0,5	0,583
	Years of education	0,453	0,547	0,430	0,477
		Sub-Index Result		0,436	
Sustainability Sub-Index	Indicator Name	State Score	Pressure Score	Response Score	PSR indicator result (P+S+R)/3
	% of study area under natural vegetation	0,5626	0,475	No Data	0,519
	Treatment plant wastewater discharges per capita	0,6875	0,0625	0,5	0,417
		Sub-Index Result		0,468	
		Water Security Index Result		0,473	

Table 4.11. Water security index calculations under RCP4.5 scenario.

<table>
<tr><td rowspan="9">Resource Sub-Index</td><td>Indicator Name</td><td>State Score</td><td>Pressure Score</td><td>Response Score</td><td>PSR indicator result (P+S+R)/3</td></tr>
<tr><td>Water Budget</td><td>-0,57</td><td>0,25</td><td>0</td><td>-0,107</td></tr>
<tr><td>Aridity Index</td><td>0,826</td><td>0,75</td><td>0</td><td>0,525</td></tr>
<tr><td>Water Quality Sub-Indicator</td><td>0,2</td><td>0,75</td><td>0,417</td><td>0,456</td></tr>
<tr><td>Proportion of municipal population receiving ww treatment service (%)</td><td>0,375</td><td>0,4375</td><td>0,5</td><td>0,4375</td></tr>
<tr><td></td><td>WQ Indicator Average</td><td colspan="3">0,447</td></tr>
<tr><td>Fertilizer Use</td><td>0,5625</td><td>1</td><td>0,4375</td><td>0,667</td></tr>
<tr><td>Reservoir Capacity</td><td>0,25</td><td>0,75</td><td>0</td><td>0,333</td></tr>
<tr><td></td><td colspan="2">Sub-Index Result</td><td colspan="2">0,373</td></tr>
<tr><td rowspan="10">Access and Use Sub-Index</td><td>Indicator Name</td><td>State Score</td><td>Pressure Score</td><td>Response Score</td><td>PSR indicator result (P+S+R)/3</td></tr>
<tr><td>Water use per capita</td><td>0,625</td><td>0,3125</td><td>0,5625</td><td>0,5</td></tr>
<tr><td>Access to clean water (3 sub-indicators)</td><td></td><td colspan="2"></td><td></td></tr>
<tr><td>1) Proportion of population receiving sewage network service</td><td>0,8125</td><td>0,5625</td><td>0,5</td><td>0,625</td></tr>
<tr><td>2) Proportion of population receiving drinking and tap water treatment service</td><td>0</td><td>0,5625</td><td>0,5625</td><td>0,375</td></tr>
<tr><td>3) Proportion of municipal population receiving drinking and tap water network service</td><td>1</td><td>0,375</td><td>0,5</td><td>0,625</td></tr>
<tr><td>Average</td><td>0,604</td><td>0,5</td><td>0,52</td><td>0,54</td></tr>
<tr><td>Cost to access</td><td>0,875</td><td>0,375</td><td>-</td><td>0,625</td></tr>
<tr><td>Population Density</td><td>-</td><td>0,6875</td><td>-</td><td>0,6875</td></tr>
<tr><td></td><td colspan="2">Sub-Index Result</td><td colspan="2">0,589</td></tr>
<tr><td rowspan="8">Capacity Sub-Index</td><td>Indicator Name</td><td>State Score</td><td>Pressure Score</td><td>Response Score</td><td>PSR indicator result (P+S+R)/3</td></tr>
<tr><td>Efficient agricultural practice</td><td>0</td><td>0</td><td>0,75</td><td>0,25</td></tr>
<tr><td>HH income</td><td>0,375</td><td>0,6875</td><td>-</td><td>0,531</td></tr>
<tr><td>Annual water investments</td><td>0,083</td><td>0,5</td><td>0</td><td>0,194</td></tr>
<tr><td>Income from agricultural activities</td><td>0,75</td><td>0,75</td><td>0,25</td><td>0,583</td></tr>
<tr><td>Number of locals employed</td><td>0,5</td><td>0,75</td><td>0,5</td><td>0,583</td></tr>
<tr><td>Years of education</td><td>0,453</td><td>0,547</td><td>0,430</td><td>0,477</td></tr>
<tr><td></td><td colspan="2">Sub-Index Result</td><td colspan="2">0,436</td></tr>
<tr><td rowspan="4">Sustainability Sub-Index</td><td>Indicator Name</td><td>State Score</td><td>Pressure Score</td><td>Response Score</td><td>PSR indicator result (P+S+R)/3</td></tr>
<tr><td>% of study area under natural vegetation</td><td>0,5626</td><td>0,475</td><td>No Data</td><td>0,519</td></tr>
<tr><td>Treatment plant wastewater discharges per capita</td><td>0,6875</td><td>0,0625</td><td>0,5</td><td>0,417</td></tr>
<tr><td></td><td colspan="2">Sub-Index Result</td><td colspan="2">0,468</td></tr>
<tr><td colspan="2"></td><td colspan="2">Water Security Index Result</td><td colspan="2">0,466</td></tr>
</table>

