TÜBİTAK

Turkish Journal of Agriculture and Forestry

http://journals.tubitak.gov.tr/agriculture/

Research Article

Turk J Agric For
(2021) 45: 495-509

doi:10.3906/tar-2010-55

Evaluation of occupational accidents in forestry in Europe and Turkey by k-means clustering analysis

Anıl Orhan AKAY[1,*], Mustafa AKGÜL[1], Abdullah İlker ESİN[2], Murat DEMİR[1], Necmettin ŞENTÜRK[1], Tolga ÖZTÜRK[1]

[1]Department of Forest Construction and Transportation, Faculty of Forestry, İstanbul University-Cerrahpaşa, İstanbul, Turkey
[2]Vocational School of Forestry, İstanbul University-Cerrahpaşa, İstanbul, Turkey

Received: 14.10.2020 • **Accepted/Published Online:** 06.06.2021 • **Final Version:** 18.08.2021

Abstract: The incidence rate of occupational accidents is an important indicator of occupational safety performance. The aim of this study was to classify the similarities and differences among 23 European Union (EU) countries along with Turkey in terms of various occupational accident evaluation criteria. This was achieved using the k-means clustering method on data from the forestry and logging sector between 2008 and 2017. The occupational accident assessment criteria used in the study include the nonfatal male accident incidence rate, the nonfatal female accident incidence rate, the total (male + female) nonfatal accident incidence rate, and the total (male + female) fatal accident incidence rate. According to the clustering analysis, three clusters were obtained, and Turkey was included in Cluster 2. By evaluating the final cluster center values and the descriptive statistical values in the clusters, it was found that the occupational accident incidence values of the countries in Cluster 2 were in all four categories below the averages of the other two other clusters as well as the 23 EU countries and Turkey considered together. Cluster 1 was above all of the other clusters as well as all the countries considered together in the total nonfatal occupational accident category, and Cluster 3 in the fatal occupational accident category. Studies similar to this one but on an intercontinental basis would provide a good foundation for improving work health and safety legislation in forestry and logging on a global scale.

Key words: Work safety, cluster analysis, accident incidence rate, forestry and logging

1. Introduction

Over the past few decades, the term occupational safety has taken on crucial importance in a wide variety of job sectors. Nowadays, rapid advances in technology and the rapid increase in production and competition in the market have further increased threats to health and safety at work. In 2017, there were just over 3.3 million nonfatal accidents that resulted in at least four calendar days of absence from work along with 3552 fatal accidents in the European Union (EU).[1] Forest work (Klun and Medved, 2007) or work in the forestry industry (Lilley et al., 2002; Wilhelmson et al., 2005; Tsioras et al., 2011; Albizu et al., 2013) is considered one of the most dangerous and hazardous occupations (sectors) in all fields of production. The higher rate of fatal accidents in forestry than in the mining and building industries can be associated with the length of the workdays; the seasonal and meteorological working conditions; and the distant, isolated, steep, and plant-covered workplaces (Klun and Medved, 2007; Enez et al., 2014; Gümüş et al., 2019). Over the past few decades, manual felling and logging techniques in forestry operations have evolved towards mechanized timber harvesting (Wei et al., 2015) Despite the progress in applications and information technologies, forestry is still one of the most hazardous lines of business, especially in countries where nonprofessional activities take place (Klun and Medved, 2007). Based on a survey of data sets, Engsaas (1993) reported that 60% of all injuries in forestry occur during logging, 20% during transportation, and 20% during silviculture and other forestry work. The results of a nine-year field study carried out by Tsioras et al. (2011) also revealed that two-thirds of accidents that occur during forestry activities occur during timber harvesting, which is only sometimes mechanized and carries a high risk of accidents, especially on steep slopes. Nikooya et al. (2012) also found that tree felling and chainsaw operations are more dangerous than loading.

[1] Eurostat (2020a). Accidents at work statistics [online]. Website https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Accidents_at_work_statistics [accessed 1 August 2020].

* Correspondence: aoakay@istanbul.edu.tr

There have been many studies regarding accident analysis in the forestry and logging sector. These studies have focused on various occupational accident issues, such as chainsaw accidents (Bentley et al., 2005; Montorselli et al., 2010), accidents during cable yarding operations (Tsioras et al., 2011), felling and skidding operations (Potočnik et al., 2009), fatal accidents in forest operations (Mitchell et al., 2001; Thelin, 2002), the determination of accident types and accident rates among private forest owners (Lindroos and Burström, 2010), and health problems related to work operations (Acar and Senturk, 1999), among others. By reviewing previous studies, it can also be found that there have been a limited number of studies comparing the occurrence of occupational accidents in the forestry sector with respect to differences between countries. Klun and Medved (2007) compared fatal forestry accidents among seven different EU countries over five-year periods between 1980 and 2004. The results of their study revealed that Sweden had the lowest numbers in this regard. In another study, the number of fatal tractor accidents in the agriculture and forestry sector among EU countries was compared (Bernik and Jeroncic, 2011). Suchomel et al. (2013) compared Austria, Slovakia, and the Czechia with regard to the forestry, agriculture, and fishing sectors by considering the fatal accident rates, concluding that Austria had the highest rates. At the same time, we found that a limited number of occupational accident assessment criteria were taken into consideration in the previous studies carried out comparing different countries.

Turkey is the only country with a land mass, both on the European continent and on the Asian continent. In this context, it forms a transition zone between Europe and Asia in geopolitical terms. For that reason, Turkish forestry is affected by the Pan-European Helsinki process having 7 criterias-63 indicators (Ozcan, 2008).

