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Evaluation of the Global Warming Impacts Using a Hybrid Method Based on Fuzzy Techniques: A Case Study in Turkey

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ABSTRACT

The aim of this study is to measure the effects of the global warming in the cities in Turkey. The results of the global warming such as drought, temperature changes and rainfall changes are considered as criteria and the evaluation of the impacts of global warming in the cities in Turkey is handled as a multi-criteria decision-making model. A hybrid method considering fuzzy analytic hierarchy process and fuzzy measure theory is proposed to determine the corresponding degree of effect. Finally, considering real data, the map of effect with respect to the cities is presented. According to the results, the city that is most affected from the global warming is determined as Kütahya City in Turkey.

Keywords: *Global warming, multi criteria decision making, fuzzy measure, Choquet integral.*

1. INTRODUCTION

Global warming that is an international issue and threats all living things on Earth refers to the considerable rise in the average temperature of the climate system and it becomes increasingly noticeable. The global temperature has increased by 0.78 degree Celsius since 1880. The 10 warmest years in the 134-year record all have occurred

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since 2000, with the exception of 1998. The year 2014 ranks as \ the warmest on record [1]. There are many artificial causes that affect global warming such as waste, the fossil fuels, increasing number of the motor vehicles in the cities, destruction of the green areas. Besides, there are natural causes that lead to the global warming such as Earth's precession movement, effect of El Niño. However, the greenhouse gases emitted to the atmosphere intensely by the industrialized countries is one of the main causes of the global warming.

Looking at the results of the global warming so far, it can be listed as follows; noticeable increase at average temperature, observed sudden rains, unusual weather phenomena, melting glaciers, reduction of some plant and animal populations. As the negative effects of the global warming have been growing up recently, scientists have become more concerned about it. There are many studies that investigate this issue from different perspectives. To consider the fuzzy and probabilistic methods is one of these perspectives.

In the literature, there are several studies in which fuzzy or probabilistic approaches are used. These studies mainly deal with the assessment of the results and effects of the global warming and climatic change. For instance, Leimbach [2] has developed a fuzzy optimization model to support global warming response policies. In the studies related to climate change impact analysis, Huang et al. [3] have used fuzzy relation analysis; Kojiri et al. [4] have assessed the global warming impacts by using fuzzy membership functions on water resources and ecology of a river basin in Japan. Considering the fuzzy relations and weights Prato [5] has studied the evaluating and managing wildlife impacts of climate change. Teegavarapu [6] has modeled the climate change uncertainties in water resources management by using fuzzy linear programming. Zaman and Shakouri [7] have studied the effects of climate change on electricity consumption in Iran by using fuzzy regression models. Cai et al. [8] have used fuzzy interval inference method for climate change impact study in Canada. Using Dempster-Shafer theory Bernetti et al. [9] have evaluated the forest crop damages due to climate change. Kim and Chung [10] have studied the vulnerability of the water supply to climate change and variability in South Korea using Fuzzy VIKOR (Vise Kriterijumska Optimizacija I Kompromisno Resenje); Jun et al. [11] have applied fuzzy TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) approach for evaluation the flood risk vulnerability in South Korea by considering climate change impacts. Batisha [12] has analyzed the Nile Delta resilience to climate change in terms of water level by implementing fuzzy decision making technique. Considering fuzzy set classification techniques Wu and Shi [13] have analyzed the changes in migratory bird distributions. In another study, Chatterjee et al. [14] have assessed the environmental factors causing wetland degradation with the help of fuzzy analytic network process. In their study, the climate change has been considered as a sub-criterion. El-Zein and Tonmoy [15] have assessed the climate change impacts in term of heat stress in Sydney using ELECTRE III (Elimination Et Choix Traduisant la Realité / Elimination and choice that translates reality) with fuzzy relationships

In the estimation studies considering climate change Kriegler and Held [16] have utilized belief functions for the estimation of future climate change. Rahmani and Zarghami [17] have proposed a novel approach to combine climate change projections considering fuzzy quantifiers. Taking into account the climate change Abdallah et al. [18] have used Likelihood-based belief functions for sea level estimation. Chen [19] has studied the forecasting the global CO2 concentrations via fuzzy neural network approach.

