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ORIGINAL RESEARCH

A Comparative Study of Marriage-Divorce and Related Factors in Türkiye's Regions Using Kohonen SOM - MDS Tandem and MULTIMOORA Approaches

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Abstract
Marriages and divorces have recently changed along with economic developments, social and cultural shifts in mostly developed countries including Türkiye, and therefore affect the countries' demography. This study is motivated by recent significant changes in Türkiye's marriage and divorce rates and regional differences. The data is retrieved from the Turkish Statistical Institute (TURKSTAT) for 26 regions of Türkiye. Kohonen's self-organizing map (SOM), multi-dimensional scaling (MDS), and MULTIMOORA (Multi-Objective Optimization by Ratio analysis plus Full Multiplicative Form) methods are used for the proposed methodology. SOM and MDS methods are employed sequentially to find similar and dissimilar regions. The variations of the regions are also evaluated by one of the multi-criteria decision-making (MCDM) methods, MULTIMOORA. Indicators of all regions differ relatively compared to the previous ten-year period, as well as the changes vary. The regions that show the changes both the most and the least are located in the country's East. The study investigates regional differences of the relationship between marriage, divorce, and socio-economic factors in a different methodology. The combined usage of SOM-MDS tandem and MCDM methodologies provides more accurate and sensitive results about region-based differences in Türkiye.

Keywords SOM · MDS · MCDM · Marriage · Divorce

Introduction

The family has been accepted as the foundation of society worldwide. The family structure's development, strengthening, andfenfefe continuity essential for healthy societies [32]. Families have historically been tasked with various societal functions, such as responsibility for the procreation and socialization of children, education, economic support, protection, religion, and recreation [31]. However, the family institution has also affected by economic developments, modernization, and technological advances that caused changes in the social structure, and it began to be ineffective in fulfilling these social duties. Decreasing marriage rates, increasing divorce rates, ages at first marriage, and reduced fertility affect the demographic structure of countries. Social and demographic transformation changed in the 1960s in European countries. It has evolved from the first demographic transformation with high fertility to a second demographic transformation [43, 78]. Frisby et al. [33] reported that a third of first marriages result in divorce within the first 10 years, and half of all first marriages end in divorce throughout their lifetime. Also, non-marital cohabitation is becoming more prevalent, and more kids are raised by single parents, which impacts societal dynamics [2, 24, 35]. The literature claims that employment rates for women, individualistic beliefs, unemployment, religion, socio-economic prospects for men, higher education, and school enrolment are significant determinants of this transformation [4, 7, 20, 22, 42, 43].

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Although Türkiye has lower divorce rates than European countries, profound transformations have taken place in the past decades in family life due to both the modernization and socioeconomic changes it experienced [20, 44, 76–78]. In addition to having high divorce rates in Türkiye, there has been a higher age at first marriage, lower marriage and fertility rates, decreased gender role specialization, and greater independence among young people [20, 45]. These things make Türkiye one of the countries in the last stage of the first demographic transformation with decreasing death rates and fertility levels since 1980 [47, 78]. However, some researchers have recently argued that Türkiye's family structure, marriage formation, and composition of the household show the characteristics of the second demographic transformation [1, 21].

Several changes affected family life in Türkiye. First, in 1988, no-fault divorce law was introduced to allow divorce by mutual consent [44]. Second, the Turkish Civil Code regulation was made in 2001 during Türkiye's bid for European Union (EU) membership. It has provided legal rules on marriage, divorce, and gender equality. It has expanded women's rights in marriage [20, 44, 77]. Third, family life has affected by the country's economic recession of 2001, and it was observed a % 20 increase in divorce rates compared to the previous years [44]. The regulations did not affect the females who live in rural areas, especially the eastern part of the country, as much as the urban parts of the country, especially the western ones [36]. According to statistics of TURKSTAT [69], the number of marriages per 1000 population decreased from 8.35 in 2001 to 6.68 in 2021. In the same period, the crude divorce rate expressing the number of divorces per 1000 population increased from 1.41 to 2.07. The average age at first marriage also rose from 22.7 to 25.4 for women and 26 to 28.1 for men in 2001 and 2021, respectively. The number of divorces in 2021 was 174.085, and 165.937 children were affected by TURKSTAT [69].

Türkiye has also a vast regional difference in economic development family life across the country [20, 44, 45]. The Western regions are developed more economically, while the East is less. Central Regions have growing industries; they are less urbanized than western ones. Divorce rates in Türkiye differ substantially according to the regions: İzmir province on the west side of Türkiye has the highest value of 3.04. In contrast, Şırnak province on the eastern side has the lowest rate of 0.38 [69]. Besides to socioeconomic features and divorce rates, there are also huge differences between fertility rates, women's education, female employment rates and the unemployment rates [20, 42, 48, 76, 77].

Türkiye has recently changed considerably in its marriage and divorce rates, and its substantial regional differences motivate this study. Therefore, the study aims to describe and compare marriage, divorce, and their associated factors in Türkiye's regions between 2011 and 2021. The data is collected from the TURKSAT. The TURKSTAT is a technical and scientific institute which produces publications to provide an open access data about Türkiye's information needs on social, economic, and cultural areas. The TURKSTAT mainly aims to define generic information of needs, collect and compile data, and put forward the information to its users with highest international standards.

Analyzing the high dimensionality of data has recently been a significant challenge in all disciplines with the improvement of science and technology. Although machine learning techniques usually focus on classification and regression problems, multivariate data visualization and dimension reduction methods are widely used on big and complex raw data to extract meaningful information in raising trends. Self-Organizing Maps (SOM) and Multidimensional Scaling (MDS) are these methods. In this study, the methods are used to map regional differences sequentially so providing more robust prediction compared to using one method [73]. Furthermore, [34] pointed out that examining demoghraphic changes is crucial to plan social life so an accurate assessment tools needed in this area and suggesting MCDM methods. These methods are a kind of operational research techniques for decision making for complex problems can apply demoghraphic data to find successful results. Therefore, we use SOM-MDS and MCDM methods are used together to evaluate the conditions and changes in the regions a more effective and realistic way. The study has several contributions to the literature. Firstly, to the best of our knowledge, this is the first study that applies the three-stage framework of SOM-MDS and MCDM methods. The proposed methodology can be applied any other topic. The study also provides a unique approach to exploring the differences, similarities, and changes in terms of marriage divorce and related factors with advanced techniques. Furthermore, the work uses an MCDM method to evaluate changes of social changes. In this context, the results provide a robust and systematic approach to assessing the regions' situations and a road map for policymakers to plan methodology. Future studies could carry this study further by using more comprehensive variables in Türkiye's social structure and demography.

The rest of the research is organized as follows: "Literature Review" presents the review of the literature. "Methodology and Data" gives an explicit insight for methodology, data and using methods. "Results" is dedicated to explain how to apply the mentioned models and show the performances of the results. A detailed discussion on the results is given in "Discussion". Finally, the last section is concludes and remarks.

Literature Review

This part focuses on two fundamental topics: the first one is understanding the variables that influence marriage and divorce patterns, and the second one is combining of the clustering and multi-criteria decision-making (MCDM) methods—especially in demographic ones.

Beginning in the 1960s in urban countries and the 1980s in Türkiye, decreasing marriage rates, increasing divorce rates, and marriage ages have started to impact each nation's demographic structure. Numerous studies have been conducted at the national and worldwide levels in response to the emergence of demographic change to explain its related factors and effects. It is affected by many different aspects, varying from country to country. Studies focusing on that topic applied different statistical methods such as ordinary least squares (OLS) regression analysis, time series analysis, survival (event history) analysis, and clustering analysis.

Time series models are used to find the causes of divorce in the USA [17, 65, 66] and it is discovered that higher female labor force participation is associated with higher levels of domestic conflict and higher rates of divorce. Kalmijn [43] predicted associated factors of ages at first marriage, marriage rates, and net/crude divorce rates in European countries by using time series models. He aimed to explain the differences among countries' secularization, gender roles, education, men's suicide rates, and unemployment rates. The research showed that female employment rates are related to lower marriage rates, higher divorce rates, and higher cohabitation rates. Another finding is that unemployment rates are negatively associated with the divorce rate, supporting the cost of divorce. The other factors vary among countries. Time series models are also applied to find the relationship between divorce and unemployment rates in USA [7] and the results show a negative relationship between them, the reasoning of the cost of divorce.