The main purpose of the study is to reveal the situations between Turkey which is an EU candidate country, and EU member states. In this context, the k-means clustering method was used to classify the forestry and logging sectors in 23 EU countries and Turkey according to their similarities and differences with respect to various occupational accident evaluation criteria between 2008 and 2017. The occupational accident assessment criteria used in the study include the nonfatal male accident incidence rate, the nonfatal female accident incidence rate, the total (male + female) nonfatal accident incidence rate, and the total (male + female) fatal accident incidence rate.

2. Materials and methods

2.1. Data description

In this study, we used 10 years (2008–2017) of data on the occupational accident incidence rates in forestry and logging in 23 EU countries and Turkey. Belgium, Estonia, South Cyprus, Luxemburg, Malta, the Netherlands, Great Britain, Iceland, and Norway, which are among the EU-member countries, were not considered because there did not exist enough data regarding these to make an accurate assessment on a 10-year basis. The occupational accident incidence rate variables included the nonfatal male accident incidence rate, nonfatal female accident incidence rate, total (male + female) nonfatal accident incidence rate, and total (male + female) fatal accident incidence rate (Tables 1–4).

According to European Statistical Office (EUROSTAT), two main types of indicators are used in the evaluation of European occupational accident statistics: the number of accidents and the accident incidence rate (Eurostat, 2013). The accident incidence rate is defined as the number of accidents per 100,000 people in employment. On the other hand, International Labor Organization (ILO) evaluates occupational accidents in terms of fatal and nonfatal accidents by taking into account the number of accidents per 100,000 people in employment in order to measure occupational accidents easily and to compare the countries in terms of time.[2] Incidence rate calculation formula is given in Eq (1).

$$\text{Incidence rate} = \frac{Number\ of\ accidents\ (fatal\ or\ nonfatal)}{Number\ of\ employed\ persons\ in\ the\ covered\ population} \times 100{,}000 \quad (1)$$

For the EU countries, the values for the relevant variables were obtained from the EUROSTAT office.[3,4] For Turkey, the incidence rate values are not given in the Republic of Turkey Social Security Institution report, the incidence rate values are calculated by authors according to Eq. (1).[5] SSI is an organization that reports on employees' insurance records. Hence, accident reports are based on hospital reports.

2.2. Clustering analysis

In this study, the occupational accident incidence rate data were analyzed using k-means clustering. Clustering

[2] ILO (2021). Indicator description: Occupational injuries [online]. Website https://ilostat.ilo.org/resources/concepts-and-definitions/description-occupational-injuries/ [accessed 9 April 2021].

[3] EUROSTAT (2020b). Non-fatal accidents at work by NACE Rev. 2 activity and sex [online]. Website https://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=hsw_n2_01&lang=en [accessed 1 August 2020].

[4] EUROSTAT (2020c). Fatal Accidents at work by NACE Rev. 2 activity https://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=hsw_n2_02&lang=en (accessed 1 August 2020).

[5] SSI (2020). SSI, Statistical data [online]. Website http://www.sgk.gov.tr/wps/portal/sgk/tr/kurumsal/istatistik/sgk_istatistik_yilliklari [accessed 1 August 2020].

Table 1. Nonfatal male occupational accident incidence rates (23 EU countries and Turkey).

	Nonfatal male accidents at work (incidence rate)									
	Years									
Country	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Turkey	225.50	371.52	285.87	313.08	252.02	594.70	565.99	449.34	1027.36	1349.14
Bulgaria	107.99	104.06	151.88	234.90	147.23	151.66	151.62	174.41	82.66	222.45
Czechia	0.00	1812.54	0	1174.28	909.30	1125.52	754.31	1073.03	730.17	837.86
Denmark	3499.77	11,885.79	2739.41	2773.78	4471.99	4837.61	4549.45	2933.80	2931.84	2118.36
Germany	15,303.13	9237.45	13,252.32	3277.39	2717.59	8091.05	8927.50	0.00	11,997.99	10,211.62
Ireland	18,156.07	1515.73	1995.34	1453.51	1504.60	3550.99	8391.44	7360.26	4224.54	940.31
Greece	5841.33	2543.79	3349.48	4935.68	5242.94	4236.18	1274.55(b)	2804.95	5625.70	2701.62
Spain	7384.03	15,194.46	13,698.43	16,916.61	13,993.06	15,771.09	7389.23	16,988.22	13,590.89	15,429.94
France	5,264.56	238.55	415.53	33,517.28(u)	0.00	5,715.02	7,073.77(b)	7,074.79	8,758.49	6,624.93
Croatıa	na	na	2991.36	3678.96	3045.44	2785.92	3187.21	2928.52	15639.04	2915.84
Italy	1617.79	18,865.70	17,432.34	15,994.71	16,660.46	11,980.09	10,194.98	2318.81	568.85	418.30
Latvia	336.43	65.96	126.61	313.06	324.5	402.94	353.21	189.33	207.25	461.1
Lithuania	251.91	385.98	716.37	286.18	528.37	295.08	264.09	334.18	201.61	399.82
Hungary	948.64	799.28	683.51	1086.82	1110.62	853.77	864.29	869.13	887.68	513.83
Austria	5182.11	6476.47	3741.46	5130.79	4275.72	5793.23	5674.90	6534.62	9764.07	10,342.40
Poland	796.79	1742.07	852.28	609.46	991.85	642.05	656.44	513.53	845.74	593.98
Portugal	na	7775.60	8840.36	9437.14	7573.48	7538.17	9812.25	11,087.76	9087.65	7482.10
Romania	188.68	136.00	472.71	1963.66	769.60	804.20	782.91	214.41	276.59	363.26
Slovenia	13,158.91	6595.11	9935.90	7940.70	7239.11	8587.14	7486.95	9099.56	7114.52	8286.36
Slovakia	769.13	487.40	476.18	643.11	874.31	360.22	313.40	863.77	712.45	733.69
Finland	1968.59	1827.38	1907.34	1842.62	2311.45	1884.70	1614.33	1257.77	1240.54	1566.88
Sweden	597.03	589.74	684.46	639.02	426.40	576.87	666.61	381.30	689.79	390.62
United Kingdom	7947.19	4161.89	4448.38	7903.78	4200.70	5269.38	5048.07	4909.72	6437.91	4566.73
Switzerland	6172.26	8848.13	5219.32	5129.65	6107.51	4827.59	4395.73	4229.26	6771.94	7941.64

na: not available, (b): break in time series, (u): low reliability.