Due to its complicated climate structure and geographical location, Turkey is one of the critical countries that are being affected from the global warming. Each one of the seven geographical regions that constitute Turkey is being affected at different levels since they have particular climates and geographic characteristics. In this study we combine fuzzy analytic hierarchy process (FAHP) and fuzzy integral theory to determinate the degree of effect of the global warming on the cities of Turkey by considering the corresponding issue as a multi criteria decision making problem. For this purpose, we construct a fuzzy measure and we evaluate Choquet integral with respect to this measure. Firstly, we determine the fuzzy measure of singletons with the help of FAHP. Then we use the method of [20] to obtain the fuzzy measure of the rest of the subsets. Finally, we calculate the Choquet integral.

Multi Criteria Decision Making (MCDM) deals with multiple criteria in decision-making environments. Decision- making processes involve a series of steps: identifying the problems, constructing the preferences, evaluating the alternatives and determining the best alternatives [21-23]. Decision making is extremely intuitive when considering single criterion problems, since decision maker only needs to choose the best alternative with the highest preference rating. However, once decision maker evaluates alternatives with multiple criteria, many factors such as weights of criteria, preference dependence and conflicts among criteria seem to complicate the problem and need to be overcome by more sophisticated methods [24].

Choquet integral that is a generalization of Lebesgue integral is a non-additive generalization of weighted arithmetic mean [25]. In the present paper, Choquet integral that uses a non-additive measure, namely fuzzy measure, is considered as a tool. As the fuzzy measure can be used to show the interactions between criteria, one can be obtained stronger approaches whenever a fuzzy measure is considered instead of an additive one. In this context many researchers have been concerned with this subject. Firstly, Sugeno [26, 27] proposed the concept of fuzzy integral. Then it was followed by many mathematical developments. Later, especially in Japan, many researchers thought that this concept could be used in MCDM. There are lots of papers that give applications of this concept such as on wood quality evaluation, evaluation of printed color images, design of speakers etc. [28-32].

In contrast to the various concepts of integral that use additive measures, Choquet integral (indeed any fuzzy integral) is much more complex. This is expressed by Grabisch with "The richness of fuzzy integrals has to be paid by the complexity of the model" [25]. It means the number of coefficients involved in the fuzzy integral method grows exponentially with the number of elements to be aggregated. Thus it is not easy to determine the interacted weights of subsets for each combination. In the step of determination of the weights, the ideas of experts, questionnaires or known data may be used.

The remainder of the study is organized as follows. The methodology is given in the next section. In Section 3, the promised MCDM problem for Turkey is conducted. Finally, the study is concluded in Section 4.

2. METHODOLOGY

2.1. Fuzzy Measure and Choquet Integral

Let X be a non-empty set and let 2^X be the class of all subsets of X. Then a set function μ over 2^X is said to be a fuzzy measure if

$\mu(\varnothing)=0$ and $\mu(X)=1$,

$\mu(A)\le\mu(B)$ whenever $A\subseteq B\subseteq X$ (monotonicity).

Recall that a fuzzy measure μ is said to be

additive if $\mu(A\cup B)=\mu(A)+\mu(B)$,

superadditive if $\mu(A\cup B)\ge\mu(A)+\mu(B)$,

subadditive if $\mu(A\cup B)\le\mu(A)+\mu(B)$,

whenever $A\cap B=\varnothing$ [25].

It is not difficult to see that it suffices to determine the weights of singletons over a finite set X to determine the weights of all combinations whenever the fuzzy measure is additive. However; unless the fuzzy measure is additive, the weights of 2^n subsets should be determined separately but convenient to the definition of fuzzy measure, especially monotonicity property. The superadditivity of a fuzzy measure refers to the synergy between criteria and the subadditivity of it refers to the redundancy [25]. Since each criterion effects each other synergistically in this study, the corresponding fuzzy measure is superadditive for singletons.