4.3. Population Increase Scenario

While change in climate patterns push down the future water quantity levels, population increase also has been, and will continue to be a major contributor to water scarcity. There are several studies in literature that give notice about the effects of population growth accompanied with the effects of climate change on future water supply levels. Fuller and Harhay (2010) predict that the combination of population growth and the undergoing effects of climate change will result in a chronic decline in the natural water resources of Southwestern United States in the coming years. In another study, Vörösmarty et al. (2000) conclude that global scale changes in population and economic development in the horizon will strike the water demand and supply relation more than climate change will do. Falkenmark and Widstrand (1992) also emphasize the need for reduction in population growth in water scarce regions and for active management of water resources which includes cooperation and commitment at all levels in order to alleviate the effects of the water scarcity crisis. In that sense, all studies and researches on future water supplies should not rule out the effects of population growth, coupled with the alterations that climate change bring along. Concordantly, future population density values as a measure for population growth was incorporated into the baseline scenario to analyse the effects of population increase on the water scarcity and security of the 4 neighbour provinces. Calculation of the future scores with reference to population density is explained in the following section, with a detailed analysis of the observed changes between the baseline and future values of the access and use sub-index and the overall water security index.

4.3.1. Calculation of Future Population Density and Its PSR Variable Scores

TURKSTAT (TÜİK) provides population projections of Turkey until the year 2080 on a national scale, however, on a provincial scale, population projections were provided until the year 2025. In order to overcome this inconsistency problem, linear regression straight line method was applied to the values of the 4 provinces in order to procure population numbers for the period 2030-2080. After this process, all of the population forecasts were converted into population density projections by simply dividing them by the relevant size of the regional area.

In the future scenario, calculation of the pressure scores are taken as the percentage changes between the historic averages (2000-2017) and the last values reported by TÜİK (year 2080) for each province and Turkey as a whole. This is mainly because some provinces had higher population growth rates between 2017 and 2080, so, it would not be meaningful if the calculations were made by omitting the change between past historic data of 2007-2017 period and the future numbers. For example, if only the averages of the future population data are taken and then normalized for scoring, Aydın would get a pressure value of 100, since it had the highest population density relative to other provinces and Turkey, and would get a score of 0. However, at the same time, population density of Aydın increases approximately by 44% from 2017 to 2080 according to the projections done by TÜİK, and it increases by 63% in Muğla, so it would be irrational if Aydın got the lowest score. Population density averages obtained from the past data and the future projections until the year 2080, as well as the relevant pressure values and the scores are shown in the Table 4.12.

Table 4.12. Population density projections and the relevant future scores.

Population Densities	Turkey	Aydın	Denizli	Muğla	Uşak
Past average	98,33	129,14	81,92	66,49	64,63
2020	107,08	138,61	87,14	76,17	70,67
2021	108,36	140,41	88,18	77,45	71,60
2022	109,64	412,20	89,23	78,74	72,52
2023	110,91	143,98	90,27	80,02	73,46
2024	112,16	145,73	91,30	81,28	74,39
2025	113,39	147,46	92,31	82,54	75,32
2030	119,86	155,65	97,20	88,49	79,86
2040	132,67	168,82	105,63	97,82	88,66
2050	145,49	177,37	111,95	103,41	97,08
2060	158,30	182,33	116,31	106,31	105,13
2070	171,12	185,02	119,16	107,71	112,85
2080	183,93	186,44	120,95	108,35	120,23
(Xn-Xo)%	87,05	44,37	47,64	62,96	86,04
Normalization	100	0	7,66	43,56	97,64
Scores	-	1	1	0,5	0

After the normalization process, Aydın and Denizli got a score of 1, while Muğla's score became 0,5 and Uşak's score is 0 (using Table 3.3). Normalized values and scores of the future population density indicator are inversely related since a higher rate of population density would exert more pressure on the environment. Eventually, the overall future population density score is calculated as (1+1+0,5+0)/4 = 0,625, which is slightly lower than the baseline score, which is 0,6825 (Section 3.5.8).