Alpekin and Luo [4] examined the association between divorce rates and female labor force participation in Organisation for Economic Co-operation and Development (OECD) countries using panel data analysis. They discovered a connection between rising divorce rates and female labor force participation rates. Sandalcılar [62] aimed to find relationship differences between divorce rates and unemployment rates among Türkiye's regions by using panel data analysis. He pointed out that there was a negative association between unemployment rates and divorce rates, because of the social and economic cost of divorce. Ucler and Kızılkaya [71] applied panel data analysis to find the effects of women's employment rates on divorcement and fertility rates in Türkiye's regions. Although there were regional differences, they found that women employment affected the divorce rate positively and fertility negatively. Another research is conducted for regional differences in Türkiye's divorce rates related factors via an econometric model [52] and it is discovered the link between divorce rates, Gross Domestic Product (GDP) per person, unemployment rates, and female employment rates including regional variations. Erkan and Yamak [30] proposed to find determinants of divorce based on Türkiye's regions by using panel data analysis. They showed that female education, female labor force participation, and unemployment increased the crude divorce rates. There was a negative relationship between male unemployment rates and crude divorce rates. They underlined the regional differences. Igdeli and Ay [42] investigated determinants of divorce in Türkiye's sub-regions by the panel data analysis. They showed that in regions with high socioeconomic development levels, women's income and education levels are the primary predictors of divorce. In regions with low socioeconomic development levels, female education levels and male unemployment levels are the primary factors of divorce.

On the other hand, Cohen [23] predicted reasons for divorce using logistic regression and suggested that the relationship between divorce and unemployment rates depends on women's education. Caarls and de Valk [20] examined regional variations of divorce in Türkiye by using multivariate discrete-time event history models. They found that divorce rates had risen recently, but there were enormous regional variations in the family's economic development and modern values. In the wealthier and more urban regions living, women were more likely to divorce than other counterparts because of cost of divorce decreased. Also, higher-educated females had a higher risk of divorce than lower-educated ones. However, this effect is more pronounced in wealthier and more urbanized regions. With the OLS regression, the female age at the first marriage is predicted and the findings show the college education is the primary predictor of it [1].

Several studies investigated the relationship between marriages and suicide rates. According to Durkheim's [28, 58] classic arguments more than a century ago, divorce reduces family ties and raises suicide rates. There were several studies examining divorce and suicide rates. Pampel [58] claim that there is no link between divorce and suicide rates in high-income nations. Cutler et al. [25] and Kposowa [51] reported that divorced men were more prone to suicide than married and single men. Brainerd [12] tested the association between suicide rates and unemployment, income, and divorce rates in 22 transition economies. He pointed out that, like it was for men, the divorce rate is substantially correlated with the female suicide rate, but unlike men, it is also correlated with alcohol usage. In Türkiye,

there were also studies supporting the relationship between them. Alptekin and Duyan [5] aimed to find socioeconomic factors of suicide among regions in Türkiye. They stated that although rates varied by region, men were more likely to commit suicide, particularly those older and divorced. Aksoy and Yerlikaya [3] measured the relationship between divorce and suicide in Türkiye's regions. They indicated that divorce increased the suicide rates of skilled men and unskilled women.

Yuksel-Kaptanoğlu et al. [78] identified high/low-risk women for marriage using event history and cluster analyses in Türkiye at the regional level. They pointed out that in parallel with the country's heterogeneous demographic structure, marriage changes are at different levels for women who cannot benefit from social and economic developments and gender equality to the same extent. Female education and employment were the main determinants of the marriage risk for women.

There are various recent studies in other areas integrating clustering analysis, and MCDM approaches aiming to rank the clusters [10, 56, 57, 72]. In addition to this, using MCDM approaches in demography studies is limited. For example, Gogodze [34] used MCDM methods to investigate demographic condition change. They demonstrated that the ranking methods are valuable tools for aggregating multidimensional indicator sets, and the MCDM framework for evaluating demographic change is a pretty effective approach.

The main focus of our study is on Türkiye's regional variance in marriage, divorce and its related factors change over time. Several studies have been performed in this area with different perspectives. However, investigating the demographic and social changes with a combination of artificial intelligence, statistical learning, and MCDM approaches has not yet been applied.

In proposed methodology, first, regions are primarily clustered according to marriage, divorce indicators, and related factors. It was used Kohonen SOM as the clustering tool to mapped the regions close together (e.g. in the same neuron, or neighbor) or far away (e.g. on the different neuron or clusters). Then, their distance (neurons) visualizes by MDS to measure similarities and dissimilarities among regions better. Lastly, regions were ranked according to study indicators to see their relative situation by MULTIMOORA method. Not only we can highlight the similarities between regions, but we can also make it possible to optimize their values relative to each other and a more sensitive and accurate assessment of regions' situation.

Methodology and Data

This section is divided into five parts. First, the proposed methodolology are presented. Then, the details of data are given briefly. The considered models—SOM, MDS and MULTIMOORA analysis— are summarized in the next parts with the main idea behind them.

Methodology

The study consists of three stages. In the first stage, regions are divided into clusters via SOM analysis based on research variables. After obtaining the weight vectors of neurons, MDS methods are applied to visualize regions' distances better. This is called as SOM-MDS tandem (sequential) approach. In the third stage, MULTIMOORA is applied to data for evaluating and ranking all the regions. The weight of the indicators are also calculated from SOM weight vectors. Finally, the methodology aims to compare the SOM-MDS tandem approach and MULTIMOORA solutions to discuss the regions'

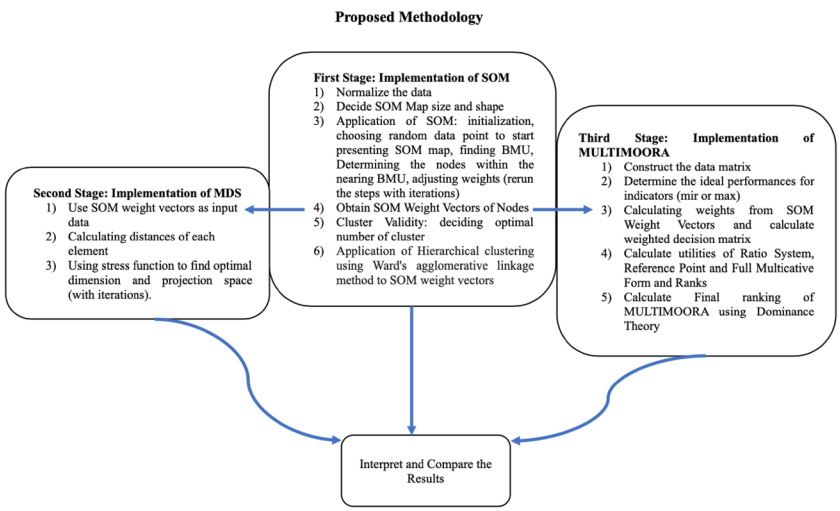

Fig. 1 Three-stage approach

differences and variations. This mentioned methodology is summarized in Fig. 1.

The SOM is an unsupervised artificial neural network technique proposed by Kohonen [49]. The SOM network learns from high dimensional input space onto a low dimensional (mostly two-dimensional) grid (lattice or map) which is topological order. The SOM is a topology-preserving technique, meaning that the closest neighbor nodes have similar input patterns. The SOM is assumed as a topographic vector quantizer, a nonlinear visualization tool, or a clustering technique [61]. The reduction of dimensions is therefore based on distance-preservation and thus similar to for example Multidimensional Scaling, but different to some other popular dimension reduction methods like Principal Component Analysis, which reduces dimensions whilst retaining as much of the original correlation structure as possible.