Assume that $X=\{x_1,x_2,...,x_n\}$ is a finite set (the set of criteria) and μ is a fuzzy measure on X. Choquet integral of a function $f:X\to[0,1]$ is defined by

$$(C)\int_X f d\mu := \sum_{k=1}^{n}(f(x_{(k)})-f(x_{(k-1)}))\mu(E_{(k)}) \qquad (1)$$

where $\{x_{(k)}\}_{k=0}^{n}$ is a permuted sequence so that $0=:f(x_{(0)})\le f(x_{(1)})\le f(x_{(2)})\le...\le f(x_{(n)})$ and $E_{(k)}:=\{x_{(k)},x_{(k+1)},...,x_{(n)}\}$ [31]. Now we can say that Choquet integral of a function is a kind of distorted average of the sequence $\{f(x_{(k)})\}_{k=1}^{n}$. In this context Choquet integral could be considered as a generalization of weighted arithmetic mean which considers the interaction between criteria. It means Choquet integral with respect to a non-additive fuzzy measure allows to consider requirements of decision maker by taking into account the interaction between criteria. Note that alternatives in a MCDM problem are considered as functions that will be integrated. Thus we may order alternatives with respect to Choquet integral.

2.2. Identification of Fuzzy Measure

In this section we give a hybrid method to identify the fuzzy measure. Let $X=\{x_1,x_2,...,x_n\}$ be the set of criteria. As we mentioned before we determine the measures of singletons by FAHP. FAHP is used for determination of the significance weights of criteria due to uncertainness in the comparison stage of the criteria. To obtain more objective results, the FAHP is used instead of AHP. In this sense, according to expert opinion, fuzzy pair-wise comparison matrix is constructed by using triangular fuzzy scale (TFS) that is given in Table 1.

Table 1. Triangular fuzzy conversion scale [33]

Linguistic scale	TFS	TFS (*reciprocal*)
Just equal	(1, 1, 1)	(1, 1, 1)
Equally important	(1/2, 1, 3/2)	(2/3, 1, 2)
Weakly important	(1, 3/2, 2)	(1/2, 2/3, 1)
Strong more important	(3/2, 2, 5/2)	(2/5, 1/2, 2/3)
Very strong more important	(2, 5/2, 3)	(1/3, 2/5, 1/2)
Absolutely strong more important	(5/2, 3, 7/2)	(2/7, 1/3, 2/5)

For defuzzification, firstly for each criterion $(k=1,...,n)$ lower and upper bounds are determined for every factor at every $\alpha-cut$ value (eq. 2, 3). If $\tilde{A}$ is a fuzzy number, then it is defined as $\tilde{A}=(l,m,u)$ where *m* is the most possible value, *l* and *u* are lower and upper limit values respectively, i.e. these limits show the extend of the fuzziness [34].

Lower Bound: $LB_k=\alpha(m_k-l_k)+l_k$ (2)

Upper Bound: $UB_k = u_k - \alpha(u_k - m_k).$ (3)

Later, combined lower $(w_{k(lower)})$ and upper bound values $(w_{k(upper)})$ are calculated for any k (eq. 4, 5) (see e.g. [34, 35]).

$$w_{k(lower)} = \frac{\sum_{i=1}^{l} \alpha_i (LB_k)_i}{\sum_{i=1}^{l} \alpha_i} \tag{4}$$

$$w_{k(upper)} = \frac{\sum_{i=1}^{l} \alpha_i (UB_k)_i}{\sum_{i=1}^{l} \alpha_i}. \tag{5}$$

Then using the following equality we obtain the final defuzzified significance weight for each criterion (see e.g. [34]).

$$W_k = \beta w_{k(lower)} + (1-\beta) w_{k(upper)},\ \beta \in [0,1]. \tag{6}$$

In practical applications, $\beta = 1$; $\beta = 0.5$, and $\beta = 0$ are used to indicate that the decision maker has an optimistic, moderate, or pessimistic view, respectively. An optimistic decision maker is apt to prefer higher values of his/her fuzzy assessments, while a pessimistic decision maker tends to favor lower values [36].