4.3.2. Analysis of The Effects of Population Increase on Water Security of the Study Area

Summary of the integration of population forecasts to the population density indicator is shown in Table 4.13:

Table 4.13. Access and use sub-index values with and without population increase scenario integration.

	Indicator Name	State Score	Pressure Score	Response Score	PSR indicator result (P+S+R)/3
Access and Use Sub-Index	Water use per capita	0,625	0,3125	0,5625	0,5
	Access to clean water (3 sub-indicators)				
	1) Proportion of population receiving sewage network service	0,8125	0,5625	0,5	0,625
	2) Proportion of population receiving drinking and tap water treatment service	0	0,5625	0,5625	0,375
	3) Proportion of municipal population receiving drinking and tap water network service	1	0,375	0,5	0,625
	Average	0,604	0,5	0,52	0,54
	Cost to access	0,875	0,375	-	0,625
	Population Density	-	0,6875	-	0,6875
Baseline Scenario		**Sub-Index Result**		0,589	
	Indicator Name	State Score	Pressure Score	Response Score	PSR indicator result (P+S+R)/3
Access and Use Sub-Index	Water use per capita	0,625	0,3125	0,5625	0,5
	Access to clean water (3 sub-indicators)				
	1) Proportion of population receiving sewage network service	0,8125	0,5625	0,5	0,625
	2) Proportion of population receiving drinking and tap water treatment service	0	0,5625	0,5625	0,375
	3) Proportion of municipal population receiving drinking and tap water network service	1	0,375	0,5	0,625
	Average	0,604	0,5	0,52	0,54
	Cost to access	0,875	0,375	-	0,625
	Population Density	-	0,625	-	0,625
Population Increase Scenario		**Sub-Index Result**		0,573	

Table 4.13 shows that the integration of future population data into the population density parameter has pulled down the overall score of the access and use sub-index nearly by 0,016 points (from 0,589 to 0,573). Although there is a downward movement is observed in the result of the access and use sub-index after the integration of population increase scenario, overall sub-index score stayed in the "medium conditions" range (Table 3.4).

Consequently, after the integration of population increase scenario into the access and use sub-index, the final value of the water security index diminishes to 0,469 from 0,472 (baseline). The 0,004 points of decrease that the population growth scenario generates is lower than the influence of RCP8.5 climate change scenario (water security index score: 0,437), but only 0,003 points below the effect of RCP4.5 scenario on overall water security level of the study area (water security index score: 0,466). Yet, the adverse impacts of population increase on future water quality and reservoir capacity levels, as well as the contribution of it to land cover change could not be estimated in this work, due to data availability. These are also important issues for the concepts of water security and environmental sustainability, and more research is needed for the sake of forming better connections to represent the dynamic nature of the issue. Ultimately, it can be seen from the calculations that the sole effect of population increase does not change the “medium conditions” of water security in the study area (Table 3.4).

4.4. Analysis of the Combined Effects of Climate Change and Population Increase on Water Security of the Study Area

High-emissions climate change scenario (RCP8.5) and population increase scenario have a combined effect of pulling down the overall water security index score from 0,473 to 0,433 (Table 4.14). This decrease of 0,04 points is again, a considerable amount if it is reckoned that there is a total of 17 indicators with equal weights that constitute the overall index.

Secondly, low-emissions climate change scenario (RCP4.5) and population increase scenario have a combined effect of pulling down the overall water security index score from 0,473 to 0,463 (Table 4.15). In this case, a 0,01 point of the overall water security index score is lower than the combined effects of RCP8.5 and population increase scenarios, which is due to the fact that it is assumed in the RCP4.5 that the efforts to reduce greenhouse gas concentrations are higher than that of RCP8.5.

Results obtained from the integration of all of the future scenarios (RCP8.5, RCP4.5 and population projections) into baseline conditions clarify that the water security of the 4 neighbour provinces (Aydın, Denizli, Muğla and Uşak) will remain in “medium conditions” (Table 3.4) until 210

Table 4.14. Combined effect of RCP8.5 and population increase scenarios on water security index.