analysis methods, which are important in data analysis, can be classified into two main categories: hierarchical and partitional (Alguwaizani et al., 2011; Wu et al., 2015). In clustering analysis, the units are divided into homogeneous and heterogeneous subgroups based on distance matrices or a similarity matrix (Mauro et al., 2013). The k-means clustering method, which is a partitional method, was introduced by MacQueen (1967). Sangita and Dhanamma (2011) state that k-means clustering is a very simple and popular method that can be easily applied. In this context, it is stated that the factors that are effective in the popularity of the k-means algorithm are its speed of convergence, its applicability to sparse data and its easy interpretation (Dhillon and Modha, 2001). Also, k-means has a concise algorithm and it can accommodate a large sample size (Pandit et al., 2011; Li et al., 2016). K-means clustering analysis is widely used in studies in different fields (Shi et al., 2011; Kijewska and Bluszcz, 2016; Javadi et al., 2017; Yock and Kim, 2017; Shakeel et al., 2018). According to the method, the highest possible level of similarity among elements in the same cluster is desired. In addition, the similarities between the created clusters are expected to be minimal (Dalton et al., 2009). Distance measurements, such as Euclidean, Manhattan and Minkowski distance, are used to determine the distances between the clusters. In the k-means clustering method, the most commonly used similarity measurement method is Euclidean distance (Li et al., 2019). According to the k-means clustering algorithm, data points of a particular size are divided into k sets, thus aiming to minimize the

Table 2. Nonfatal female occupational accident incidence rates (23 EU countries and Turkey).

	Nonfatal female accident at work (incidence rate)									
	Years									
Country	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Turkey	114.63	142.29	264.62	77.12	55.97	361.41	294.33	428.47	799.01	533.48
Bulgaria	51.35	19.59	42.65	0.00	0.00	87.36	28.82	28.51	0.00	28.09
Czechia	0.00	2108.34	0.00	1512.84	902.34	788.95	868.99	1153.88	1493.89	817.94
Denmark	1228.74	3917.99	1695.62	2397.26	12,146.42	6208.09	2177.29	2706.86	0.00	2084.24
Germany	9063.58	2734.53	1830.51	637.54	955.67	0.00	36,579.54	41,530.91	1874.88	21,365.96
Ireland	0.00	0.00	3265.61	0.00	0.00	0.00	0.00	0.00	39,874.97	2630.11
Greece	1070.94	0.00	0.00	754.62	0.00	0.00	0.00(b)	0.00	955.96	259.90
Spain	5240.82	7252.46	6641.95	6282.58	4117.57	4413.38	5709.69	4598.74	2942.82	5493.53
France	3338.06	41.56	0.00	1834.94	0.00	1066.98	801.38(b)	864.95	775.44	929.81(b)
Croatia	na	na	611.07	0.00	0.00	312.70	367.12	894.04	173.51	595.10
Italy	565.96	46,921.18(u)	41,327.67	31,495.27(u)	37,596.69	29,127.26(u)	22,775.23(u)	1359.02	164.98	217.85
Latvia	51.60	58.62	94.48	135.87	143.55	69.34	232.47	51.12	103.63	43.75
Lithuania	122.51	58.16	163.96	505.97	102.34	147.04	112.42	103.23	0.00	183.26
Hungary	543.70	936.30	897.45	504.41	1951.92	959.50	1358.92	683.47	1375.53	1036.14
Austria	1646.57	1373.71	907.69	1655.91	1104.14	805.87	729.73	1837.21	3445.58	2381.08
Poland	304.22	580.54	614.51	314.51	447.43	288.72	296.10	336.71	361.43	372.3
Portugal	na	3092.78	5115.41	2338.01	4068.18	7345.48	5960.41	6603.62	7925.00	9389.45
Romania	55.7	0.00	8.29	11.67	16.89	0.00	14.31	49.06	83.04	82.45
Slovenia	991.64	1922.88	1183.24	543.43	1162.67	376.07	1530.55	1176.45	1063.75	573.57
Slovakia	674.28	327.95	312.54	154.02	192.49	285.29	160.49	780.67	438.38	630.27
Finland	818.57	1059.86	865.74	795.10	418.05	618.17	792.07	589.74	583.08	772.59
Sweden	778.52	615.47	681.45	749.04	403.93	528.05	886.79	763.47	431.25	115.12
United kingdom	660.39	1792.07	1908.85	0.00	4,533.91	617.72	838.47	470.63	1040.65	977.29
Switzerland	636.27	414.75	645.14	243.43	458.23	152.37	237.84	350.47	690.25	545.99

na: not available, (b): break in time series, (u): low reliability.

sum of the squares within the cluster (Hartigan and Wong, 1979; Krishna and Murty, 1999; Jain, 2010).