Now we determine the interdependence coefficient $\lambda_{ij} \in [0,1]$ for each pair of criteria $(x_i,\ x_j)$. For this purpose the decision maker may use the method of [20]. After determining all interdependence coefficients we obtain the fuzzy measure of singletons by normalizing the set

$\{W_1,...,W_n\}$ such that for any $k = 1,2,...,n$

$$\sum_{k=1}^{n} g_k = 1 - \max \lambda_{ij}\ \ and\ \ g_k \geq 0 \tag{7}$$

where for each k , g_k that is the normalized value of W_k will be the fuzzy measure of singleton x_k i.e. $\mu(\{x_k\}) = g_k$. Now we are ready to calculate the measure of each subset $A \subset X$ such that $Card(A) \geq 2$ by using the formula (5) of [20]. For the sake of completeness we keep the formula:

$$\mu(\{x_i, x_j\}) = g_i + g_j + \lambda_{ij},\ i \neq j \tag{8}$$

$$\mu(A) = \sum_{x_k \in A} g_k + \max_{x_i, x_j \in A, i \neq j} \lambda_{ij},\ A \subset X,\ Card(A) > 2. \tag{9}$$

For concurrency we define $\mu(\varnothing) = 0$ and note that from equalities (7) and (9) one can get that

$$\begin{aligned} \mu(X) &= \sum_{k=1}^{n} g_k + \max \lambda_{ij} \\ &= 1 - \max \lambda_{ij} + \max \lambda_{ij} \\ &= 1. \end{aligned}$$

Monotonicity is obvious. Moreover super-additivity for singletons of the fuzzy measure μ can be checked from eq. (8). Thus we obtain the promised fuzzy measure on X. Figure 1 shows the proposed hybrid method for identification of the fuzzy measure.

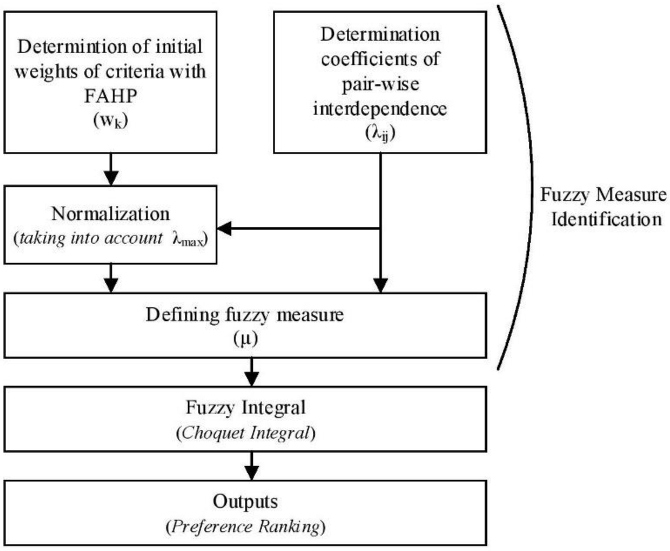

Figure 1. The schematic representation of the proposed hybrid method

3. THE CASE STUDY

In this section we consider the determination of degree of the cities of Turkey affected by global warming as a MCDM problem by taking into account the criteria such as changes in rainfall and temperature. For this purpose, four criteria are considered to rank cities of Turkey and these criteria are given in Table 2. The data with regard to criteria that mentioned in Table 2 is acquired from Turkish State Meteorological Service [37].

Table 2. Description of the criteria

Criteria	
C_1	The ratio of maximal rainfall to the normal rainfall of the month in which The maximal rainfall occurs (*last 42 years*)
C_2	The number of years in which the rainfall is abnormal (*last 42 years*)
C_3	The degree of drought (*last 21 years*)
C_4	The ratio of the average temperature of the last 10 years to seasonal normal

After determining the criteria, significance weights of the criteria are calculated in accordance with the hybrid method that is proposed above. Firstly, the fuzzy pair-wise comparison matrix for the criteria is constructed in FAHP stage. The pair-wise comparison matrix and fuzzy weights for the criteria are summarized in Table 3.