	Indicator Name	State Score	Pressure Score	Response Score	PSR indicator result (P+S+R)/3
Resource Sub-Index	Water Budget	-0,521	0	-1	-0,507
	Aridity Index	0,642	0,75	-0,375	0,339
	Water Quality Sub-Indicator	0,2	0,75	0,417	0,456
	Proportion of municipal population receiving ww treatment service (%)	0,375	0,4375	0,5	0,4375
		WQ Indicator Average	0,447		
	Fertilizer Use	0,5625	1	0,4375	0,667
	Reservoir Capacity	0,25	0,75	0	0,333
		Sub-Index Result		0,256	
Access and Use Sub-Index	Indicator Name	State Score	Pressure Score	Response Score	PSR indicator result (P+S+R)/3
	Water use per capita	0,625	0,3125	0,5625	0,5
	Access to clean water (3 sub-indicators)				
	1) Proportion of population receiving sewage network service	0,8125	0,5625	0,5	0,625
	2) Proportion of population receiving drinking and tap water treatment service	0	0,5625	0,5625	0,375
	3) Proportion of municipal population receiving drinking and tap water network service	1	0,375	0,5	0,625
	Average	0,604	0,5	0,52	0,54
	Cost to access	0,875	0,375	-	0,625
	Population Density	-	0,625	-	0,625
		Sub-Index Result		0,573	
Capacity Sub-Index	Indicator Name	State Score	Pressure Score	Response Score	PSR indicator result (P+S+R)/3
	Efficient agricultural practice	0	0	0,75	0,25
	HH income	0,375	0,6875	-	0,531
	Annual water investments	0,083	0,5	0	0,194
	Income from agricultural activities	0,75	0,75	0,25	0,583
	Number of locals employed	0,5	0,75	0,5	0,583
	Years of education	0,453	0,547	0,430	0,477
		Sub-Index Result		0,436	
Sustainability Sub-Index	Indicator Name	State Score	Pressure Score	Response Score	PSR indicator result (P+S+R)/3
	% of study area under natural vegetation	0,5626	0,475	No Data	0,519
	Treatment plant wastewater discharges per capita	0,6875	0,0625	0,5	0,417
		Sub-Index Result		0,468	
		Water Security Index Result		0,433	

Table 4.15. Combined effect of RCP4.5 and population increase scenarios on water security index.

	Indicator Name	State Score	Pressure Score	Response Score	PSR indicator result (P+S+R)/3
Resource Sub-Index	Water Budget	-0,57	0,25	0	-0,107
	Aridity Index	0,827	0,75	0	0,525
	Water Quality Sub-Indicator	0,2	0,75	0,417	0,456
	Proportion of municipal population receiving ww treatment service (%)	0,375	0,4375	0,5	0,4375
		WQ Indicator Average	0,447		
	Fertilizer Use	0,5625	1	0,4375	0,667
	Reservoir Capacity	0,25	0,75	0	0,333
		Sub-Index Result		0,373	
Access and Use Sub-Index	Indicator Name	State Score	Pressure Score	Response Score	PSR indicator result (P+S+R)/3
	Water use per capita	0,625	0,3125	0,5625	0,5
	Access to clean water (3 sub-indicators)				
	1) Proportion of population receiving sewage network service	0,8125	0,5625	0,5	0,625
	2) Proportion of population receiving drinking and tap water treatment service	0	0,5625	0,5625	0,375
	3) Proportion of municipal population receiving drinking and tap water network service	1	0,375	0,5	0,625
	Average	0,604	0,5	0,52	0,54
	Cost to access	0,875	0,375	-	0,625
	Population Density	-	0,625	-	0,625
		Sub-Index Result		0,573	
Capacity Sub-Index	Indicator Name	State Score	Pressure Score	Response Score	PSR indicator result (P+S+R)/3
	Efficient agricultural practice	0	0	0,75	0,25
	HH income	0,375	0,6875	-	0,531
	Annual water investments	0,083	0,5	0	0,194
	Income from agricultural activities	0,75	0,75	0,25	0,583
	Number of locals employed	0,5	0,75	0,5	0,583
	Years of education	0,453	0,547	0,430	0,477
		Sub-Index Result		0,436	
Sustainability Sub-Index	Indicator Name	State Score	Pressure Score	Response Score	PSR indicator result (P+S+R)/3
	% of study area under natural vegetation	0,5626	0,475	No Data	0,519
	Treatment plant wastewater discharges per capita	0,6875	0,0625	0,5	0,417
		Sub-Index Result		0,468	
		Water Security Index Result		0,463	