The general procedure of the k-means clustering algorithm is as follows:

Let $X = \{X_1, X_2, X_3,..., X_n\}$ be the set of data points and $V = \{V_1, V_2, V_3,\ldots,V_n\}$ be the set of centers. The k-means algorithm aims at minimizing an objective function known as the squared error function, given by:

$$J(V) = \sum_{i=1}^{c} \sum_{j=1}^{c_i} (\|x_i - v_i\|)^2 \quad (2)$$

Here, is the Euclidean distance between and , c_i is the number of data points in *i*th cluster, and c is the number of cluster centers. can be expressed as follows:

$$v_i = (1/c_i) \sum_{j=1}^{c_i} x_i$$

The Euclidean distance is written as follows:

$$D(x,v) = \sqrt{\sum_{i=1}^{n} (x_i - v_j)^2} \quad (3)$$

The steps for implementing the k-means clustering method are listed below (Aggarwal and Reddy, 2014):

1) k cluster points are determined.

2) Observations are assigned to the cluster along with the points closest to it.

3) The average vector of the elements assigned to a cluster is calculated so that the cluster points are updated. In the case of an observation that is closer to the points of a cluster other than that in which it is located, the observation is transferred to the other cluster.

Table 3. Total (male + female) nonfatal occupational accident incidence rates (23 EU countries and Turkey).

	Total (male+female) nonfatal accidents at work (incidence rate)									
	Years									
Country	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Turkey	214.75	349.44	283.73	286.27	232.83	569.80	536.57	443.67	995.21	1125.80
Bulgaria	91.22	79.55	131.99	185.19	121.85	137.83	124.99	142.66	65.48	179.60
Czechia	0.00	1857.87	0.00	1222.75	908.01	1057.60	772.00	1086.64	801.96	835.14
Denmark	2914.03	8842.58	2609.26	2708.33	4821.58	4955.88	4207.36	2994.95	3018.65	2227.94
Germany	14,821.30	8221.70	10,264.93	2748.62	2556.87	8481.80	9310.48	0.00	9375.76	10,491.74
Ireland	16,604.34	1548.85	2133.66	1335.77	1383.79	3311.30	7543.46	6778.00	4598.28	1053.07
Greece	4819.12	2309.80	2820.32	4040.26	4659.28	3937.15	1156.65(b)	2383.13	5220.89	2080.97
Spain	7122.65	13,953.24	12,640.92	15,010.43	12,385.29	13,885.00	7283.63	15,173.20	11,913.37	14,064.42
France	5096.49	200.95	328.72	27567.49(u)	0.00	4885.79	6069.72(b)	6324.49	7662.27	6007.54(b)
Croatia	na	na	2555.85	2998.71	2476.65	2351.39	2638.05	2676.64	3356.32	2503.35
Italy	1492.31	22,261.72(u)	20,350.10	18,056.06	19,216.71	13,954.05	11,748.57	2215.34	524.14	396.25
Latvia	268.95	64.61	120.75	281.17	291.14	333.23	333.94	169.42	186.53	325.91
Lithuania	226.30	310.01	588.46	312.26	469.18	270.34	242.30	294.28	165.54	376.45
Hungary	875.45	820.41	721.93	955.72	1223.64	873.12	950.82	831.49	978.83	578.65
Austria	4710.14	5664.13	3317.63	4578.35	3725.00	4916.69	4247.21	5676.05	8921.59	8783.48
Poland	721.90	1547.92	815.36	563.94	917.10	585.38	600.97	489.88	759.57	560.98
Portugal	na	7060.78	8444.66	8069.39	7208.14	7520.17	9399.98	10,465.62	8978.50	7605.67
Romania	177.53	125.52	168.33	240.40	321.64	357.58	419.47	193.97	257.25	333.01
Slovenia	10,776.47	6106.00	9235.24	7303.37	6742.78	7572.73	6977.76	8245.24	6596.91	7469.74
Slovakia	753.98	461.61	453.71	511.02	661.35	346.88	293.16	853.55	660.13	715.85
Finland	1836.43	1762.63	1815.61	1711.65	2037.00	1730.54	1537.51	1184.65	1179.11	1483.25
Sweden	614.95	592.13	684.19	649.87	425.08	573.37	682.84	413.12	661.14	352.81
United Kingdom	6177.62	3847.80	4155.22	8507.51	4219.27	4239.52	4203.85	3182.22	4854.44	3668.48
Switzerland	5315.77	6594.51	3947.21	4032.79	4295.73	3057.52	3136.75	2945.72	5516.09	5547.43

na: not available, (b): break in time series, (u): low reliability.

4) Step 3 is repeated until all transitions have stopped.

Although there are different approaches for determining the number of clusters according to the k-means clustering method, the most commonly used approach is given as follows (Marola et al., 1979):

$$k \cong \sqrt{\frac{n}{2}} \tag{4}$$

Here, k is the number of clusters, and n is the number of samples.

All calculations related to clustering analysis were carried out using the SPSS Statistics 21.0 program. The mean values of the occupational accident data between 2008 and 2017 were used in the k-means clustering analysis performed herein. The mean values are shown in Table 5 and Figure 1.

Since there are different types and sizes of occupational accident data, some related data were normalized for a more accurate clustering analysis. The minimum/maximum normalization method was applied on data in Table 5 by using Eq. (5). And finally, the normalized values are indicated in Table 6.

$$X_{nor} = \frac{x_0 - x_{min}}{X_{max} - X_{min}} \tag{5}$$

Here, X_{nor} is the normalized value, X_{max} is the maximum value, X_{min} is the minimum value, and X_0 is the original value.

Table 4. Total (male + female) fatal occupational accident incidence rates (23 EU countries and Turkey).