Table 3. Pairwise comparison matrix and fuzzy weights for the criteria

Criteria	**C_1**	**C_2**	**C_3**	**C_4**
C_1	(1, 1, 1)	(2/5, 1/2, 2/3)	(1/3, 2/5, 1/2)	(2/3, 1, 2)
C_2	(3/2, 2, 5/2)	(1, 1, 1)	(2/5, 1/2, 2/3)	(2/5, 1/2, 2/3)
C_3	(2, 5/2, 3)	(3/2, 2, 5/2)	(1, 1, 1)	(1, 3/2, 2)
C_4	(1/2, 1, 3/2)	(3/2, 2, 5/2)	(1/2, 2/3, 1)	(1, 1, 1)
Geometric mean of the 1th row: (0.546, 0.669, 0.904) Geometric mean of the 2nd row: (0.699, 0.841, 1.027) Geometric mean of the 3rd row: (1.316, 1.655, 1.968) Geometric mean of the 4th row: (0.783, 1.075, 1.392) The sum of the fuzzy geometric averages: (3.344, 4.24, 5.291)				
The fuzzy weight of C_1: (0.103, 0.158, 0.270) The fuzzy weight of C_2: (0.132, 0.198, 0.307) The fuzzy weight of C_3: (0.249, 0.390, 0.589) The fuzzy weight of C_4: (0.148, 0.254, 0.416)				

Now, for defuzzification, lower and upper bounds are determined for each criterion (C_1, C_2, C_3, C_4) at every $\alpha - cut$ value and it is shown in Table 4 (see eq. 2, 3).

Table 4. Calculation of LB_1 and UB_1

$\alpha - cut$	**0.1**	**0.2**	**0.3**	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**
LB_1	0.1085	0.114	0.1195	0.125	0.1305	0.136	0.1415	0.147	0.1525
UB_1	0.2588	0.2476	0.2364	0.2252	0.214	0.2028	0.1916	0.1804	0.1692

Combined lower and upper bound values for criteria are shown in Table 5 (eq. 4, 5). The defuzzified significance weights of them are also shown in the last column of Table 5. Note that in the present study β is considered as 0.5.

Table 5. Defuzzified significance weights for the criteria

Criteria	***l***	***m***	***u***	w_{lower}	w_{upper}	***W***
C_1	0.103	0.158	0.270	0.137833	0.199067	0.17
C_2	0.132	0.198	0.307	0.1738	0.237967	0.21
C_3	0.249	0.390	0.589	0.3383	0.462967	0.40
C_4	0.148	0.254	0.416	0.215133	0.3134	0.26

In this step according to the opinion of experts, it is concluded that there is a weak dependence between any two criteria. The value of each λ_{ij} is given in Table 6.

Table 6. Interdependence coefficients between the criteria

$\lambda_{12} = \lambda_{21} = 0.02$
$\lambda_{13} = \lambda_{31} = 0.01$
$\lambda_{14} = \lambda_{41} = 0.01$
$\lambda_{23} = \lambda_{32} = 0.01$
$\lambda_{24} = \lambda_{42} = 0.02$
$\lambda_{34} = \lambda_{43} = 0.04$

After determining interdependence coefficient between any two criteria we get normalized value g_k of W_k as $g_1 = 0.16$, $g_2 = 0.19$, $g_3 = 0.37$, and $g_4 = 0.24$. One can check that

$$\begin{aligned}\sum_{i=k}^{4} g_k + \max \lambda_{ij} &= 0.16 + 0.19 + 0.37 + 0.24 + 0.04 \\ &= 1\end{aligned} \tag{10}$$

On the other hand, using the normalized values and formulas (8) and (9) we define the set function μ over the power set of the set of the criteria as shown in Table 7, immediately.