MDS is a dimension reduction method first introduced by [67] and aims to visualize the level of similarity (or dissimilarity) among pairs of objects by retaining the distances between pairs of objects in the input space, to the extent possible, in the lower dimensional space. Four main reasons for using MDS are that the representation ability of (dis)similarity data as distances of low-dimensional space in order to make these data accessible to visual inspection and exploration, allowance one to test id and how certain criteria by which one can distinguish among different objects of interest are mirrored in corresponding experimental differences of these objects, a data analytic approach that allows one to discover the dimensions that underlie judgements of (dis)similarity, a psychological model that explains judgements of dissimilarity in terms of a rule that mimics a particular type of distance function [11].

This study used the SOM-MDS tandem approach was first used by [73] to analyze changes in financial statements over time. The tandem approach was proposed to overcome the limitation of SOM analysis. The methodology provides to allocate the position of units more accurately than using only SOM method. For this reason, using SOM and MDS methods sequentially enhance ability to find cross-sectional and longitudinal differences between units better.

On the other hand, MCDM approaches are a systematic decision-making procedure on complex problems that aim to find the best solution from alternatives. In real life, there are no dominant alternatives, so researchers try to find an appropriate solution [37]. Estimating the ideal point in MDS or finding the best clusters in SOM are complicated issues. This study use MCDM methods called MULTIMOORA to rank the regions and find ideal areas according to study indicators.

Data

Türkiye has been included in the Nomenclature of Territorial Units for Statistics (NUTS) since 2002 as a candidate of the European Union (Statistical Regions Outside the EU - NUTS - Nomenclature of Territorial Units for Statistics - Eurostat, n.d.). It regularized the statistical regions of Türkiye according to three levels: NUTS-1 (12 regions), NUTS-2 (26 subregions), and NUTS-3 (81 cities). Eurostat develops regional plans according to the NUTS-2 plan. For this reason, this study develops segmentations of NUTS-2 statistical areas based on Türkiye's marriage patterns and related factors for 2011 and 2021. These regions and their corresponding provinces are given in Table 1 and Fig. 2. Figure 3 visualizes crude divorce rate of NUTS-2 regions in Türkiye for 2022.

We have used eight variables to evaluate the marriage pattern of Türkiye's regions and have collected all data from the TURKSTAT for 26 regions in 2011 and 2021 [69]. In order to better explain the difference of regions between years, the data from two years are combined. For this reason, "2" (TR10_2, İstanbul2,...etc.) has been added to separate the 2021 regions in the study. Therefore, the input to the

Table 1 NUTS-2 regions and covering cities

TR10	İstanbul
TR21	Tekirdağ, Edirne, Kırkareli
TR22	Balıkesir, Çanakkale
TR31	İzmir
TR32	Aydın, Denizli, Muğla
TR33	Manisa, Afyonkarahisar, Kütahya, Uşak
TR41	Bursa, Eskişehir, Bilecik
TR42	Kocaeli, Sakarya, Düzce, Bolu, Yalova
TR51	Ankara
TR52	Konya, Karaman
TR61	Antalya, İsparta, Burdur
TR62	Adana, Mersin
TR63	Hatay, Kahramanmaraş, Osmaniye
TR71	Kırıkkale, Aksaray, Niğde, Nevşehir, Kirşehir
TR72	Kayseri, Sivas, Yozgat
TR81	Zonguldak, Karabük, Bartın
TR82	Kastamonu, Çankırı, Sinop
TR83	Samsun, Tokat, Çorum, Amasya
TR90	Trabzon, Ordu, Giresun, Rize, Artvin, Gümüşhane
TRA1	Erzurum, Erzincan, Bayburt
TRA2	Ağrı, Kars, Iğdır, Ardahan
TRB1	Malatya, Elazığ, Bingöl, Tunceli
TRB2	Van, Muş, Bitlis, Hakkari
TRC1	Gaziantep, Adıyaman, Kilis
TRC2	Şanlıurfa, Diyarbakır
TRC3	Mardin, Batman, Şırnak, Siirt

Fig. 2 NUTS-2 Regions of Türkiye [68]

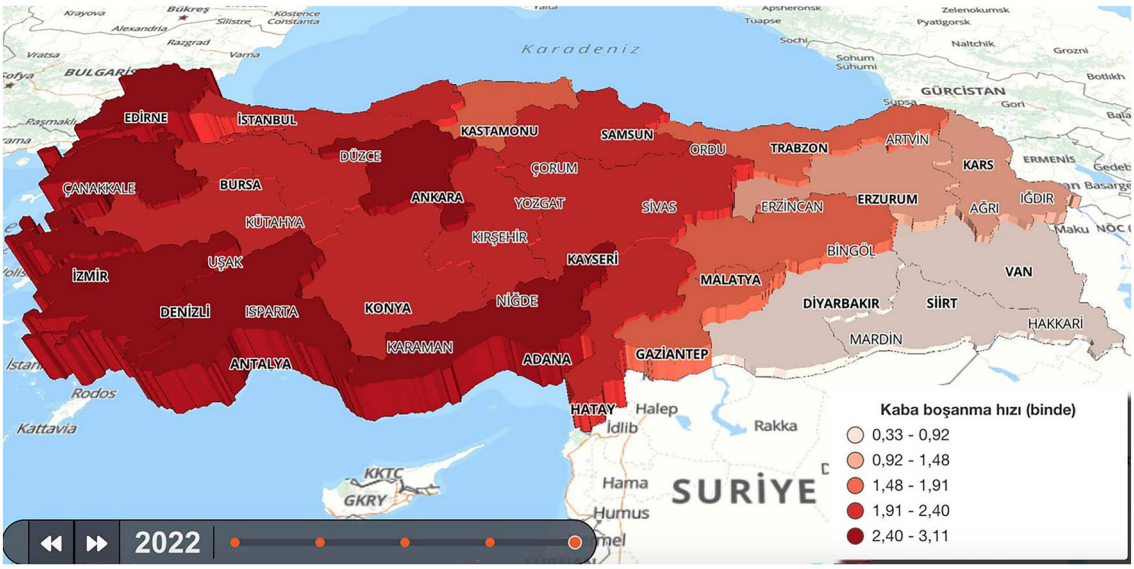

Fig. 3 Crude Divorce Rate of NUTS-2 in Türkiye for 2022 [70]

proposed methodology used in the paper is 52 regions by eight variables data matrix.

The mean, standard deviation (sd), minimum, maximum, coefficient variation (CV) of study variables for both years can be seen in Table 2. The primary aim of this study is variability of the study indicators so CV is also used to measure of dispersion. CV is used as sigma convergence for socioeconomical variables [55, 64]. Considering marriage and divorce variables, the mean of crude divorce rate is increased, and the marriage rate is decreased from 2011 to 2021 in Turkey's regions. On the other hand, the convergence fell for both indicators, meaning that regional differences are declining in the country. The crude divorce rate in the regions is highly heterogeneous because the CV is greater than 30%. While the age of first marriage has increased for both genders, the regional variations in these indicators have also increased over the years. According to socioeconomic variables, the relative variability of the unemployment rate is the highest. Although its average has increased from 2011 to 2021, its variability remains the same.

SOM

A SOM map is a neural-network method that uses unsupervised learning (adaptive). The SOM algorithm is summarised as follows [40]:

- *Initilization*: Choose random values for the initial weight vectors $w_j(0)$. The $w_j(0)$ should be different for $j = 1, 2, ..., l$, where I is the number of neurons in the lattice. It is appropriate that the size of the weights might be small.
- *Sampling*: Draw a sample x from the input space with a certain probability. The x vector has m dimensions.

