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Research Article

Assessment of Vulnerability, Resilience Capacity and Land Use Within the Scope of Climate Change Adaptation: The Case of Balıkesir-Susurluk Basin

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Abstract

Aim of study: Countries will be affected by climate change in different levels and ways. Therefore, it is necessary to focus on methods and options specific to regions. Basin approach, the sustainability of the basins and their capacity to be exposed to the possible effects of climate change, adapting to and resisting climate change should be addressed with an integrated approach. “Basin vulnerability analysis” methods are developed to ensure ecosystems sustainability and reveal their adaptive capacities. The purpose of these analyses is to calculate the basin’s vulnerability to all anthropogenic stress factors, especially climate change, for prioritizing investments and measures.

Area of study: This study applied in Balıkesir-Susurluk sub-basins.

Material and methods: This study applied a vulnerability analyses and mapped in Balıkesir-Susurluk sub-basins. The vulnerability analysis results were evaluated together with land use and resilience capacity.

Main results: We obtained a high correlation (r^2=0.788) between the vulnerability values and the water quality scores. The used method was verified and found to be successful and applicable.

Highlights: The dissemination of the method with its application to other basins is critical in analyzing the vulnerability at the basin scale and directing the basin restoration investments.

Keywords: Basin Vulnerability, Adaptation, Resilience, Climate Change

İklim Değişikliğine Uyum Kapsamında Kırılganlık, Direnç Kapasitesi ve Arazi Kullanımı Değerlendirilmesi: Balıkesir-Susurluk Havzası Örneği

Öz

Çalışmanın amacı: İklim değişikliğinden ülkeler farklı düzeyde ve şekilde etkilenecektir. Bu durumda hem ülkelere hem de farklı bölgelere özgü uyum yöntem ve seçenekleri üzerinde durulması gerekmektedir. Havza yaklaşımı kapsamında havzaların sürdürülebilirliği ve iklim değişikliğinin olası etkilerine maruz kalma, iklim değişikliğine uyum sağlama ve direnç gösterme kapasiteleri de entegre bir yaklaşımla ele alınmalıdır. Ekosistemlerin sürdürülebilirliğinin sağlanabilmesi ve adaptif kapasitelerinin ortaya konulabilmesi için “havza kırılganlık analizi” yöntemleri geliştirilmektedir. Bu analizlerde amaç yatırımların ve önlemlerin önceliklendirilmesi ve doğru yönlendirilmesi bakımından havzanın iklim değişikliği başta olmak üzere tüm antropojenik stres faktörlerine karşı kırılganlığının hesaplanmasıdır.

Çalışma alanı: Bu çalışma Balıkesir-Susurluk alt havzalarında gerçekleştirilmiştir.

Materyal ve yöntem: Balıkesir-Susurluk alt havzalarında kırılganlık analizi uygulanmış ve haritalanmıştır. Kırılganlık analizi sonuçları, arazi kullanımı ve direnç kapasitesi ile birlikte değerlendirilmiştir.

Temel sonuçlar: Kırılganlık değerleri ile arazi ölçümlerinde elde edilen su kalitesi skorları arasında elde edilen yüksek korelasyon (r^2=0.788) sayesinde uygulanan yöntemin doğrulaması yapılmış ve yöntem başarılı ve uygulanabilir bulunmuştur.

Araştırma vurguları: Yöntemin başka havzalara uygulaması ile yaygınlaştırılması, havza ölçeğinde kırılganlığın analizi ve havza restorasyon yatırımlarının yönlendirilmesi bakımından son derece önemlidir.

Anahtar Kelimeler: Havza Kırılganlığı, Uyum, Direnç, İklim Değişikliği

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Introduction

As a result of the rapid increase in population over the next last century, changes in food, soil, land use, and the demand for access to water will lead to changes in the amount of water, an increase in desertification, and deterioration in air quality (Roy & Majumder, 2016; McCarthy et al., 2001; Watson, 2001). Recent global developments at the United Nations Climate Change Conference (COP21) held in Paris in 2015, countries agreed to apply their Nationally Determined Contributions (NDC) as part of an agreement to limit global warming to below 2°C by the end of this century (WBG, 2016). According to the 5th assessment report (AR5) of the IPCC (Intergovernmental Panel on Climate Change), greenhouse gas concentration and temperature scenarios consist of five high priority scenarios (Shared Socioeconomic Pathway) (SSP1-1.9, SSP1-2.6, SSP2-4.5, SSP3-7.0 ve SSP5-8.5) in addition to the SSP1-1.9 scenario, which most closely reflects the 1.5 ºC target specified in the Paris Climate Agreement. The optimistic scenario for the 1.5 ºC target of the Paris Agreement (by 2050) that the IPCC (AR6) considers is SSP1-1.9 (Figure 1).