Table 7. Definition of μ

$\mu(\varnothing) = 0$	$\mu(\{C_2, C_3\}) = 0.57$
$\mu(\{C_1\}) = 0.16$	$\mu(\{C_2, C_4\}) = 0.45$
$\mu(\{C_2\}) = 0.19$	$\mu(\{C_3, C_4\}) = 0.65$
$\mu(\{C_3\}) = 0.37$	$\mu(\{C_1, C_2, C_3\}) = 0.74$
$\mu(\{C_4\}) = 0.24$	$\mu(\{C_1, C_2, C_4\}) = 0.61$
$\mu(\{C_1, C_2\}) = 0.37$	$\mu(\{C_1, C_3, C_4\}) = 0.81$
$\mu(\{C_1, C_3\}) = 0.54$	$\mu(\{C_2, C_3, C_4\}) = 0.84$
$\mu(\{C_1, C_4\}) = 0.41$	$\mu(\{C_1, C_2, C_3, C_4\}) = 1$

Now, we can calculate the Choquet integral of alternatives, which are the 81 cities of Turkey, after normalizing the values of alternatives on each criterion in $[0,1]$ such that 0 and 1 is less and most prone to global warming, respectively. Table 8 (see Appendix A) shows these normalized values and the scores of Choquet integral. As an illustration, score of Choquet integral of Ankara City is calculated:

$$\begin{aligned}(C)\int_X f d\mu &= \sum_{k=1}^{n} (f(C_{(k)}) - f(C_{(k-1)}))\mu(E_{(k)}) \\ &= (0.2382942 - 0) \times 1 + (0.4727869 - 0.2382942) \times 0.84 \\ &+ (0.5416667 - 0.4727869) \times 0.57 + (0.5673935 - 0.5416667) \times 0.37 \\ &= 0.48405\end{aligned}$$

where $X = \{C_1, C_2, C_3, C_4\}$ and f denotes Ankara City.

4. CONCLUSION

In the previous studies, the evaluation of the impacts of the climate change and global warming is handled via different fuzzy techniques. In this study the degrees of effect of the global warming on the cities are calculated via the proposed method reinforced with fuzzy measure theory in terms of the investigation of the impacts on Turkey of the global warming. The map of the effect with respect to the cities is presented in Figure 2. According to the map, the coast cities and the cities that receive regular rain have being affected less than the others.

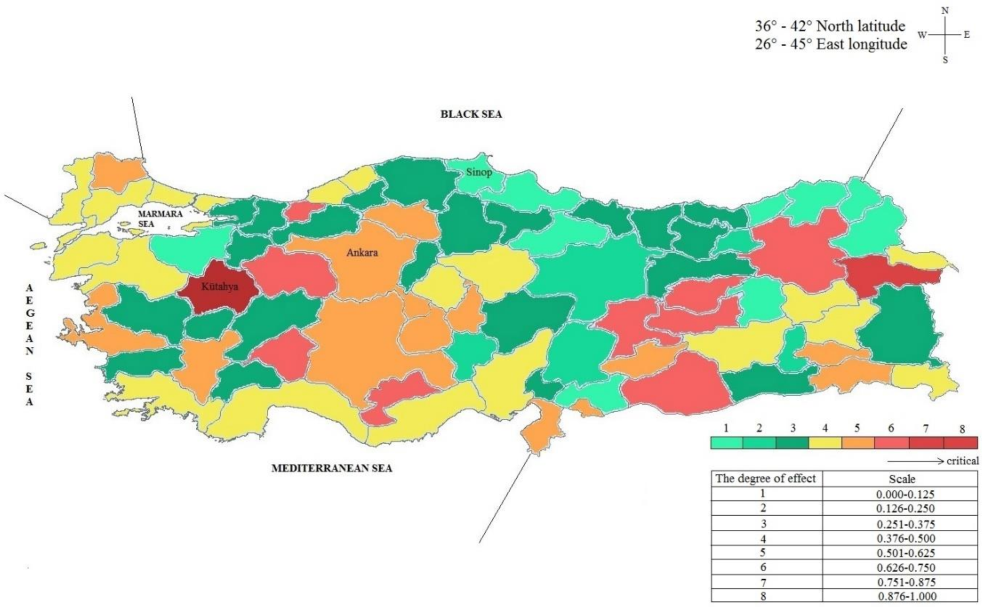

Figure 2. The map of the effect with respect to the cities

The city that is most affected from the global warming is determined as Kütahya City. It is not an unexpected result if we consider the location of Kütahya City. Since this city is located on the interior of the country, according to years, the antecedent precipitation index is distributed irregularly. Moreover, industry has rapidly developed in the last 20 years in this region. Kütahya City has 641 firms that are operating in different activity area though it has small surface area [38]. This industrialization affects to the results negatively. Table 9 gives an information about the scope of the Industry of Kütahya City.