Table 2 Study Indicators and descriptive statistics

	Indicators	2011				
		Min	Max	Mean	Sd	CV
Marriage-Divorce Indicators	CDR	0.20 (Van)	2.73 (İzmir)	1.47	0.65	44%
	CMR	6.79 (Kastamonu)	9.75 (Gaziantep)	8.01	0.79	10%
	AMAFM	25.2 (Samsun)	27.1 (İzmir)	26.15	0.56	2%
	AFAFM	21.56 (Van)	24.0 (Malatya)	22.75	0.68	3%
Socio-Economic Indicators	CSR	2.93 (Gaziantep)	6.59 (Aydın)	4.45	0.88	20%
	FER	6.4 (Şanlıurfa)	45.6 (Zonguldak)	29.78	9.32	31%
	UR	4.4 (Manisa)	21.3 (Mardin)	8.64	3.42	40%
	FE	13.1 (Van)	41.66 (Ankara)	24.63	6.71	27%
	Indicators	2021				
		Min	Max	Mean	Sd	CV
Marriage-Divorce Indicators	CDR	0.56 (Van)	3.04 (İzmir)	1.92	0.67	35%
	CMR	5.55 (Kastamonu)	7.98 (Gaziantep)	6.7	0.55	8%
	AMAFM	26.5 (Konya)	29.1 (İstanbul)	27.92	0.71	3%
	AFAFM	23.1 (Ağrı)	26.7 (İstanbul)	25.11	0.9	4%
Socio-Economic Indicators	CSR	2.74 (İstanbul)	8.10 (Aydın)	4.36	1.12	26%
	FER	12.6 (Mardin)	34.7 (Trabzon)	25.94	5.35	21%
	UR	5.8 (Kastamonu)	29.8 (Mardin)	12.00	4.77	40%
	FE	27.11 (Şanlıurfa)	51.27 (Ankara)	37.33	5.91	16%

CDR Crude Divorce Rate, *CMR* Crude Marriage Rate, *AMAFM* Average Male Age at First Marriage, *AFAFM* Average Female Age at First Marriage, *FE* Female Education, *CSR* Crude Suicide Rate, *FER* Female Employment Rate, *UR* Unemployment Rate

- *Similarity matching*: Find the best-matching (winning) neuron $i(x)$ at time-step n by using the minimum-distance criterion:

  $$i(x) = \text{argmin}_j \|x(n) - w_j\|, \quad i = 1, 2, ..., I.$$

- *Updating*: Adjust the synaptic-weight vectors of all excited neurons by using the update formula. Where $\eta(n)$ is the learning-rate parameter and h_j, $i(x)$ (n) is the neighborhood function centered around the winning neuron $i(x)$; both $\eta(n)$ and h_j, $i(x)$ (n) are varied dynamically during learning for best results.

  $$w_j(n+1) = w_j(n) + \eta(n)h_(j, i(x))(n)(x(n) - w_j(n))$$

- *Continuation*: Continue with step-2 until no noticeable changes in the feature map are observed.

MDS

Basically, MDS uses the $n \times p$ dimensional data matrix in order to obtain the distance table. Based on the distance table, two- or three-dimensional coordinates are found where the inter-point distances are close as possible to the original distances.

The steps involved in metric MDS (mMDS) (which adopted in this paper) are as follows:

- Compute the $n \times n$ distance matrix $D = d_{ij}$, where we take into consideration Euclidean distance as below:

$$d_{ij} = \sqrt{\sum_{i=1}^{p} \left(x_{ik} - x_{jk}\right)^2}.$$

- Since the diagonal elements of matrix D is zero, it is not positive-semi definite. However, there is a possibility to find a positive definite matrix B with $n \times n$ based on distance matrix D.
- With i_n is a vector consists of 1 s and I_n is an identity matrix with $n \times n$ dimensional, the matrix B is obtained as follows:

$$B = -\frac{1}{2}[I_n - \frac{1}{n} i_n i_n^\top] D^2 [I_n - \frac{1}{n} i_n i_n^\top].$$

- Compute the non-negative eigenvalues (λ_i) and the corresponding eigenvectors (v_i).
- Decide the optimal number of dimensions based on stress value given as follows:

$$stress = \sqrt{\frac{\sum_{i<j} \left(d_{ij} - \hat{d}_{ij}\right)^2}{\sum_{i<j} d_{ij}^2}}, \tag{1}$$

where $\hat{d}_{ij}$ corresponds to the predicted distance obtained by MDS model.

- Find graphical coordinates using $\sqrt{\lambda_i} v_i$, which correspond to the selected largest eigenvalues.

MULTIMOORA

MCDM approaches have three aims: value measurement, goal or reference level, and outranking [37]. MULTIMOORA, a MCDM method, was used to rank regions according to research variables. Multi-Objective Optimization by Ratio analysis (MOORA), which combines ratio and reference point approaches, was first proposed by Brauers and Zavadskas in 2016 [14]. They extended MOORA by adding a Full Multiplicative Form and applying Dominance Theory to obtain final raking and call it MULTIMOORA [15]. We used MULTIMOORA because it integrates three methods, so a more robust result than a single method [37, 53].

The MCDM methods begin with decision matrix $\mathbf{X}$. The x_{ij} elements correspond to ith criteria of jth alternative:

$$\mathbf{X} = \begin{bmatrix} X_{11} & \dots & x_{1m} \\ \vdots & \ddots & \vdots \\ X_{n1} & \dots & x_{nm} \end{bmatrix} \tag{2}$$

The MULTIMOORA method first calculates the ratio system and needs data normalization by vector normalization:

$$x_{ij}^{\star} = \frac{x_{ij}}{\sqrt{\Sigma_{i=1}^{n} x_{ij}^2}} \tag{3}$$

where $g = 1, \dots, n$ denotes the number of objectives to be maximized. After that, the result per alternative is ranked in descending order to find the ratio system solution. Secondly, the Reference Point approach is calculated according to ratios obtained in the Ratio System, according to ratios found in Eq. (3). The j-th coordinate of the reference point can be described as $r_j = {}^*arg\, max_j x_{ij}^{\star}$ in case of maximization. After that, every element of the normalized matrix is recalculated, and ranks are calculated according to the Min-Max Metric of the Tchebycheff formula:

$$\arg\min_i \left(\arg\max_j \mid r_j - x_{ij}^{\star} \mid \right) \tag{4}$$

Then, the values for alternatives are ranked in ascending order to find the reference point solution.

The Full Multiplicative Form method embodies the maximization and minimization of the purely multiplicative utility function. The overall utility of the ith alternative can be expressed as a dimensionless number:

$$U_i' = \frac{A_i}{B_i} \tag{5}$$

where $A_i = \prod_{j=1}^{g}$, $i = 1, 2, \dots, m$ denotes the product of objectives of the $i-$th alternative to be maximized with $g = 1, 2, \dots, n$ being the number of objectives (structural indicators) to be maximized and $B_i = \prod_{j=g+1}^{n}$ denotes the product of objectives of the $i-$th alternative to be minimized with $n - g$ being the number of objectives (indicators) to be minimized.

After calculating the three methods' rankings, we need to aggregate these rankings to obtain the final ranking of alternatives. Various ranking aggregation tools are used in MULTIMOORA [37]. The rank position method [6] is used in this study. The formula:

$$RPM(A_i) = 1/\left(1/r(y_i) + 1/r(z_i) + 1/r(u_i), \right) \tag{6}$$

which are

RPM (A_i): ranking Position method
$r(y_i)$: ranking of Ratio System
$r(z_i)$: ranking of Reference Point approach
$r(u_i)$: ranking of Full Multiplicative Form
The minimum the $RPM(A_i)$ the better rank.

Results

Implementation and Results of SOM

Implementation of SOM in R, we used the Kohonen package [75] to perform unsupervised SOM. Firstly, data were normalized and converted to matrix form. Secondly, It is essential to determine the grid's size and the topologies' shape (hexagonal or circular). According to Kohonen [50], hexagonal arrays are suggested because of convenient visualization for neighboring. However, it is hard to decide the right topology size because a grid with a large or small number of nodes hinders the SOM visualization. Choosing a large grid might result in empty nodes, so they need to be excluded from the clustering process [9]. In some literature [19, 41], the suggested number of nodes in the output layer is $5\sqrt{n}$. In our case studies, a 6×7 SOM grid (42 neurons) was created with hexagonal topologies after experimental trials.

The training process has three essential parameters: iteration size (rlen), learning rate-alpha, and neighborhood shape and radius [9]. After normalizing the data, the input (matrix) data started an iterative training process to the final form of SOM. It repeats until there is no further change in the SOM reference vectors. The number of iterations is recommended to be at least 500 times the number of neurons in the network [40]. The learning rate determines the connection of weights and decreases over time. The learning rate should start at 0.1 and decreases to 0.01 in iterations but never be 0. The aim is to reduce the error as much as possible in each iteration. During each iteration, the distance of the input vector (the input layer) and weight vector of each node on the output layer calculates using Euclidean distance measure. The weight vector of neurons with the lowest distance to the input vector calls as "winner node" and Best Matching Unit (BMU).