	Total (male+female) fatal accidents at work (incidence rate)									
	Years									
Country	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Turkey	14.81	0.00	14.78	17.53	5.48	20.77	7.16	20.19	20.15	13.41
Bulgaria	5.07	0.00	15.53	17.64	21.50	6.26	18.75	12.41	0.00	18.58
Czechia	22.51(u)	6.17	20.84	20.96	9.46	3.79	2.91	8.26	3.12	12.75
Denmark	33.40(u)	63.93(u)	0.00	0.00	37.41	31.69	0.00	0.00	23.52	0.00
Germany	43.34(u)	16.25	25.93	6.68	3.83	27.50	29.56	617.08	16.11	41.25
Ireland	45.44(u)	50.62(u)	100.64	0.00	0.00	0.00	0.00	52.06	0.00	0.00
Greece	24.18(u)	0.00	37.15	51.09(u)	22.66	0.00	18.36(b)	69.08	82.87	99.09
Spain	16.95	39.08(u)	34.18	67.78(u)	13.02	33.31	22.04	11.92	52.09	39.15
France	0.00	0.00	0.00	344.59(u)	0.00	0.00	10.13	43.24	31.06	24.19(b)
Croatıa	na	na	44.71	21.57(u)	64.38	65.93	0.00	20.13	57.47	26.44
Italy	4.82	34.26(u)	35.74	29.56(u)	29.53	24.88	35.95	15.63	3.65	7.37
Latvia	24.45(u)	21.54(u)	51.75	36.67(u)	52.93	0.00	37.10	36.83	20.73	28.34
Lıthuania	16.16	26.96(u)	75.93	24.02(u)	56.87	32.77	48.46	8.92	24.83	18.36
Hungary	35.73(u)	32.82(u)	25.78	18.93	24.28	13.30	9.70	12.99	31.90	31.47
Austria	94.20(u)	54.67(u)	59.39	68.68(u)	27.39	91.05	92.70	140.82	133.38	75.20
Poland	19.82	23.10	16.60	18.56	19.75	13.23	6.75	15.01	12.06	14.87
Portugal	na	20.83(u)	23.04	59.56(u)	74.39	29.60(u)	20.80	37.83	57.40	34.68
Romania	67.74(u)	37.47(u)	81.45	96.16(u)	130.67	65.01	142.08	66.68	107.88	102.12
Slovenia	0.00	0.00	0.00	187.27(u)	47.48	46.46	130.83	42.28	90.99	0.00
Slovakia	14.36	0.00	12.26	5.94	0.00	8.46	12.75	32.01	9.30	36.25
Finland	0.00	0.00	4.77	0.00	0.00	4.18	0.00	3.80	3.89	9.57
Sweden	17.47	3.57	16.77	3.69	2.39	9.45	6.60	0.00	3.62	14.36
United Kingdom	10.26	8.55	22.66	35.13	24.06	0.00	8.90	7.33	0.00	8.7
Switzerland	49.22	129.3(u)	11.21	21.86	45.22	0.00	8.00	0.00	14.25	13.6

na: not available, (b): break in time series, (u): low reliability.

In determining the number of clusters, Ward's method was used for a priority hierarchical grouping (Figure 2). According to Ward's method, the Euclidean distance is used to evaluate the distance between the clusters (Ward Jr, 1963). In addition, the number of clusters were calculated by using Eq. (4) as shown below:

$$k \cong \sqrt{\frac{24}{2}} \cong 3$$

Considering the results obtained using both methods, the appropriate number of clusters was determined to be three.

3. Results and discussion

For the analysis considering three clusters, the distribution and distances of the countries according to the clusters are given in Table 7. In addition, the distribution of countries by cluster and the number of elements in each cluster are given in Table 8 and Figure 3. Turkey was placed in Cluster 2.

The final cluster center results for each cluster are given in Table 9. The mean values of each cluster and the mean values of the 23 EU countries and Turkey are listed in Table 10 as descriptive statistics.

The distances between the final cluster centers are given in Table 11. When the values of the distances between the related clusters were analyzed, Cluster 3 was found to be closer to Cluster 2 than Cluster 1. Moreover, the distance between Cluster 1 and Cluster 2 was the greatest among the clusters.

An analysis of variance (ANOVA) was performed to examine the effect of the different variables on

Table 5. Mean values for nonfatal and fatal occupational accident incidence rates (23 EU countries and Turkey).

	Nonfatal accidents at work (incidence rate) (2008–2017)			Fatal accidents at work (incidence rate) (2008–2017)
Country	Male	Female	Total (male + female)	Total (male + female)
Turkey	543.458	307.137	503.812	13.415
Bulgaria	152.886	28.637	126.036	11.574
Czechia	841.701	964.717	854.197	11.077
Denmark	4274.180	3456.251	3930.056	18.995
Germany	8301.604	11,657.312	7627.320	82.753
Ireland	4909.279	4577.069	4629.052	24.876
Greece	3855.622	304.142	3342.757	40.448
Spain	13,635.596	5269.354	12,343.215	32.952
France	7468.292	965.312	6414.346	45.321
Croatia	4646.536	369.193	2694.620	37.579
Italy	9605.203	21,155.111	11,021.525	22.139
Latvia	278.039	98.443	237.565	31.034
Lithuania	366.359	149.889	325.512	33.328
Hungary	861.757	1024.734	881.006	23.690
Austria	6,291.577	1,588.749	5454.027	83.748
Poland	824.419	391.647	756.300	15.975
Portugal	8737.168	5759.816	8305.879	39.792
Romania	597.202	32.141	259.470	89.726
Slovenia	8544.426	1052.425	7702.624	54.531
Slovakia	623.366	395.638	571.124	13.133
Finland	1742.160	731.297	1627.838	2.621
Sweden	564.184	595.309	564.950	7.792
United Kingdom	5489.375	1283.998	4705.593	12.559
Switzerland	5964.303	437.474	4438.952	29.266

cluster formation, and the results are shown in Table 12. The ANOVA results reveal that there are significant differences among the clusters with respect to these variables, considering p values <0.05 to indicate statistical significance. In other words, it can be stated that variables had an important effect on the cluster analysis.