Table 9. Industry of Kütahya City [38]

Scope	%	Scope	%	Scope	%
Nourishment	28.08	Tile	6.4	Iron & Aluminum Joinery	2.65
Forestry Products	6.08	Chemistry	3.28	Production of Machine	6.55
Furniture	8.11	Packaging & Paper	1.72	Ceramic & Glass	7.18
Plastic & Rubber	2.96	Textile	4.99	Marble	2.34
Forage	0.47	Building Trade	7.33	Electric & Electronic	0.62
Mine, Soil	7.966.	Automotive	2.18	Other	1.09

The city that is least affected from the global warming is determined as Sinop City. The location of Sinop City is at Black Sea Region. It is clear that the cities Rize, Samsun, Artvin have also lower scores than other cities, in this region. Owing to the climate of the region, rainfall and temperature are stabile contrary to the other regions of Turkey.

CONFLICT OF INTEREST

No conflict of interest was declared by the authors.

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APPENDIX A

Table 8. Scores of Choquet Integral

Cities	C_1	C_2	C_3	C_4	Scores
Adana	0.082100059	0.625	0.665014866	0.239602715	0.448884
Adıyaman	0.01913584	0.666666667	0.668979187	0.318240147	0.469842
Afyon	0.118056069	0.458333333	0.35728444	0.440908309	0.359949
Ağrı	0.266131464	0.625	0.862735382	0.489735844	0.619022
Amasya	0.435783012	0.5	0.151635282	0.498558856	0.353488
Ankara	0.2382942	0.5416667	0.5673935	0.4727869	0.48405
Antalya	0.122942251	0.958333333	0.377106046	0.344639647	0.438107
Artvin	0.081594608	0.291666667	0.247770069	0.423706012	0.272625
Aydın	0.052921443	0.833333333	0.457879088	0.23534785	0.404339
Balıkesir	0.134571797	0.25	0.698216056	0.337283014	0.421811
Bilecik	0.21002141	0.333333333	0.411298315	0.417017568	0.365653
Bingöl	0.073156777	0.291666667	0.409811695	0.157899062	0.264301
Bitlis	0.022685392	0.666666667	0.548067393	0.290843069	0.41709
Bolu	0.064985753	0.416666667	0.496035679	0.463036143	0.402748
Burdur	0.269531295	0.5	0.383052527	0.437888635	0.401367
Bursa	0.147076845	0.208333333	0.265113974	0.39035613	0.265498
Çanakkale	0.130251719	0.583333333	0.57185332	0.295229911	0.42869
Çankırı	0.446657962	0.625	0.582259663	0.291798638	0.491808
Çorum	0.078301566	0.375	0.477205154	0.401322146	0.372714
Denizli	0.847139826	0.666666667	0.332507433	0.363743661	0.492519
Diyarbakır	0.075429879	0.625	0.664519326	0.286089481	0.460185
Edirne	0.156423011	0.666666667	0.420713578	0.404943434	0.4209
Elazığ	0.118209542	0.541666667	0.792368682	0.488251405	0.552251
Erzincan	0.095957694	0.333333333	0.415262636	0.442461943	0.355135
Erzurum	0.223329613	0.625	0.723984143	0.484136287	0.559324
Eskişehir	0.447018701	0.041666667	0.89246779	0.458699425	0.538089
Gaziantep	0.028742479	0.291666667	0.28741328	0.330090312	0.257162
Giresun	0.187326544	0.416666667	0.420713578	0.346805967	0.362607
Gümüşhane	0.077105235	0.583333333	0.368681863	0.459046438	0.386308
Hakkari	0.024535739	0.375	0.638255699	0.346221806	0.40856
Hatay	0.535713953	0.541666667	0.582259663	0.257946639	0.481907
Isparta	0.090686194	1	0.692765114	0.308681163	0.551104
Mersin	0.130990696	0.625	0.557978196	0.309643219	0.435344
İstanbul	0.353265629	0.666666667	0.264618434	0.459605107	0.405888
İzmir	1	0.625	0.289395441	0.270448136	0.468643
Kars	0.0729925	0.166666667	0.21456888	0.578416994	0.270139
Kastamonu	0.08175076	0.75	0.381565907	0.343134461	0.393221
Kayseri	0.067836377	0.5	0.492566898	0.376032154	0.394558
Kırklareli	0.272891713	0.75	0.618434093	0.324050791	0.508661
Kırşehir	0.166546743	0.5	0.623389495	0.379393137	0.459738
Kocaeli	0.280793285	0.666666667	0.273538157	0.403625327	0.383216
Konya	0.209977731	0.5	0.614469772	0.402085964	0.469513
Kütahya	0.08342551	0.583333333	0.812685828	0.499748232	0.696778
Malatya	0.055212835	0.458333333	0.910307235	0.388523816	0,542216
Manisa	0.084279879	0.416666667	0.656095144	0.230632659	0.401844
K.Maraş	0.039464217	0.458333333	0.35579782	0.310805911	0.312518
Mardin	0.094125605	0.708333333	1	0.308458927	0.37
Muğla	0.245575173	0.666666667	0.543111992	0.23624128	0.43622
Muş	0.039102511	0.5	0.630327056	0.319790544	0.425821
Nevşehir	0.03129948	0.541666667	0.633795837	0.50603888	0.484476
Niğde	0.107126887	0.291666667	0.355302279	0.429211522	0.321242
Ordu	0.204506493	0.333333333	0.458374628	0.399637957	0.377552
Rize	0.052983074	0.083333333	0.340931615	0.385245661	0.256552
Sakarya	0.17268178	0.5	0.367195243	0.51080609	0.398429