The iteration process is visualized in SOM with a plot called the "Training process" (Fig. 4). It shows the iteration process and how distances reach a minimum value. The learning rate is between 0.05−0.01, and iteration of 5000, the mean distance to the closest unit in the map is 0.421. Iteration around 4000 reaches a convergent process according to the iteration plot, and the smaller mean length is reached. Around 0.02, the training iteration started by stabilizing the mean of the distance cluster.

SOM quality is visually measured with node counts, node quality (distance), and SOM neighbors distances plots (U plots) (Fig. 5). Node counts plot visualize distributions of samples over the node. Models show uniform distribution over the node counts plot in a good quality SOM. If there are grey nodes, it means the nodes are empty. In our study, most of them (except three grey nodes) are evenly distributed and have around 1–3 samples per node. Also, plots can be used to visualize neighborhood relations. The quality plot represents the average distance of regions. SOM neighbor distances (U-matrix) demonstrate the distance between each node and its neighbors. They give the idea of determining cluster numbers. The red color srepresents neighboring neurons with similar

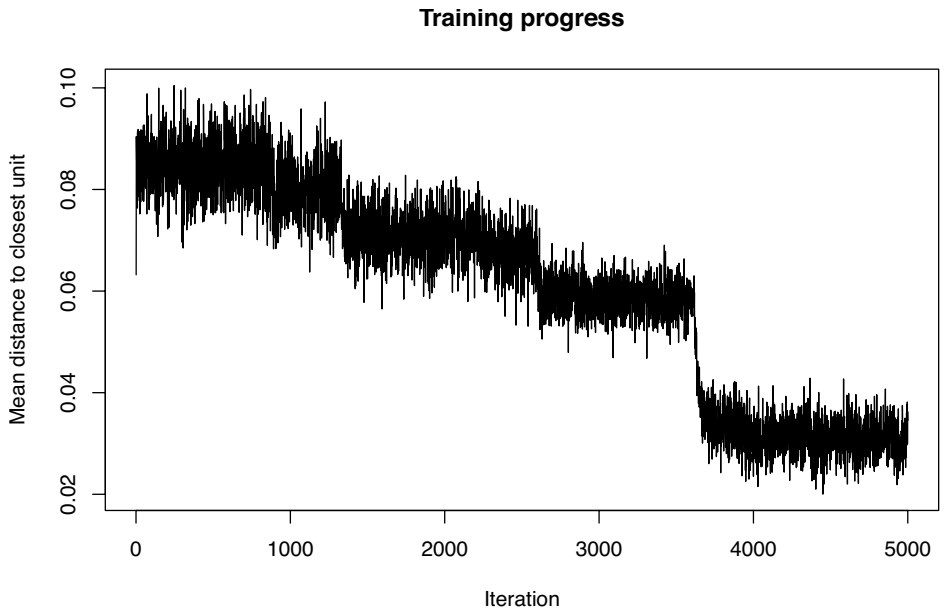

Fig. 4 The training process of SOM)

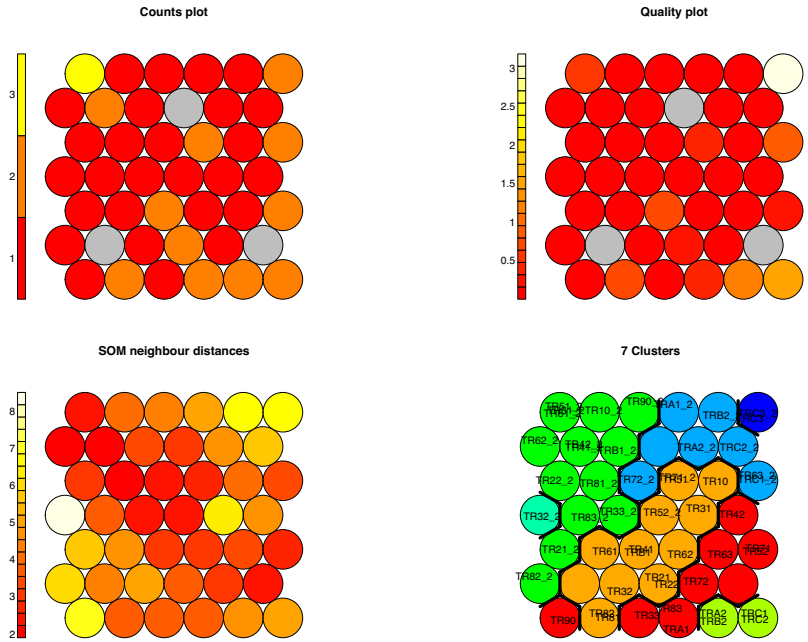

Fig. 5 SOM quality and SOM clusters plots

characteristics, and the straw yellow indicates neighboring neurons with different aspects.

Visualizing a single variable's distribution through nodes by heat maps is also possible (Fig. 6). According to the plots, red indicates low-ranking variables, while straw yellow indicates high-ranking ones.

U-matrix shows neighborhood distances, but it is hard to determine distinct clusters. Vesanto and Alhoniemi [74] suggested a two-level approach to clustering SOM to reduce the computational cost, noise reduction, and better deal with outliers. According to this approach, the first level finds the SOM codes, and in the second level, SOM codes are clustered by hierarchical and partitive approaches. This study's SOM findings are clustered by hierarchical clustering using Euclidean distance and Ward's agglomerative linkage method. The internal validity measures use to find the objective clusters. They aim to analyze the solutions in three dimensions: separation, connectedness, and compactness [18, 39]. Dunn Index [27], the Davies-Bouldin Index [26], and the Silhouette index [60] were the most popular ones. We calculated all of them but decided on the best clusters according to the Silhouette index (Fig. 7). According to Lui et al. [54], larger than 0.65 of the Silhouette index indicates well clusters. The optimal clusters were three, but seven clusters were chosen to compare other methods more effectively, and its average Silhouette value is higher than 0.65. The mean (median) value of seven clusterters were given in the Table 3.

When clusters are examined, it is observed that regions for 2011 and 2021 differ in general. Besides, it is seen that Konya and Kirikkale regions in 2021 are the same cluster as the regions of 2011, while Mardin in 2011 is the same cluster and node as Mardin in 2021.

Clusters 1,2 and 3 mainly comprise regions from 2011. SOM Map was applied to determine similarities and differences between areas. For instance, close observations mean similar characteristic regions (e.g., the most similar ones in the same neuron regions) or far apart regions are dissimilar. Cluster 3 areas are located in the eastern part of the country and consist of two nodes and four regions (Agri-Van and Gaziantep-Sanliurfa) in 2011. It exhibited the lowest average male and female age at first marriage, the female education rate, and the highest crude marriage rate. It also has less than average crude divorce rate, male crude suicide rates, female employment, and unemployment rates. The characteristic features of Erzurum in 2011, another eastern region, are more similar to other part of the country regions and is located in Cluster 1. Cluster 1 has the lowest unemployment rate and below the general average crude divorce rates, average male and female age at first marriage, female education rates, and male suicide rates. The regions of this cluster also have above the average crude marriage and female employment rates. In addition, Cluster-2 consisted of 12 areas in 2011 and two (Konya2 and Kirikkale2) in 2021, including Istanbul, Ankara, and Izmir, Turkey's three most urbanized regions. The regions of Tekirdag-Balikesir (V10) and Ankara-Kirikkale2 (V28) are in the same nodes. It differs from other clusters by having the highest female employment rate.