5. DISCUSSION

This study aims to fill the gap in water security literature by integrating future projections into water security indices. To achieve this goal, climate change projections (both RCP 4.5 and RCP 8.5 scenarios) and population increase projections were integrated into the water security index specially developed for the 4 neighbour provinces in the Aegean region (Aydın, Denizli, Muğla and Uşak). While working towards this goal, a number of challenges were faced. One of the most challenging issue was the lack of future projection data regarding sub-indices such as capacity and sustainability. For indicators such as land use and land cover change, reservoir capacity levels, annual GDP, levels of education, there are no established future projections. Due to this fact, most of the dynamic cross-scale processes could not be reflected in future scenarios. For instance, population growth certainly has a downward pressure on the land cover as more people will occupy more space through expanding urban areas. However, to evaluate this dynamic link between the population density projections and future land uses, land use and land cover change modelling is necessary, which is beyond this work's scope. Likewise, along with climate change, population increase will result in more water use, creating a downward pressure on future water supplies and thus, future occupancy rates. Again, these interconnections between indicators could not be evaluated in this study due to data availability. Further future research could be more extensive and have sub-modules which focus on deliberating the future projections especially on resource, capacity and sustainability sub-index indicators. Nested models and simulations can be a method to integrate the dynamic relationships between selected indicators.

Another source of challenge was the lack of data or the inconsistencies between measurement times and methods. In Turkey, General Directorate of State Hydraulic Works is the authority in water quality/quantity monitoring and data storage practices. However, access to data is cumbersome, which limits the boundaries of scientific studies and their success. Due to this problem, this study could only be carried out for the 4 neighbour provinces (Aydın, Denizli, Muğla and Uşak), not at the basin level. It is mentioned above that these 4 provinces actually constitute more than 80% of Büyük Menderes River Basin. It would be more accurate if this study is oriented towards Büyük Menderes River Basin, in order to obtain better results that would be more beneficial for water planners and water managers.

At the regional level, the greatest dilemma of the study area is that the region's economy being dependent on 2 heavily dirty industries: textile and leather. These two industries are extremely detrimental for the water quality and quantity of the area, however, they also contribute the most to the local economy and create jobs. Büke et al. (2013) emphasize that especially the extremely hot wastewaters coming as outputs from textile and paint factories result in sudden temperature changes in the rivers, which is fatal for the aquatic life in near zones. Moreover, the colorants used in the textile industry cause the wastewaters to prevent penetration of sunlight and oxygen from reaching the water, thus, degrading water quality and threatening the aquatic ecosystem health. When industrial pollution is combined with agricultural pollution through excessive fertilizer use, it is a fact that the water resources of Aydın, Denizli, Muğla and Uşak are even further challenged. Population increase will exacerbate the existing fragile condition of the study area. Unfortunately, industrial pollution will most likely keep polluting the aquatic ecosystems unless the industry is incentivized for eco-friendly technologies or regulated strictly.

6. CONCLUSION

Water security, an already existing challenge in the developing regions of the world, has become an even more challenging problem as the exploitation of water resources has intensified with the ever-growing needs of the increasing population. When the potential future impacts of climate change with more frequent extreme events such as droughts and storms are brought to the scene, access to clean water, as well as the sustainability of the existing water resources will be under greater risk. The exacerbation of risk on water security is the main motivation of integrating the potential effects of climate change and population increase in the water security index of the 4 neighbour provinces were investigated. The area of interest, which is a great contributor to Turkish economy through extensive agricultural and industrial production is chosen for this study because the water resources of the region are currently deemed as water secure however future climate change impacts might challenge the water security within the area (Büke et al., 2013). In that sense, to investigate the impacts of climate change and population increase on the region's water resources and water security, a baseline scenario is created through index development. Following the definition of water security introduced by UN (2013), the water security index was divided into 4 sub-indices, which were given equal weights in the calculation process. Four sub-indices that form the water security index are resource sub-index, access and use sub-index, capacity sub-index and sustainability sub-index. Each sub-index consists of representative indicators of the major problems and properties of the study area, and each indicator contains state, pressure and response variables that give information about the current status of the environment and the societal capacity, the pressures upon environmental resources induced by human activities, as well as the societal response to the changes occurring in natural ecosystems through environmental, economic and sectoral policies. PSR framework is quite useful for index development since it allows the observation of cause-effect relations within indicators.