Table 8. (Continued) Scores of Choquet Integral

Cities	C_1	C_2	C_3	C_4	Scores
Samsun	0.271456687	0	0.347373637	0.397532213	0.281264
Siirt	0.098482394	0.583333333	0.757185332	0.331532816	0.502096
Sinop	0.130666476	0.333333333	0.149653122	0.369365769	0.237919
Sivas	0.058882219	0.5	0.24826561	0.483527151	0.326962
Tekirdağ	0.213341605	0.75	0.347869177	0.372173723	0.409069
Tokat	0	0.416666667	0.280971259	0.348667189	0.279399
Trabzon	0.338977622	0.375	0.2864222	0.447040976	0.351981
Tunceli	0.069242653	0.875	0.763131814	0.285449477	0.54439
Şanlıurfa	0.11061727	0.791666667	0.743310208	0.307551948	0.533612
Uşak	0.085237905	0.708333333	0.346382557	0.291407843	0.358527
Van	0.116200096	0.333333333	0.478691774	0.313156138	0.346927
Yozgat	0.063899477	0.875	0.414767096	0.437673558	0.452028
Zonguldak	0.504158936	0.5	0.502477701	0.340768926	0.460207
Aksaray	0.250279375	0.458333333	0.598612488	0.423459576	0.467532
Bayburt	0.088859194	0.625	0.051040634	0.559970526	0.298466
Karaman	0.132806549	0.416666667	0.831020813	0.430743937	0.528502
Kırıkkale	0.276214615	0.541666667	0.476709613	0.281264455	0.404202
Batman	0.055389525	0.458333333	0.647175421	0	0.340538
Şırnak	0.067897288	0.5	0.704261645	0.486696741	0.502848
Bartın	0.191645634	0.708333333	0.420218038	0.372271727	0.425443
Ardahan	0.063536072	0.666666667	0.1	0.250801	0.250801
Iğdır	0.04525158	0.875	0.349355798	0.49476192	0.438377
Yalova	0.352390365	0.291666667	0.546085233	0.326949493	0.405651
Karabük	0.145830422	0.333333333	0.476883053	0.308305486	0.349689
Kilis	0.072679088	0.666666667	0.710604559	0.293764331	0.487202
Osmaniye	0.117981073	0.5	0.52475223	0.183399381	0.362553
Düzce	0.272582709	0.5	0.810703667	0.398403331	0.551142