After ten years period, all eastern regions are similar with each other and consist Cluster 6 with Hatay2 and Kayseri2. Hatay2, the southern region, and the eastern

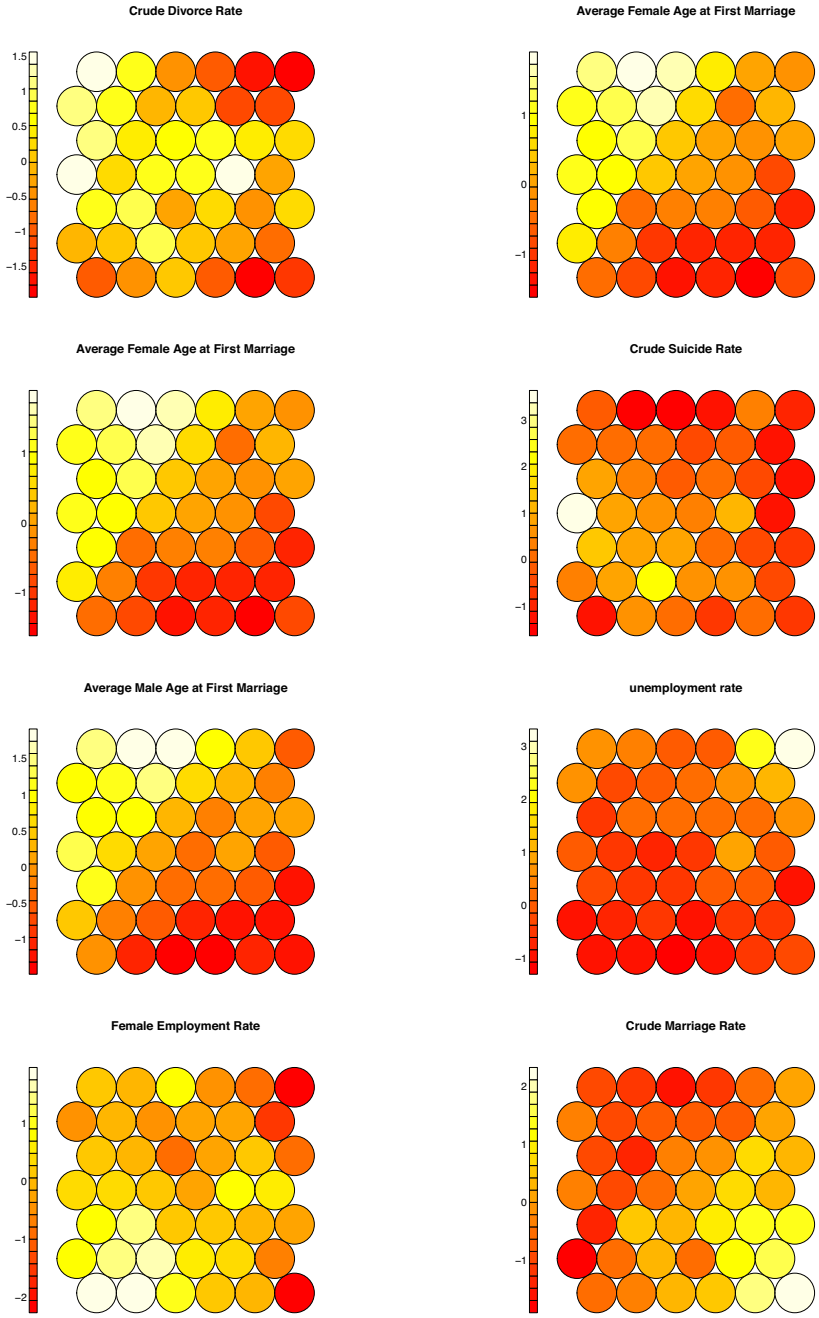

Fig. 6 SOM property plots of research variables

region Gaziantep2 (V30) are at the same node. In addition, Aydın2 region in the west is constituted the Cluster-5. Next, the eastern region Mardin for both years locates in the same node and constituted Cluster-7. It has the lowest divorce rate, crude suicide rate, female employment rate, and highest unemployment rate across the seven clusters. Furthermore, other regions in the second period form Cluster 4. It also contains, the most urbanized regions of Turkey, Istanbul2, Ankara2, and Izmir2. Compared to other clusters, it has the highest average female age at first marriage and the lowest crude marriage rate. The regions of Bursa2-Kocaeli2-Adana2 (V31) and Ankara2-Izmir2-Antalya2 (V37) are in the same nodes in this cluster.

Implementation and Results of MDS

While we can say that the regions in the same neuron in the SOM have the most similar features, the similarity between neurons cannot be measured numerically. Therefore, the degree of difference between neurons formed in the SOM is measured by MDS. Figure 6 had depicted the MDS representation of the weight vectors of 42 neurons and SOM neighbor distances visualization. The relationship of the

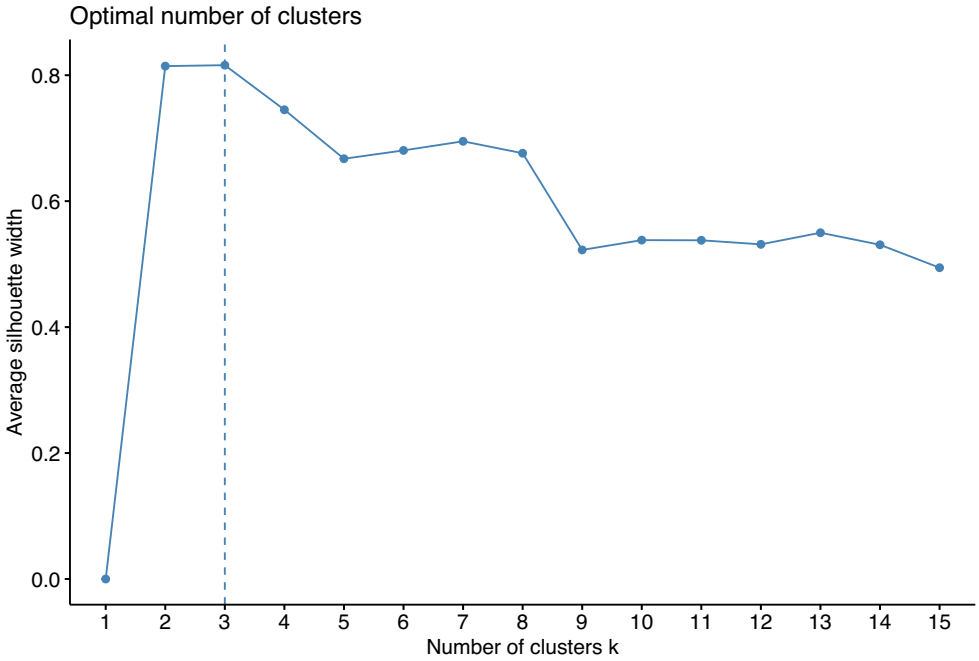

Fig. 7 Silhoutte Index Gaph

Table 3 Comparison of clusters (mean value (median))

Cluster	n	CDR	CMR	AMAFM	AFAFM	FE	CSR	FER	UR
1	9	1.43	8.07	25.89	22.46	23.58	3.80	31.03	7.19
		(1.54)	(8.06)	(25.70)	(22.20)	(22.92)	(3.77)	(30.30)	(6.30)
2	14	1.95	7.53	26.53	23.27	30.10	5.05	32.78	8.90
		(1.92)	(7.46)	(26.62)	(23.40)	(29.76)	(5.09)	(30.90)	(8.05)
3	4	0.57	9.31	25.78	22.15	15.51	4.04	19.45	8.75
		(0.45)	(9.42)	(25.65)	(22.05)	(14.94)	(4.11)	(18.85)	(8.15)
4	15	2.20	6.39	28.32	25.70	40.16	4.49	28.91	10.21
		(2.21)	(6.40)	(28.30)	(25.61)	(39.63)	(4.49)	(28.00)	(9.90)
5	1	2.68	6.96	28.55	25.55	41.19	8.10	31.40	10.20
6	7	1.29	7.08	27.39	24.18	32.12	3.67	21.10	14.00
		(1.61)	(6.80)	(27.69)	(24.81)	(35.49)	(4.14)	(24.50)	(10.20)
7	2	0.45	7.49	26.53	23.75	22.17	3.46	10.05	25.55
Total	52	1.69	7.36	27.03	23.93	30.93	4.41	27.86	10.32
		(1.83)	(7.33)	(26.94)	(23.82)	(30.76)	(4.45)	(27.90)	(9.55)

CDR Crude Divorce Rate, *CMR* Crude Marriage Rate, *AMAFM* Average Male Age at First Marriage, *AFAFM* Average Female Age at First Marriage, *FE* Female Education, *CSR* Crude Suicide Rate, *FER* Female Employment Rate, *UR* Unemployment Rate

neighboring neurons is more complex in the SOM visualization. We can also see in the MDS map that the location of the regions matches with the SOM map. Neighboring neurons mean high similarity, and distance means no similarity. The most similarity is between V22 (Konya2) - V28 (Kırıkkale2 and Ankara). It can be said that Ankara's situation regarding the research variables in 2011 is quite similar to the situation of Konya and Kırıkkale in 2021. After that, V13 (Tekirdağ2) -V25 (Balıkesir2) and V20 (Samsun2)-V25 (Balıkesir2), respectively. The most dissimilarity is between V19 (Cluster-5; Aydın 2) and V42 (Cluster-7; Mardin and Mardin2). According to clusters, the most similarity is between Cluster-1 and Cluster-2 (Fig. 8).