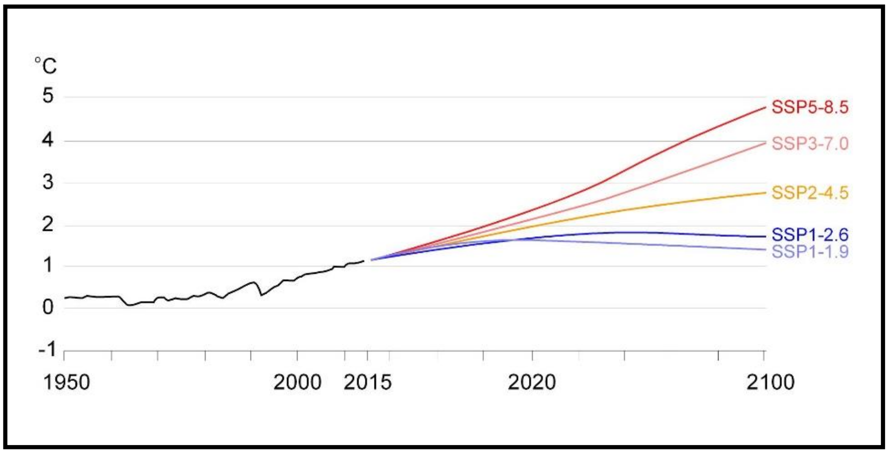


Figure 1. Global surface temperature change (relative to 1850-1900) (IPCC, 2021).

In consequence of climate change, basin management and sustainability of natural resources are exposed to hazard, and adaptation management should be provided in sensitive and vulnerable basins by determining strategies at different scales within the scope of adaptation to climate change (Aytekin, 2021). Basin resistance is a synthesis of basin condition, which expresses physical and biological characteristics. The deterioration of the basin condition is related to the magnitude of the degradation of natural ecosystems (Furniss et al., 2010; USDA, 2013). The World Bank (WBG, 2021) is expected to increase support, including technical assistance and financing, for cities to build carbon neutral and climate change resilience in urban basins. This support means providing new regulations to improve urban air quality, decarbonizing urban energy systems, promoting green infrastructure and integrated solid waste management, promoting urban transport by public transport (renewable energy), improving the scope-efficiency-flexibility of wastewater treatment.

Since climate change substantially impacts the hydrological processes of a basin system in the assessment and development of adaptation strategies, it can be used at the basin scale through best management practices and conservation of natural resources. With these methods, basin systems can become more resistant to external influences (Randhir et al., 2014).

The World Bank's Climate Change Action Plan (2021-2025) aims at green, resilient and inclusive development by increasing support for countries to integrate them into their development strategies (WBG, 2021). Climate change will cause increased vulnerability on the underdeveloped countries', infrastructure, economy, agricultural enterprises, and wildlife, which lack the necessary resources and skills to adapt rapidly to severe conditions. Temperatures and extreme weather events will increase over the next century with increased flood and landslide risks (Roy & Majumder, 2016). Globally, one-third of the population lives in water-stressed countries in Central Asia, South Africa and the Mediterranean region. According to climate change scenarios, it is expected that there will be decreases in stream flow and groundwater in the Mediterranean Basin (McCarthy et al., 2001). Changes in the total amount of precipitation and its frequency will affect the runoff and the intensity of floods and droughts (Roy & Majumder, 2016).

We carried out the study in the Balıkesir-Susurluk Basin. Balıkesir-Susurluk Basin is vital basin where the Mediterranean climate is combined with terrestial to certain extent, hosting ecologically critical aquatic ecosystems. At the same time, especially agricultural activities are common human influence. The waters of the Balıkesir-Susurluk Basin also contribute to the pollution and related mucilage problem of the Marmara Sea. The basin also has an important place in the country’s economy in terms of agriculture and includes important provincial centers such as Bursa and Balıkesir. The fact that it contains significant spatial differences in land use provides an advantage in testing the method. Although there are sub-basins that include mostly forests within the central basin of Balıkesir-Susurluk, there are also entirely agricultural sub-basins. These features provides suitable environment for testing the applicability of the developed approach. Within the scope of the research, the main basin of Balıkesir-Susurluk was divided into sub-basins and analyzed both in the field and by GIS-based methods. The aim is to develop numerical, objective and verifiable approach that will demonstrate the adaptive capacity on a basin basis.

Material and Method

Study Site

The study was conducted in the Balıkesir-Susurluk Basin, one of the main 25 river basins of Turkey located in the south of the Marmara Region (Figure 2). It has an area of approximately 24,385.31 km² (3.1% of the country's surface area). The study plots were located between 39° 1' 8" – 40° 31' 43" N and 27° 9' 50"– 29° 51' 42" E. According to CORINE (2018) data, while forest area occupies the largest portion, agricultural land, pasture areas and urban areas are also exist in the basin (Aytekin, 2021).

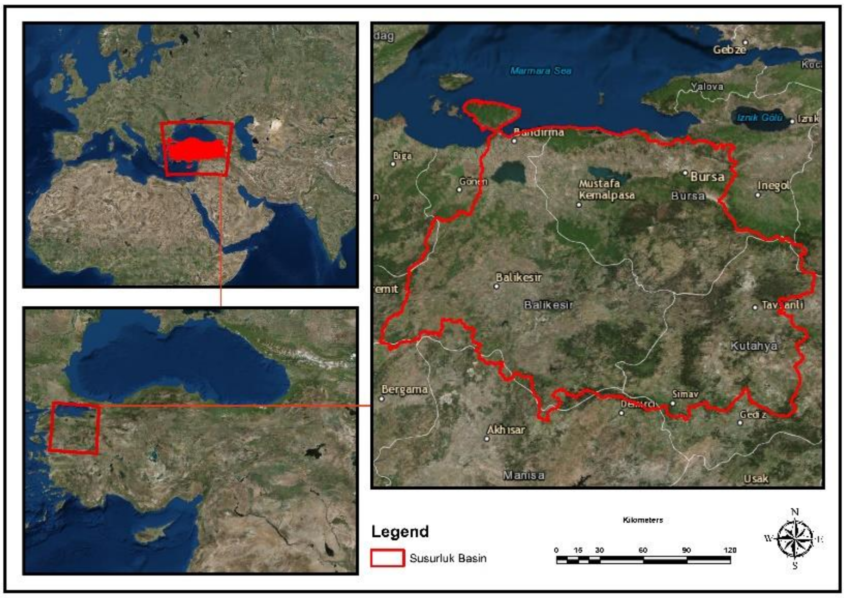


Figure 2. Study area (Aytekin, 2021).