In addition, the minimum and maximum averages in each cluster are given in Table 13 and represented in Figure 4 to reveal the relationships and differences among the groups.

When the final center values and descriptive statistical values in the clusters were evaluated, it was found that the occupational accident incidence values of the countries in Cluster 2 were in all four categories below the averages of both the other clusters as well as the 23 EU countries and Turkey. Cluster 1 was above the averages of both the other clusters as well as the 23 EU countries and Turkey in the total nonfatal occupational accident category, and Cluster 3 in the fatal occupational accident category (Figure 4).

Cluster 1 consists of Italy and Spain (Table 7). Ambrosio et al. (2001) have stated that there is a lack of professionalism in Spain along with faults in active and passive protection equipment. According to our results, Italy is behind Spain in all other nonfatal accident categories except nonfatal female accidents. Italy has a frequency four-times higher than Spain in terms of nonfatal work accidents to women workers. With respect to the nonfatal male accident incidence rate, Spain has more than three times the average of the 23 EU countries and Turkey (Table 10 and Figure 4). While the nonfatal female accident incidence average of this cluster is approximately five times that of the 23 EU countries and Turkey, it is 3 times higher than the 23 EU

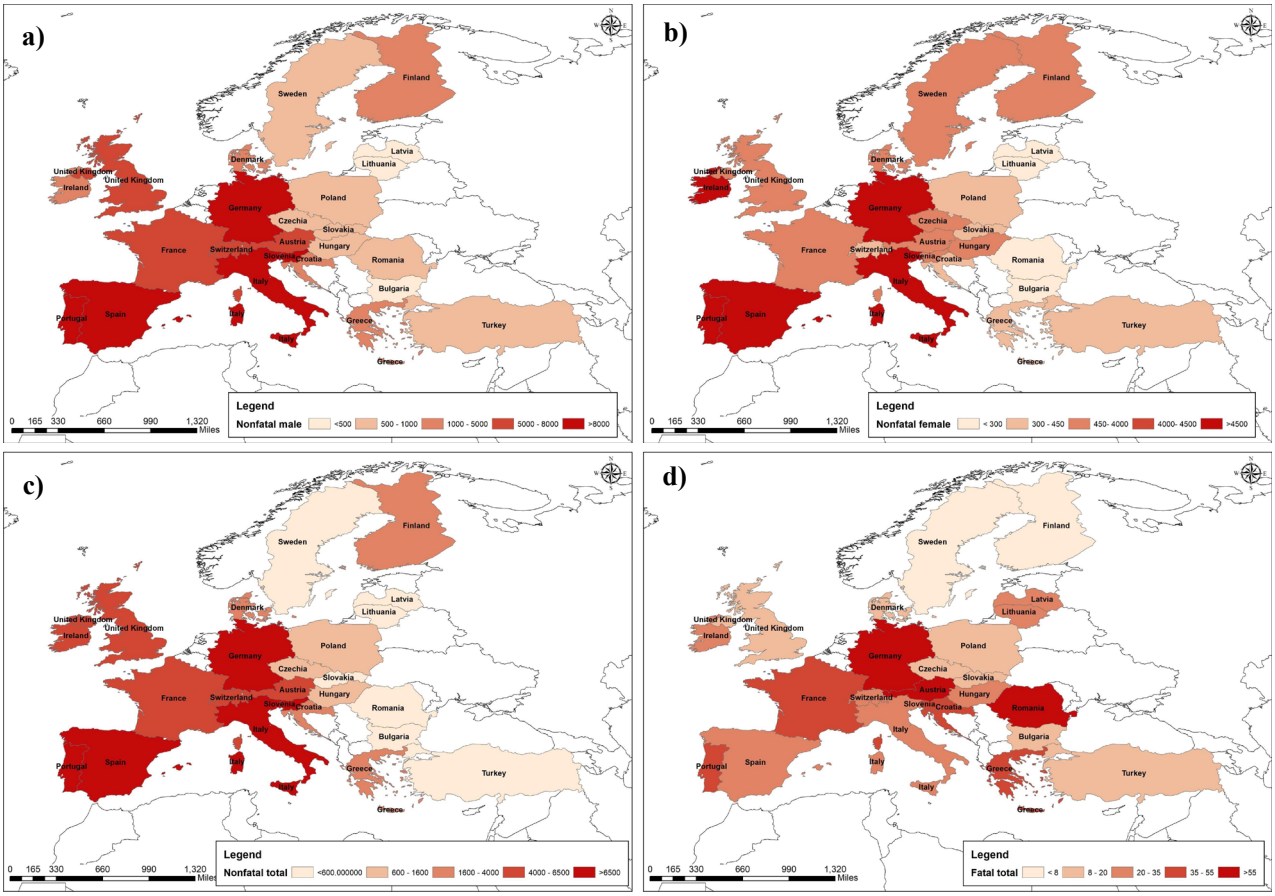

Figure 1. Geographical distribution of the countries in terms of accident incidence rates. a) Nonfatal male. b) Nonfatal female. c) Total (male + female) nonfatal. d) Total (male + female) fatal.

countries and Turkey with respect to the total incidence. Despite all of this, Cluster 1 is below the average of the 23 EU countries and Turkey in terms of the fatal accident incidence rate.