Identifying the dimensions is often complex, and MDS analysis lacks specific methods to name them [38]. In this study, it is used to the correlation between two dimensions and eight attributes to name the dimensions (Appendix A). The correlations pointed out that the crude divorce rate is measured by two dimensions almost equally. Dimension 1 showed significance with crude marriage rate, average

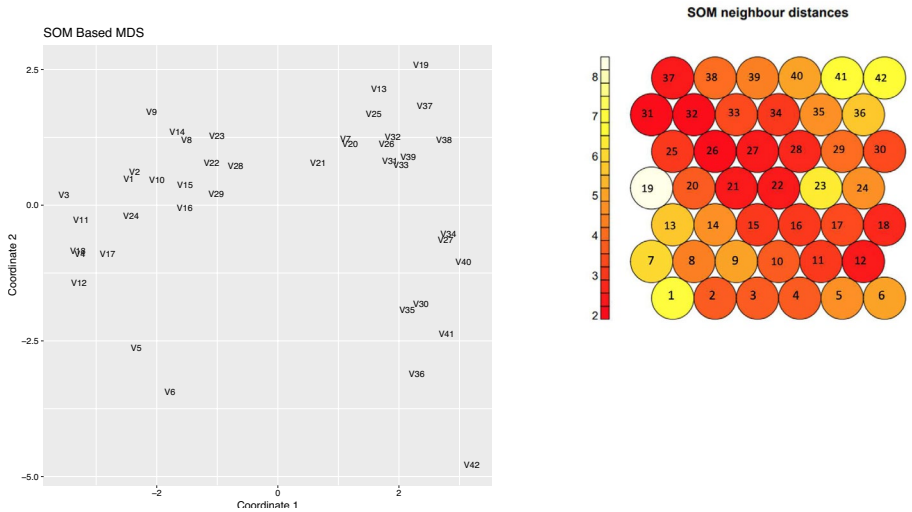

Fig. 8 SOM based MDS results (left side) and SOM neighbour distance results (right side)

male and female age at first marriage, and female education. Moreover, Dimension 2 showed significance with crude suicide, female employment, and unemployment rates.

Implementation and Results of MULTIOMOORA

We used all the features to rank the region's conditions: crude divorce rate (minimum value better the performance of the region), crude marriage rate (maximum value better the performance of the region), the average age of first marriage in male and females (minimum the value better the performance of the region), female education (maximum the value better the performance of the region), crude suicide rate (minimum the value better the performance of the region), the female employment rate (maximum the value better the performance of the region), unemployment rate (minimum the value better the performance of the region). The decision matrix of the study contains our alternatives (52 regions) and objectives (8 indicators). It has 416 elements. Brauers et al. [13] proposed to examine the areas in MULTIMOORA in 3 groups: best condition regions (best performance), less favorable regions (medium performance), and the least favorable regions (low performance) for the research indicators. Rankings of Ratio, Reference Point, Full Multiplicative Form approaches presented in the Appendix B.

Determination of the indicators weights

The weights of the indicators are calculated considering the variable importance of the SOM clustering analysis. The importance level of the variables is determined by applying multivariate ANOVA analysis to SOM weights vectors of neurons using sensitivity analysis [8]. The results are showed in Table 4. The most influential features are unemployment rate, crude suicide rate, crude marriage rate and female employment rate.

The MCDM rankings are calculated for both weighted and equal weighted of indicators. Equal weighted rankings can be seen in the Appendix B.

Table 5 presents the rankings of the regions, clusters, and neurons number. The result of weighted MULTIMOORA method is shown in Table 5. Trabzon region ranks the first regarding marriage-divorce and related factors in this study. Shared nodes regions of Samsun and Erzurum rank as 2nd and 4th, respectively. Manisa ranks as third. In addition, Mardin regions for both years and Van2 are found as the least favorable regions considering study variables.

MULTIMOORA is classified regions as best conditions (holding ranks 1–17), less favorable (18–34), and low

Table 4 Weights of indicators calculated by SOM weight vectors

Dimensions	Indicators	Weights
Marriage-Divorce Indicators	Crude divorce rate	3.70%
	Crude marriage rate	12.30%
	Average male Age at first marriage	9.30%
	Average male age at first marriage (min)	9.30%
Socio-Economic Indicators	Female education	7.70%
	Crude suicide rate	20.40%
	Female employment rate	12.30%
	Unemployment rate	25.00%

Table 5 Summary of Kohonen SOM, MDS and MULTIMOORA results

Cluster	Code	Region	MDS	MULTI-MOORA
1	TR33	Manisa	V3	3
	TR42	Kocaeli	V24	14
	TR52	Konya	V18	7
	TR63	Hatay	V17	23
	TR71	Kırıkkale	V18	6
	TR72	Kayseri	V11	18
	TR83	Samsun	V4	2
	TR90	Trabzon	V1	1
	TRA1	Erzurum	V4	4
2	TR10	İstanbul	V29	28
	TR21	Tekirdağ	V10	17
	TR22	Balıkesir	V10	35
	TR31	İzmir	V23	46
	TR32	Aydın	V9	32
	TR41	Bursa	V15	25
	TR51	Ankara	V28	24
	TR61	Antalya	V14	16
	TR62	Adana	V16	33
	TR81	Zonguldak	V2	5
	TR82	Kastamonu	V2	12
	TRB1	Malatya	V15	21
	TR52_2	Konya2	V22	19
	TR71_2	Kırıkkale2	V28	43
3	TRA2	Ağrı	V5	42
	TRB2	Van	V5	8
	TRC1	Gaziantep	V6	30
	TRC2	Şanlıurfa	V6	29
4	TR10_2	İstanbul2	V38	26
	TR21_2	Tekirdağ2	V13	38
	TR22_2	Balıkesir2	V25	35
	TR31_2	İzmir2	V37	47
	TR33_2	Manisa2	V21	20
	TR41_2	Bursa2	V31	34
	TR42_2	Kocaeli2	V31	27
	TR51_2	Ankara2	V37	41
	TR61_2	Antalya2	V37	37
	TR62_2	Adana2	V31	45
	TR82_2	Zonguldak2	V26	40
	TR82_2	Kastamonu2	V7	15
	TR83_2	Samsun2	V20	31
	TR90_2	Trabzon2	V39	10
	TRB1_2	Malatya2	V33	36
5	TR32_2	Aydın2	V19	49
6	TR63_2	Hatay2	V30	48
	TR72_2	Kayseri2	V27	39
	TRA1_2	Erzurum2	V40	11
	TRA2_2	Ağrı2	V35	42
	TRB2_2	Van2	V41	50
	TRC1_2	Gaziantep2	V30	22
	TRC2_2	Şanlıurfa2	V36	44
7	TRC3	Mardin	V42	51
	TRC3_2	Mardin2	V42	52

performance (35–52). The first best group consisted primarily of regions in 2011 and Trabzon, Erzurum, and Kastamonu regions in 2021. These three regions are also in the best group in both 2011 and 2021. The second less favorable group included seven areas from 2021 and ten from the previous period. The third and the least favorable group has 16 regions in 2021 and 2 regions (İzmir and Mardin regions) in 2011. Istanbul, Ankara and Izmir regions, the three most developed regions of the country, are in the second less and least favorable groups in the rankings.