Climate parameters (temperature, precipitation, humidity, etc.) in the study area change with the altitude. The mean elevation was about 631.24 m (0-2531.98 m). According to the slope groups of the study area, a medium slope areas (6-12%) occupy the largest (7700.26 km²) part. While the aspect of the study area is mostly northwest (333.94 km^2) and west (3212.40 km^2), the dendritic type drainage distribution is typical. The soil structure of the study area is mainly the lands with non-calcareous brown forest soils and VII. class lands (highly inclined and eroded) are the lands that have the most area in the study area with 57.13% (Aytekin, 2021).

The Balıkesir-Susurluk Basin has a transitional climate between the Mediterranean, the Black Sea, and the continental climate. According to Thornthwaite climate classification, Bursa is semi-humid and other provinces are semi-arid and less humid (Thornthwaite, 1948; MGM, 2016). In the Balıkesir-Susurluk Basin, Bursa's average temperature (1928 – 2020) is the highest average temperature of 14.9 ^oC, while Kütahya (1929 – 2020) is the lowest average temperature of 11.2 ^oC. In the Balıkesir-Susurluk Basin, the highest average precipitation is Bursa (1928 - 2020) with 719.1 mm, and the province with the least precipitation is Balıkesir (1929 - 2020) with 524.2 mm. The highest daily wind speed is in the north (N) direction in Bursa (47.3 m/sec), and the lowest wind speed is in the NW (NW) direction in Balıkesir (27.6 m/sec). Northerly winds are dominant throughout the basin. According to Corine 2018 data, coniferous forests (15.3%) have more than deciduous forests (8.5%). There are mainly *Quercus sp.*, *Fagus sp.*, *Pinus brutia* Ten. and *Pinus nigra* Arnold. species in the forest formation.

Climate Change and Resilience

To determine the vulnerability and resilience of the Balıkesir-Susurluk Basin, various indicators have been developed based on GeoREWIEW, the location-based regional vulnerability index model of basins and ecosystems (Tiburan et al., 2013). Although the indicators that may affect the vulnerability score of the Balıkesir-Susurluk Basin are micro-scale, measurable and applicable parameters, the parameters that do not have a statistically significant effect were eliminated after a correlation evaluation between the indicators (Aytekin, 2021).

Scientific studies were taken into account in order to conduct a basin vulnerability analysis, and 28 indicators were determined in terms of being calculable regarding sensitivity parameters (physiographic characteristics of the basin), exposure parameters (climatic data), and adaptive capacity (socio-economic status) (Table 1) (Aytekin, 2021). Each indicator was scaled with a degree of significance between 1 and 5, and the vulnerability point score was calculated for each basin (Table 2) (Tiburan et al., 2009)(Eq. 1). Resilience capacity parameters are between exposure and adaptive capacity, and the following calculation method has been developed for resilience (Aytekin, 2021).

$$R = \frac{E\ x\ \alpha + A\ x\ \beta}{2} \tag{1}$$

R: Resilience indicator
E: Exposure
A: Adaptive capacity
α ve β: The weights of exposure and adaptive capacity, respectively.

Calculation of overall vulnerability point (Tiburan et al., 2009) (Eq. 2);

$$OVP = \frac{1/n \sum_{i=1}^{n}(\mathrm{Si})}{Smax}\ x100 \tag{2}$$

OVP: Overall vulnerability point
Si: i scale of indicator
Smax: Maximum scale
n: Total number of indicators

Table 1. Basin vulnerability indicators (Aytekin, 2021).

Sensitivity	Reference
Stream order	Strahler, 1964
Drainage density	Horton, 1945
Stream frequency	Horton, 1945
Form factor	Horton, 1945
Circularity ratio	Miller, 1953
Maximum relief	Özhan, 2004
Mean slope	EU-DEM, 2018
Channel erosion	Quantitative assessment
Potential evapotranspiration	Thornthwaite, 1948
Erosion	Quantitative assessment
Exposure	
Watersed area	EU-DEM, 2018
Elevation	EU-DEM, 2018
Maximum temperature	MGM, 2018
Minimum temperature	MGM, 2018
Precipitation	MGM, 2018
Flow	DSI, 2018
Drought	RDI (Tsakiris et al., 2007)
Wet season	MGM, 2018
Dry season	MGM, 2018
Air quality index	EPA, 2018
Adaptive capacity	
Forest area	Corine, 2018
Agriculture area	Corine, 2018
Settlement area	Corine, 2018
Range area	Corine, 2018
Road density	DIVA-GIS (Hijmans et al., 2001)
Railway density	DIVA-GIS (Hijmans et al., 2001)
Population density	TUIK, 2020
Natural rate	Quantitative assessment

Table 2. Range of basin vulnerability point and classification values (Tiburan et al., 2009).