Grzywiński et al. (2020) state that there is a common assumption that occupational accident rates in forestry have decreased significantly over the past 10–20 years, especially in Central and Eastern Europe. Most of the countries in Cluster 2 are located in Central and Eastern Europe, and although the 16 countries in Cluster 2 have the lowest mean values for both fatal and nonfatal accident incidence rates and are generally below the average of the 23 EU countries and Turkey for each category, there are some exceptions (Figure 4). In this cluster, Bulgaria has the lowest averages in the total nonfatal accident category (Table 13). With respect to fatal accidents, the lowest value was found to belong to Finland, while the highest belonged to Greece. Similarly, Albizu et al. (2013) found that among the six European countries they studied Finland and Sweden had the lowest fatal accident rates per m^3 in the forestry sector. Analyzing the nonfatal accidents experienced by male workers in this cluster, Switzerland, the UK, Ireland, Croatia, Denmark, and Greece, which are among the countries with the highest values, are above the average of the cluster. At the same time, Ireland has the highest average in terms of the incidence of nonfatal accidents faced by women workers. Denmark, Hungary, and the Czechia, which follow Ireland in that order, are also above the average of Cluster 2. With respect to the total nonfatal accident frequency, the countries with the highest values are the UK, Ireland, Switzerland, Denmark, Greece, and Croatia, in that order, and their values are also all above the average of their cluster. Of these countries, the average values of the first four are also higher than that of the 23 EU countries and Turkey. Considering the fatal accident incidence, Greece, Croatia, and Lithuania are above the averages both of their cluster and the 23 EU countries and Turkey, while Latvia, Switzerland, Ireland, and Hungary, which follow them, are above the average of Cluster 2. With respect to the countries in Cluster 2, there are several differences among them regarding economical and topographic conditions. Bernik and Jeroncic (2011) investigated the relationship between the relief and economic conditions of countries with work

Table 6. Normalized values for occupational accident incidence rates (23 EU countries and Turkey).

	Nonfatal accidents at work (incidence rate) (2008–2017)			Fatal accidents at work (incidence rate) (2008–2017)
Country	Male	Female	Total (male + female)	Total (male + female)
Turkey	0.029	0.013	0.031	0.124
Bulgaria	0	0	0	0.103
Czechia	0.051	0.044	0.060	0.097
Denmark	0.306	0.162	0.311	0.188
Germany	0.604	0.550	0.614	0.920
Ireland	0.353	0.215	0.369	0.255
Greece	0.275	0.013	0.263	0.434
Spain	1	0.248	1	0.348
France	0.543	0.044	0.515	0.490
Croatia	0.333	0.016	0.21	0.401
Italy	0.701	1	0.892	0.224
Latvia	0.009	0.003	0.009	0.326
Lithuania	0.016	0.005	0.016	0.353
Hungary	0.053	0.047	0.062	0.242
Austria	0.455	0.073	0.436	0.931
Poland	0.050	0.017	0.052	0.153
Portugal	0.637	0.271	0.67	0.427
Romania	0.033	0.000	0.011	1
Slovenia	0.622	0.048	0.62	0.596
Slovakia	0.035	0.017	0.036	0.121
Finland	0.118	0.033	0.123	0
Sweden	0.031	0.026	0.036	0.059
United Kingdom	0.396	0.059	0.375	0.114
Switzerland	0.431	0.019	0.353	0.306

accidents in 22 European countries between 1990 and 1999. According to their analysis, these factors had no significant impacts on the incidence rate. In addition, Berg et al. (2012) and Spinelli et al. (2013) state that the majority of Northern European countries have full-mechanized harvesting systems, while the Southwest and Central European countries have motor-manual felling and mechanized extraction (i.e. forwarders, skidders, and cable yarders), and Eastern European countries have a low level of mechanization. Similarly, the countries in Cluster 2 were found to have different mechanization levels. These results thus indicate that there is no significant relationship between mechanization rate and accident incidence rate. It is stated that the motor-manual method is a risky method in the occurrence of work accidents in wood transportation (Tsioras et al. 2014, FAO, 2018). In addition, it has been emphasized that due to the cut-to-length technology, which is partially safe in mechanization in logging activities, new risks may arise due to increasing complexity and mental stress of the operator (Gellerstedt et al., 1999; Ovaskainen and Heikkilla, 2007; Jankovsky et al., 2018). Accident incidence rate is instead is probably related to the educational level and experience of the operator as well as the usage of protective equipment.

The mean values of Cluster 3 are above the average of the 23 EU Countries and Turkey in all categories (Table 10 and Figure 4). With respect to fatal accidents in particular, the mean value of Cluster 3 is approximately 2–3 times the averages of the other clusters and the 23 EU Countries and Turkey (Table 10). In this cluster, the situation of Romania differs from those of all the others. While Romania is the country with the lowest value in the cluster for total nonfatal accident incidence (Table 13), it has the highest value in terms of fatal accidents among all the 24