The positions of the regions in the rankings are not always consistent with their positions in the SOM-MDS tandem approach, as expected. For example, while Ankara and Kırıkkale2 regions are in the same nodes in SOM analysis, their rankings are 27 and 45, respectively, in MULTIMOORA. On the other hand, the lowest dissimilarity between the Konya2 region (V22), and Kirikkale2, Ankara regions (V28) in MDS analysis, but their ranking are 35, 45, and 27, respectively, in MCDM analysis. Also, the three regions are in Cluster 2 in the cluster analysis.

When the rankings of the same regions in the previous and next periods are compared, the previous period rankings are higher in 24 regions. However, the rankings of Gaziantep and Istanbul in the following period are higher than in the previous period. (Gaziantep2: 22; Gaziantep: 30; Istanbul2: 26; Istanbul: 28).

Discussion

To explain differences, hidden structures, and changes in Türkiye's marriage, divorce, and related features among 26 regions in last ten years through the proposed research model, firstly, Kohonen-SOM and MDS models are

conducted to find similarities and distances between regions. Also, the MULTIMOORA model is applied to rank the regions according to conditions for their marriage, divorce, and related features.

Türkiye's substantial variational differences in marriage, divorce, and related features pattern are determined with this study like the literature [3, 20, 30, 42, 52, 62, 71, 77]. In addition, it is concluded that the values of all regions differ relatively compared to the previous ten-year period, except the Mardin region. Mardin, Hatay, Konya are regions that this changed the least throughout this time, while Van, Erzurum, Zonguldak are the most,respectively.

According to the proposed method in that study, the most dissimilar regions are Aydın in 2021 and Mardin for both years. It can be said that they are outlier regions for this study. The Aydın region in 2021 shows the highest crude divorce rate, average male first marriage, female education, and crude suicide rate. Mardin regions are also the other outliers in Türkiye with the lowest crude divorce rate, female employment rate, crude suicide rate in men, and highest unemployment rate.

The aim of using sequentially Kohonen-SOM clustering and MDS analysis is to explore and visualize relative differences between regions. As a result, it is possible to find hidden structures of regions for marriage-divorce and related factors. In the SOM-MDS tandem approach, we effectively investigated similar and dissimilar clusters and also regions. Furthermore, MULTIMOORA is used to optimize the region's relative situation according to study indicators. For these reasons, it is expected that the rankings of the regions do not reflect where they stand in the tandem SOM-MDS strategy.

Conclusion

The findings of this study indicate huge regional differences between marriage-divorce and related indicators in Türkiye. The most important factors associated with marriage and divorce patterns in regions of Türkiye are the education and employment of living women. The region's situation also changed in time but the changes were also vary according to regions.

The study's contributions to the literature are as follows: (1) It proposes a unique three-stage framework using SOM-MDS tandem and MCDM methodologies. (2) this paper is the first comparative study of marriage-divorce and associated indicators using ANN, statistical learning, and MCDM methods. (3) Marriage-divorce and related indicators are clustered to find cross-sectional and longitudinal variations with unique approach (4) Social changes data evaluated and ranked through an MCDM method(5) The suitability of the proposed model is demonstrated using real data targeting social and demographic changes.

The study has also several limitations. Firstly, the second-hand data is used instead of collecting it directly from the regions. Secondly, the cross-sectional and longitudinal differences examine 26 regions of methodology. Future studies could carry this study further by using more comprehensive variables in Türkiye using limited indicators. It is also assumed that the years 2011 and 2021 are sufficient to examine the 10-year variations for study indicators in the regions. Furthermore, there are several confounding variables to examine the relationship, like cohabitation rates, gender roles of families, and level of religiosity. Lastly, social life was profoundly impacted by the COVID-19 pandemic, both internationally and Türkiye. The disparity observed in the 2021 data has been eliminated. Despite these limitations, our study investigates the region's similarities, differences and changes over time objective and effective methodology. Future studies could carry this study further by using more comprehensive variables in Türkiye and also comparing countries. The proposed methodology can be also applied any field.

Appendix A

See Table 6.

Table 6 Correlations Between MDS Dimensions and Study Indicators

MDS Dimensions	CDR	CMR	AMAFM	AFAFM	FE	CSR	FER	UR
Dimension-1	0.625**	−0.825**	0.945**	0.941**	0.954**	0.221	0.118	0.153
Dimension-2	0.510**	0.014	−0.212	−0.250	−0.036	0.727**	0.818**	−0.733**

CDR Crude Divorce Rate, *CMR* Crude Marriage Rate, *AMAFM* Average Male Age at First Marriage, *AFAFM* Average Female Age at First Marriage, *FE* Female Education, *CSR* Crude Suicide Rate, *FER* Female Employment Rate, *UR* Unemployment Rate

**$p < 0.01$

Appendix B

See Table 7.

Table 7 MOORA and MULTIMOORA results

Region	RSR	RPR	MFR	WM	EWM
TR10/İstanbul	23	23	23	28	23
TR21/Tekirdağ	14	6	15	17	15
TR22/Balıkesir	19	20	16	13	19
TR31/İzmir	47	47	48	46	47
TR32/Aydın	34	39	30	32	32
TR33/Manisa	6	21	6	3	7
TR41/Bursa	27	19	25	25	26
TR42/Kocaeli	9	3	11	14	10
TR51/Ankara	25	33	26	24	27
TR52/Konya	15	22	14	7	16
TR61/Antalya	21	40	21	16	22
TR62/Adana	31	16	33	33	30
TR63/Hatay	18	14	20	23	18
TR71/Kırıkkale	12	18	13	6	13
TR72/Kayseri	13	8	18	18	14
TR81/Zonguldak	5	11	8	5	6
TR82/Kastamonu	10	24	10	12	11
TR83/Samsun	4	17	5	2	4
TR90/Trabzon	1	7	1	1	1
TRA1/Erzurum	2	13	3	4	2
TRA2/Ağrı	3	32	4	9	3
TRB1/Malatya	16	9	12	21	12
TRB2/Van	8	41	2	8	8
TRC1/Gaziantep	22	26	29	30	24
TRC2/Şanlıurfa	24	46	36	29	36
TRC3/Mardin	51	50	52	51	51
TR10_2/İstanbul2	26	31	24	26	25
TR21_2/Tekirdağ2	40	37	41	38	40
TR22_2/Balıkesir2	39	42	39	35	39
TR31_2/İzmir2	49	51	51	47	50
TR32_2/Aydın2	50	45	50	49	49
TR33_2/Manisa2	33	30	27	20	31
TR41_2/Bursa2	37	34	38	34	37
TR42_2/Kocaeli2	29	29	32	27	34
TR51_2/Ankara2	42	44	45	41	43
TR52_2/Konya2	35	35	35	19	35
TR61_2/Antalya2	38	48	40	37	38
TR62_2/Adana2	46	43	49	45	46
TR63_2/Hatay2	45	36	46	48	44
TR71_2/Kırıkkale2	44	38	47	43	45
TR72_2/Kayseri2	41	28	42	39	41
TR81_2/Zonguldak2	43	25	40	40	42
TR82_2/Kastamonu2	17	5	17	15	17
TR83_2/Samsun2	30	15	28	31	29
TR90_2/Trabzon2	7	1	7	10	5
TRA1_2/Erzurum2	11	2	9	11	9
TRA2_2/Ağrı2	28	10	19	42	20
TRB1_2/Malatya2	32	4	34	36	28
TRB2_2/Van2	48	49	37	50	48
TRC1_2/Gaziantep2	20	12	22	22	21
TRC2_2/Şanlıurfa2	36	27	31	44	33
TRC3_2/Mardin2	52	52	43	52	52

RSR Ratio System Rank, *RPR* Reference Point Rank, *MFR* Multiplicative Form Rank, *WM* Weighted MULTIMOORA Rank, *EWM* Equal Weighted MULTIMOORA Rank

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Declarations

Conflict of interest On behalf of all authors, the corresponding author states that there is no conflict of interest.

Ethical approval The research involves no human participants and animals and consequently no need for informed consent.

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