Category	Classification	Overall Vulnerability Point
5	Extremely Vulnerable	> 85
4	Highly Vulnerable	70 – 85
3	Vulnerable	55 – 70
2	At Risk	40 – 55
1	Resilience	< 40

Basin vulnerability assessment including validation (14 sub-basin) and test (14 sub-basin) basins, was used in the study (Figure 3). The basin vulnerability score was calculated, including all parameters (28 parameters) for the validation and test basins. Also, resilience capacity values were calculated for all basins. The coefficient of determination (R^2) value was determined with the trend line between the test basins and the ecological water quality values, and the vulnerability score of the basin was estimated in the validation basin with the linear regression equation (y=a+bx) (y: dependent variable-water quality value, a: constant value, b: regression coefficient, x: independent variable-predicted vulnerabilty score value) obtained as a result of the graphic, and basin vulnerability score values were examined by the least-squares method (Aytekin, 2021).

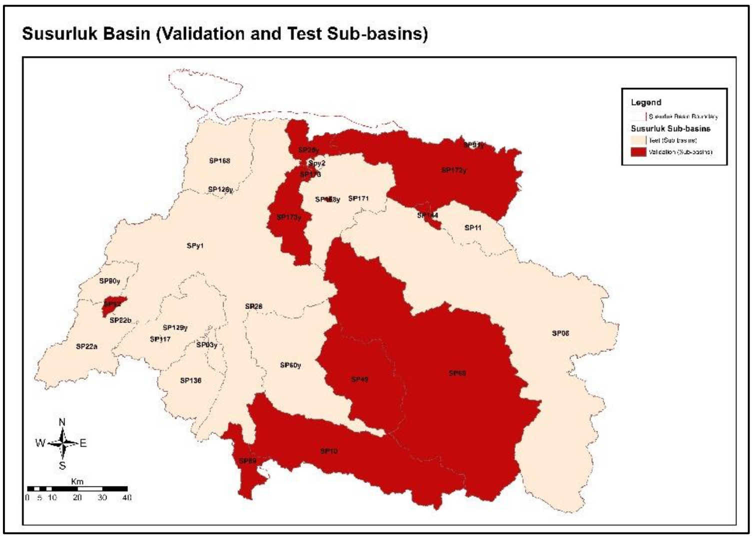


Figure 3. Validation and test sub-basin area in Balıkesir-Susurluk Basin (Aytekin, 2021).

Water Quality Parameters

Generally accepted indicators for monitoring and evaluating aquatic ecosytems are divided into 4 groups: physico-chemical, biological, habitat and flow indicators. Electrical conductivity, pH, turbidity, stream width and depth, dissolved oxygen, nitrate (NO_3^-), ammonium (NH_4^+), phosphate (PO_4-P), water temperature and flow rate indicators were measured once for each sample point over two years. Ecological indicators like turbidity, dissolved oxygen, nitrate, ammonium and phosphate indicators were taken into consideration for water quality evaluation. Ecological water quality (WQeco) scoring was made between 1 and 2 values, and the ecological water quality value is obtained by scoring all parameters. (Table 3) (Aytekin, 2021).

Table 3. Water indicator values (Aytekin, 2021).

Turbidity (NTU)	Dissolved oxygen (DO)(mg/l)	Nitrate (NO_3^-) (mg/l)	Ammonium (NH_4^+) (mg/l)	Phosphate (PO_4-P) (mg/l)
Turbidity < 5 *2 point*	DO > 8 *2 point*	$NO_3 < 5$ *2 point*	$NH_4 \leq 0.2$ *2 point*	$PO_4 - P < 0.02$ *2 point*
Turbidity < 50 *1 point*	DO > 6 *1 point*	$NO_3 < 10$ *1 point*	$NH_4 \leq 1.0$ *1 point*	$PO_4 - P < 0.1$ *1 point*

Results

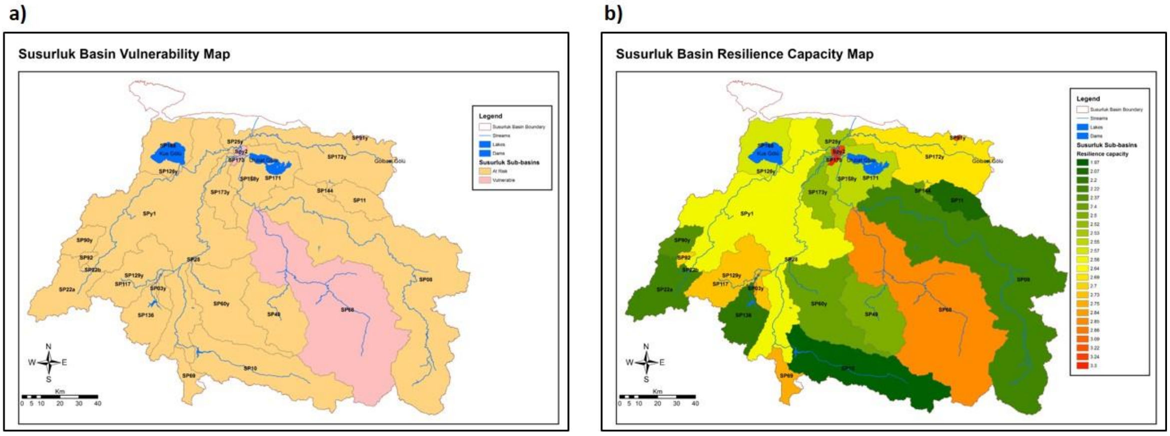
Basin Vulnerability Analysis

Results showed that Balıkesir-Susurluk Basin is at risk against climate change of basin vulnerability points (51.71). According to sub-basins, the SP91y sub-basin has the highest value (vulnerable) with 62.14 points, while the SP10 and SP22b sub-basins have the lowest value (at risk) with 42.86 points. According to the resilience capacity, the basin is at a risk of 2.6 points. As a result of the sub-basin evaluation, the SPy2 sub-basin is the most (least resilience) with 3.24 points, and the SP10 sub-basin is the least (most resilience) with 1.97 points (Table 4). Balıkesir-Susurluk Basin was assessed as sub-basins, and the map expresses basin vulnerability and resilience capacity (Figure 4).