After the determination of PSR variables, indicators and sub-indices, baseline scenario is created with historical data and the calculations yielded the baseline sub-index results for the resource, access and use, capacity and sustainability sub-indices are 0,399, 0,589, 0,436 and 0,468, respectively. These baseline sub-index results regarding Aydın, Denizli, Muğla and Uşak reveal that the water resources of the region are in "poor conditions" currently, while the current statuses of access to clean water, capacity of the society in terms of taking actions towards more sustainable use of water resources, and sustainable use of resources within the area of study are in "medium conditions". Since all of the sub-indices have equal weights in the calculation of the overall index, the baseline score of the water

security index of the 4 neighbour provinces became the arithmetic mean of the sub-indices and is calculated as:
(0,399+0,589+0,436+0,468)/4 = 0,473.

Final baseline result of the water security index indicates that the current water security of the region of interest is in "medium conditions" according to Table 3.4.

Once the baseline result for the water security index is calculated, future climate change data under RCP8.5 and RCP4.5 scenarios, as well as data for future population projections are incorporated into the baseline scenario through water budget, aridity index and population density indicators, in order to measure the sole and combined effects of climate change and population increase on Aydın, Denizli, Muğla and Uşak's water resources and water security. Results show that under the high emissions scenario (RCP8.5), the resource sub-index has a score of 0,256, reduced by 0,143 compared to the baseline scenario. This means that the status of water resources of the area of interest will degrade towards "very poor conditions" in the future, and there is a risk of water scarcity within the region in the face of climate change. Under the RCP8.5 scenario, the overall water security index score is 0,437, 0,036 points lower than the baseline scenario. As a result, the water security level of the region remained in "medium conditions". It is important to remind that the water security index created for the 4 neighbour provinces has 4 sub-indices and 17 indicators with equal weight, therefore it would be unrealistic to expect drastic differences by changing the conditions of only one variable.

Under the low emissions scenario (RCP4.5) the resource sub-index has a score of 0,373, which is 0,026 points below the baseline scenario. It also resulted in the overall water security index result of 0,466, which is 0,007 points below the baseline scenario. Thereby, RCP4.5 scenario did not have a striking effect on the conditions of water resources and water security of the area. This result was parallel with the expectations since in the RCP4.5 scenario, efforts to decrease the greenhouse gas concentrations are high relative to the RCP8.5 scenario, therefore greenhouse gas emissions and consequent impacts are lower than the RCP 8.5 scenario.

Under the population increase scenario, future population projections are integrated into the population density indicator and access and use sub-index has a score of 0,573, and water security index has a score of 0,469. These results are slightly lower than the baseline results, however, potential effects of population growth on water security are not fully represented at the current state of the water security index. When population density increases, it's plausible to expect that sustainability sub-index (through land cover-land-use change) and capacity sub-index (through number of locals employed) would be affected. However, investigating these dynamic relationships are beyond the scope of this study, therefore not represented in the overall water security index.

When combined the combined effect of climate change and population increase are investigated, under RCP8.5 scenario the result of the overall water security index is 0,433, 0,04 lower than the baseline scenario. Although the water security status of the region stays in "medium conditions" in this case, the difference between the baseline and future scores is substantial. The combined effects of RCP4.5 scenario and population increase show that the overall water security index result goes 0,01 points below its baseline score and stays in the "medium conditions" range. Although this effect is milder than the former (combined effect of RCP8.5 and population increase scenarios), it is non-negligible in the presence of 17 indicators that form the overall water security index.

The aim of this study is to show the potential effects of climate change and population growth on the water resources and water security of the 4 neighbour provinces in the Aegean region (Aydın, Denizli, Muğla and Uşak). On a broader sense, these future changes which are also seen as the two most important environmental challenges that the humanity faces, must be incorporated into any work regarding water resources and planning. Under these conditions, it's compulsory to consider water as a fragile non-renewable resource and take actions towards the sustainable use of water to provide water security today and in future.

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