Table 4. Balıkesir-Susurluk sub-basin vulnerability, adaptive capacity, resilience and WQEco values (Aytekin, 2021).

Sub-basins	OVP	Adaptive capacity	Resilience	WQEco
SP11	47.14	2.13	2.07	9
SP144	52.14	2.0	2.4	8
SP173y	50.0	2.13	2.52	4
SP168	47.14	2.63	2.57	8
SP68	61.43	2.0	2.85	4
SP08	51.43	2.13	2.22	5
SP49	52.14	2.0	2.5	2
SP91y	62.14	3.63	3.22	2
SP136	48.57	2.29	2.2	6
SP03y	52.14	2.88	2.84	7
SP10	42.86	2.13	1.97	5
SP69	55.0	2.0	2.75	8
SP117	53.57	2.25	2.58	6
SP92	53.57	2.5	2.7	2
SP22a	45.71	2.13	2.22	8
SP22b	42.86	1.5	2.2	7
SP90y	47.86	2.13	2.37	9
SP129y	52.14	2.75	2.73	6
SP28	53.57	3.38	3.09	8
SP60y	52.86	2.0	2.4	4
SP126y	56.43	2.75	2.88	10
SP168y	50.0	2.38	2.64	5
SPy1	54.29	2.25	2.58	5
SP171	49.29	2.5	2.55	7
SP173	55.71	3.5	3.3	6
SPy2	55.71	3.38	3.24	3
SP172y	52.86	2.88	2.69	0
SP25y	49.29	2.25	2.53	2
Average	*51.71*	*2.45*	*2.6*	

*SP: Susurluk point.



Susurluk Basin Vulnerability Map

Susurluk Basin Resilience Capacity Map

Figure 4. Balıkesir-Susurluk sub-basin vulnerability (a) and resilience capacity (b) maps (Aytekin, 2021).

The Relationship Between Basin Vulnerability and Water Quality

The statistical results of correlation and regression analysis for basin vulnerability point score (OVP) and water quality values for the application basin showed that there is a strong correlation ($p < .001$) between the basin overall point score and ecological water quality values (Table 5).

Table 5. Mean statistical values in the test basin vulnerability point and ecological water quality (Aytekin, 2021)

Correlation matrix		OVP	WQEco
OVP	Pearson's r	-	- 0.89***
	p – value		< 0.001
	95% CI Upper		- 0.68
	95% CI Lower		- 0.96
	Spearman's rho		- 0.87***
	p-value		< 0.001
	R^2		0.7882

Not. * *p* < .05, ** *p* < .01, *** *p* < .001

According to the regression analysis equation and graph between the basin vulnerability point score (OVP) and the water quality values, the basin vulnerability score of the basins selected as the validation basin was estimated and the difference was found to be 31.68 by the least-squares method.

Assessment of Basin Vulnerability, Resilience Capacity and Land Use

When the land use, basin vulnerability, and resilience capacity are evaluated, it has been observed that the resilience of the basins increases as the forest area ratio increases, and the resilience of the basins increases as the settlement area ratio increases (Table 6 and Figure 5) (Aytekin, 2021).

Table 6. Vulnerability point score, land use and resilience capacity values (Aytekin, 2021).

Sub-basins	Forest area (%)	Agricultural area (%)	Settlement area (%)	Range area (%)	Wetlands area (%)	OVP	Resilience
SP11	71.5	27.8	0.3	0	0.4	47.14	2.07
SP144	91.7	7.7	0.6	0	0	52.14	2.4
SP173y	34.2	59.0	3.04	3.69	0.07	50.0	2.52
SP168	1.7	64.7	4.4	5.21	23.99	47.14	2.57
SP68	65.8	33.1	1.0	0.07	0.03	61.43	2.85
SP08	58	38.0	2.84	0.85	0.31	51.43	2.22
SP49	71.6	27.7	0.63	0.07	0	52.14	2.5
SP91y	12.5	87.5	0	0	0	62.14	3.22
SP136	51.9	42.6	0.74	3.24	1.52	48.57	2.2
SP03y	1.2	95.2	1.1	2.5	0	52.14	2.84
SP10	60.5	36.8	0.84	1.3	0.56	42.86	1.97
SP69	66.14	32.1	1.6	0.16	0	55.0	2.75
SP117	58.4	41.6	0	0	0	53.57	2.58
SP92	35.8	61.5	1.35	0	1.35	53.57	2.7
SP22a	51.4	46.1	1.4	0.7	0.4	45.71	2.22
SP22b	100	0	0	0	0	42.86	2.2
SP90y	42.6	55.6	1.8	0	0	47.86	2.37
SP129y	33.4	53.4	7.74	5.4	0.06	52.14	2.73
SP28	0	54.1	45.9	0	0	53.57	3.09
SP60y	64.3	34.8	0.6	0.29	0.01	52.86	2.4
SP126y	0	100	0	0	0	56.43	2.88
SP168y	0	71.8	9.4	18.4	0.4	50.0	2.64
SPy1	41.0	53.8	2.5	2.34	0.36	54.29	2.58
SP171	24.6	54.8	2.01	2.05	16.54	49.29	2.55
SP173	0	87.9	10.5	0.13	1.47	55.71	3.3
SPy2	0	77.4	10.32	6.7	5.58	55.71	3.24
SP172y	44.5	40.1	14.5	0.47	0.43	52.86	2.69
SP25y	56.1	40.4	1.6	0.98	0.92	49.29	2.53

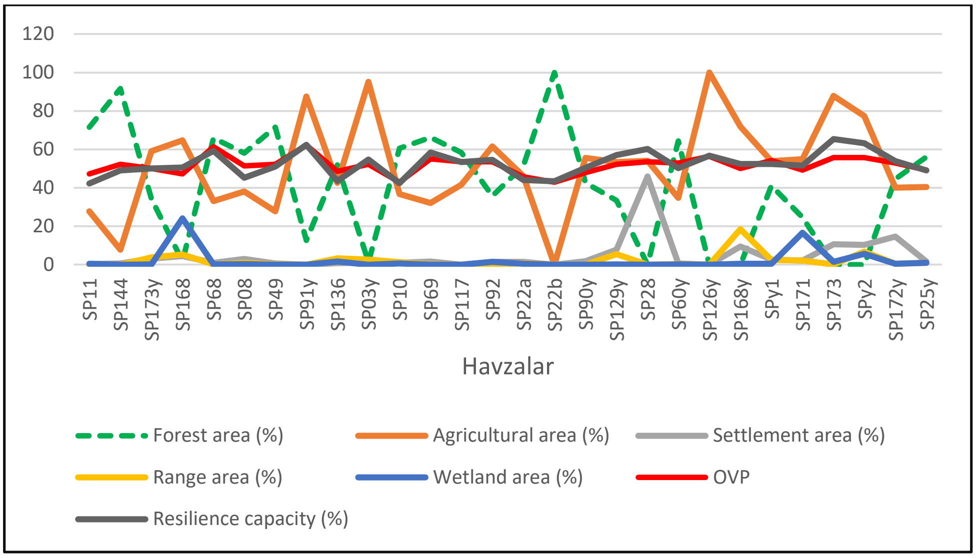


Figure 5. Relationship between basin vulnerability, land use and resilience (Aytekin, 2021).

Discussion and Conclusion

Increasing atmospheric disasters in recent years have brought integrated land and natural resource planning based on the basin scale to the agenda. The basis of this planning approach is to deal with the atmosphere and ecosystems in interaction with people. This approach currently forms the core of climate change adaptation studies on a global scale. In this study, the concepts of "vulnerability" and "resilience", were added to the aforementioned approach and a method was suggested to evaluate the basins' adaptation and resilience capacities, study was permofed on the sub-basins with varying sizes. Climate change will affect the basin in terms of water quality and quantity through the hydrological cycle. In the study area, the resilience capacity of the basins was interpreted by sampling the sub-basins and evaluating the changes based on water quality. As a result, a high correlation was found between vulnerability values and water quality values, and the method applied was verified and the method was found to be applicable.

GeoReview model, which constitutes the basic approach of the study, besides being a location-based regional environmental vulnerability index model for basins, does not limit its capacity in vulnerability studies on its own. With this feature, and the basic evaluations in the model, the dynamics that make up the basin have been tried to be integrated into the model. The work is combined with spatially based technologies such as geographic information system (GIS) and remote sensing. Although the methodology reveals different levels according to different indicators, similar methods should be applied in other basins. An algorithm should be developed by obtaining coefficients put forward scaling as a standard (Aytekin, 2021). By creating new socio-economic parameter data (i.e., schooling rate, GDP, number of tourists, soil quality and human development index, etc.). Applying the method to other basins and the analysis of vulnerability at the basin scale is essential in adaptation capacity, ecological planning, ecosystem services, and the direction of basin restoration investments. With a study similar to the one we have done, the vulnerability point score was calculated in an urban basin using the GeoReview approach and found in the risky category (Tiburan et al., 2013).

According to the results, the significant resilience indicators were; basin area, population density, settlement, channel erosion and form factor, while considerable vulnerability basin indicators were forest area, runoff, drought, range-land area and maximum temperature. According to the study results, urban sub-basins are more vulnerable than rural-based sub-basins. It is necessary to make plans to improve their capacity to adapt to climate change (Aytekin, 2021). For example, outdoor ornamental plants that are tolerant to increasing temperature in urban basins and have low water consumption and maintenance requirements should be chosen. Scientific research will be beneficial to understand the effects of changes in the basin ecology due to climate change. According to the basin vulnerability assessment, Richardson & Amankwatia (2019) created a regional-scale risk map. The slope, drainage density, precipitation, vegetation, land use, land cover, soil erosion, soil texture and soil permeability were analyzed and mapped. The study's shortcoming is that field studies have not verified it. According to another study, it has been shown that the closer a basin is to nature and uninterrupted, the greater its capacity to resilience anthropogenic pressures (Potyondy & Geier, 2011; Williams et al., 1997). In another study conducted by Tran et al., (2012), 50 different indicators were determined in the basin-based environmental vulnerability assessment, and vulnerability assessment was made according to the weights of these indicators. The study showed that in general the most vulnerable basins are in the transition zone between highly populated areas and inaccessible areas in terms of land use. This study shows a similar working method to ours, as it compares vulnerability between basins in a region. Ahn & Kim (2017) conducted a study that included an assessment of basin health and vulnerability to determine conservation and restoration priorities. The study evaluated six components including basin landscape, fluvial geomorphology, hydrology, water quality, aquatic habitat conditions and biological conditions in 237 sub-basins using the SWAT model to assess basin health. As a result of the study, priority areas for restoration and conservation were determined and a perspective was presented to determine management strategies. To combat climate change, plans should be made to create low-carbon and resilient cities in urban basins.

Climate change adaptation aims to increase resilience against climate change, affecting sectors such as agriculture, forestry, health, energy, water management, transportation, tourism, soil protection, biodiversity, ecosystem goods and services, and fisheries. Therefore, adaptation options should be carefully considered in vulnerable landscapes (coastal areas, wetlands, rivers, mountains and glaciers, Mediterranean Basin, etc.) and related sectors (EU, national, regional and local level). Adaptation is often integrated into other intersecting and management actions such as disaster preparedness, coastal zone management, rural development, health care, spatial planning and regional development, water management and ecosystems. Increasing consideration of adaptation issues in decision-making and many basin-based international studies are expected to lead to new assessment tools and more integrated adaptation measures (EEA, 2008). There is also a strong correlation between vulnerability and the capacity to adapt to all possible impacts (risks) of climate change.

Acceleration of urbanization causes changes in land use. As a result of the increase in population, the fragmentation of forest areas and new pressures in forest areas increase. Basin management should be built on sustainable use of natural resources, soil and water protection, land use and participatory planning processes. Land use and land-use change affect climate change by anthropogenic greenhouse gas emissions. Changes in land cover can affect energy and mass flows at a landscape scale. For example, when large forest areas are converted into agricultural areas or residential areas, decreases transpiration, cloud formation, and precipitation (IPCC, 2021; Serengil, 2018). All basin problems (flood, erosion, drought, etc.) should be evaluated and taken into account in climate change adaptation planning. While evaluating adaptation actions, decision-makers should avoid actions that will increase the risk in the other area while reducing the existing risk (CCME, 2015). In order to increase and develop the resilience of a basin as a result of climate change, by the basin managers, an approach based on thinking, collaborating and acting is established (Furniss et al., 2010). A basin-based adaptation strategy has been developed for climatic adaptation. Among these adaptation strategies, surface flow is reduced through vegetation, and water is collected in the basin as the best management practices. Considering the balance between evapotranspiration and precipitation, practices to reduce evapotranspiration should be reviewed and methods to increase the amount of infiltration (for example, green stripes should be designed in park areas for urban areas) should be applied (Randhir et al., 2014). According to the new climate change action plan of the World Bank (WBG, 2021), stabilization of coastlines, reduction of floods and overflows, and nature-based solution methods in the amount and quality of water are critical elements in agricultural practices and landscape areas affected by land degradation. The nature-based solution could yield benefits for soil health, carbon sequestration, biodiversity and climate resilience. It is crucial issue to develop adaptive planning approaches that increase the adaptation capacity of forest ecosystems to climate change and increase the resistance level of the way forest use is planned and operated (Serengil, 2018).

Since Turkey is a party to the Paris Climate Agreement and is preparing to submit its National Declaration of Contribution (NDC), it should put forward a strong strategy in terms of reduction and adaptation. This strategy should be basin-scale and strengthen mitigation and adaptation capacity. Floods, mudflows and landslides that have taken place in Turkey and other countries in the recent period are the confirmation of this thought in the field.

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Conflict of Interest

The authors have no conflicts of interest to declare.

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References

Ahn, S.R. & Kim, S.J. (2017). Assessment of watershed health, vulnerability and resilience for determining protection and restoration priorities. *Environmental Modelling & Software*, 122,1-19.

Aytekin, M. (2021). Development of a watershed vulnerability assessment method to support climate change adaptation action. PhD Thesis, Istanbul University-Cerrahpasa Institute of Graduate Studies, Istanbul.

CCME, Canadian Council of Ministers of the Environment. (2015). Implementation framework for climate change adaptation planning at a watershed scale. PN 1529, ISBN: 978-1-77202-011-3.

CORINE (2018). Copernicus Pan-European Land Monitoring Service. https://land.copernicus.eu/pan-european/corine-land-cover/clc2018 (Data accessed: 26.01.2018).

DSI (2018). General Directorate of State Hydraulic Works. https://www.dsi.gov.tr (Data accessed: 16.05.2018).

EEA (2008). European Environment Agency, Impacts of Europe's changing climate – 2008 indicator-based assessment. EEA Official Publications of the European Communities, 2008, ISBN: 978-92-9167-372-8.

EPA (2018). U.S. Environmental Protection Agency (epa.gov). Technical Assistance Document for the Reporting of Daily Air Quality – the Air Quality Index (AQI), Office of Air Quality Planning and Standards Air Quality Assessment Division Research Triangle Park, NC.

EU-DEM (2018). Copernicus Land Monitoring Service. EU-DEM v.1.1. https://land.copernicus.eu/imagery-in-situ/eu-dem/eu-dem-v1.1. (Data accessed: 15.02.2018).

Furniss, Michael J.; Staab, Brian P.; Hazelhurst, Sherry; Clifton, Cathrine F.; Roby, Kenneth B.; Ilhadrt, Bonnie L.; Larry, Elizabeth B.; Todd, Albert H.; Reid, Leslie M.; Hines, Sarah J.; Bennett, Karen A.; Luce, Charles H.; Edwards & Pamela J. (2010). US Forest Service, Pacific Northwest Research Station (fs.usda.gov/pnw). Water, climate change, and forests: watershed stewardship for a changing climate. Gen. Tech. Rep. PNW-GTR-812. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station.

Hijmans, R.J., Cruz, M., Rojasand, E. & Guarino, L. (2001). DIVA-GIS Version 1.4. A geographic information system for the management and analysis of genetic resources data. Manval International Potato Center, Lima, Peru.

Horton, R.E. (1945). Erosional development of streams and their drainage basins: hydrophysical approach to quantitative morphology. *Bulletin of the Geological Society of America*, 56, 275-370.

IPCC (2021). Summary for Policymakers. In: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Masson-Delmotte, V., P. Zhai, A. Pirani, S. L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M. I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T. K. Maycock, T. Waterfield, O. Yelekçi, R. Yu and B. Zhou (Ed.)]. Cambridge University Press. In Press.

McCarthy, J.J., Canziani, O.F., Leary, N.A., Dokken, D.J. & White, K.S. (Ed.). (2001). Climate Change 2001: Impacts, Adaptation, and Vulnerability, Cambridge University Press, Cambridge.

MGM (2016). General Directorate of Meteorology. Climate of Turkey according to Thornthwaite Climate Classification. Ankara.

MGM (2018). General Directorate of Meteorology.https://mevbis.mgm.gov.tr/mevbis/ui/index.html#/Workspace (Data accessed: 01.13.2018).

Miller, V.C. (1953). A quantitative geomorphic study of drainage basin characteristics in the Clinch Mountain area, Virginia and Tennessee, Columbia University, Department of Geology, ONR, Geography Branch, New York.

Özhan, S. (2004). Watershed management, Cantay Book-Stationery-Photocopy ind.trade.co.ltd., Istanbul, ISBN: 975-4040-739-1.

Potyondy, J.P. & Geier, T.W. (2011). Watershed condition classification technical guide, USDA Forest Service.

Randhir, T., Ekness, P. & Tsvetkova, O. (2014). Climatic Change Impacts on Watershed Hydrologic Dynamics: A Systems Approach to Adaptation. Watershed Management, Restoration and Environmental Impact. ISBN: 978-161668667-3.

Richardson, C.P. & Amankwatia, K. (2019). Assessing watershed vulnerability in Bernalillo County, New Mexico using GIS-Based Fuzzy Inference. *Journal of Water Resource and Protection,* 11, 2, 99-121.

Roy, U. & Majumder, M. (2016). IPCC Watersheds to Climate Change Assessed by Neural Network and Analytical Hierarchy Process. Springer Briefs in Water Science and Technology. Springer, ISBN 978-981-287-343-9.

Serengil, Y. (2018). Climate change and carbon management. Agriculture, Forestry and Other Land Uses, UNDP, Ankara, ISBN: 978-605-9239-11-0.

Strahler, A. (1964). Quantitative Geomorphology of Drainage Basins and Channel Networks. In: Chow, V., Ed., Handbook of Applied Hydrology, McGraw Hill, New York, 439-476.

Tiburan, C,J.R., Saizen, I., Kobayashi, S. & Mizuno, K. (2009). Developing a spatial-based approach for vulnerability assessment of Philippine watersheds and its potental in disaster management, Disaster Management and Human Health Risk, *WIT Transactions on The Built Environment*, 110,21-32.

Tiburan, C.J.R., Saizen, I. & Kobayashi, S. (2013). Geospatial-based vulnerability assessment of an urban watershed. The 3rd International Conference on Sustainable Future for Human Security SUSTAIN 2012.

Thornthwaite, C.W. (1948). An Approach toward a rational classification of climate, *Geographical Review*, 38,1, 55-94.

Tran, L.T., O'Neill, R.V.O. & Smith, E.R. (2012). A watershed-based method for environmental vulnerability assessment with a case study of the Mid-Atlantic region. *Environmental Impact Assessment Review*, 34, 56-64.

Tsakiris, G., Pangalou, D. & Vangelis, H. (2007). Regional drought assessment based on the reconnaissance drought index (RDI), *Water Resources Management*, 21, 821-833.

TUIK (2020). Turkish Statistical Institute. https://data.tuik.gov.tr/ (Data accessed: 10.04.2020).

USDA (2013). US Department of Agriculture (usda.gov). Assessing the Vulnerability of Watersheds to Climate Change, Results of National Forest Watershed Vulnerability Pilot Assessments. General Technical Report.

Watson, R. T. (2001). Climate change 2001: Synthesis Report. IPCC Third Assessment Report.

WBG (2016). World Bank (worldbank.org). World Bank Group Climate Change Action Plan 2016-2020.World Bank, Washington, DC. World Bank. https://openknowledge.worldbank.org/handle/10986/24451 License: CC BY 3.0 IGO.

WBG (2021). World Bank (worldbank.org). World Bank Group Climate Change Action Plan 2021–2025: Supporting Green, Resilient, and Inclusive Development.World Bank, Washington, DC. WorldBank.https://openknowledge.worldbank.org/handle/10986/35799 License: CC BY 3.0 IGO.

Williams, J. E., Wood, C.A. & Dombeck, M.P. (Ed.). (1997). Watershed restoration: principles and practices. Bethesda, M.D.: American Fisheries Society, ISBN-10 : 1888569042.