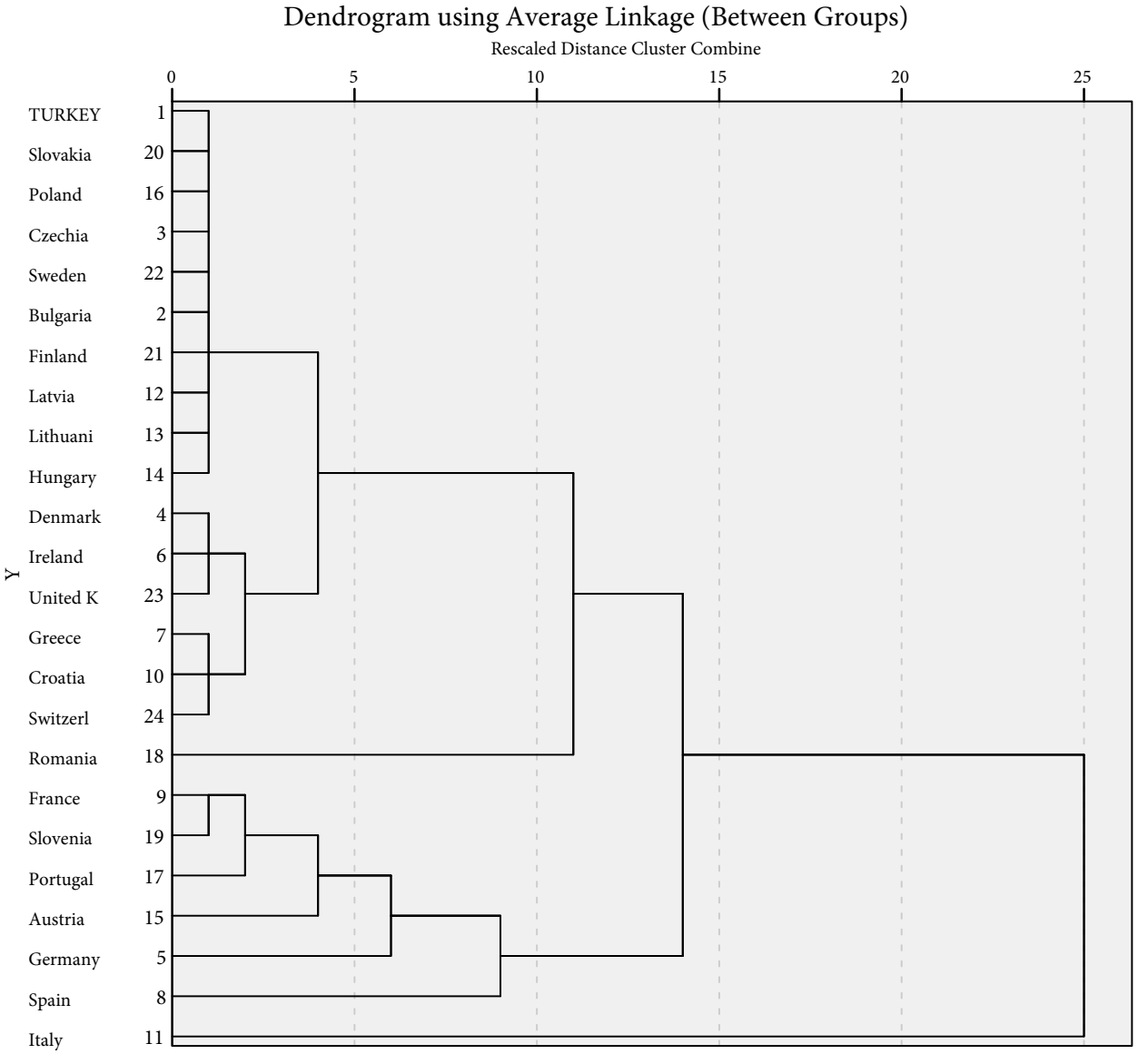

Figure 2. Results of the hierarchical grouping of occupational accident incidence rates for 23 EU countries and Turkey.

countries. Following Romania in this category, Austria and Germany also have fatal accident incidence values above the cluster average. According to the frequency of fatal accidents, the lowest average in Cluster 3 is in Portugal. In terms of both nonfatal male and total nonfatal accident incidence, Portugal, Slovenia, Germany, and France have higher values than the averages. According to the nonfatal female accident incidence rates, Germany has a frequency of more than three times the cluster average.

In all four categories discussed in the study, Turkey is below the average both within its cluster and among the 24 countries (Table 10 and Figure 4). Within the 24 countries subject to research, Turkey is the fourth lowest in the class of nonfatal male occupational accident incidence rates, sixth in nonfatal female accident incidence, and fifth in the total nonfatal accident incidence. Considering fatal occupational accidents, it has the seventh lowest average of the 24 countries (Table 5).

4. Conclusion

In this study, 23 EU countries and Turkey were clustered according to fatal and nonfatal occupational accident incidence in the forestry and logging sector. Clustering analysis results showed Turkey was included in Cluster 2 which also contains Greece, Bulgaria (border to Turkey) and the majority consisting of the northern European countries and central European countries. A clustering analysis method was used to efficiently to evaluate and

Table 7. Cluster numbers and distances from center of countries.

Country	Cluster	Distance
Turkey	2	0.190
Bulgaria	2	0.239
Czechia	2	0.172
Denmark	2	0.255
Germany	3	0.468
Ireland	2	0.349
Greece	2	0.286
Spain	1	0.413
France	3	0.275
Croatia	2	0.275
Italy	1	0.413
Latvia	2	0.236
Lithuania	2	0.243
Hungary	2	0.137
Austria	3	0.229
Poland	2	0.152
Portugal	3	0.403
Romania	3	0.722
Slovenia	3	0.266
Slovakia	2	0.184
Finland	2	0.210
Sweden	2	0.221
United Kingdom	2	0.346
Switzerland	2	0.361

Table 8. Countries in clusters and number of cluster elements.

Cluster no	Countries	Number of cluster elements
1	Italy, Spain	2
2	Turkey, Bulgaria, Czechia, Denmark, Ireland, Greece, Croatia, Latvia, Lithuania, Hungary, Poland, Slovakia, Finland, Sweden, United Kingdom, Switzerland	16
3	Germany, France, Austria, Portugal, Romania, Slovenia	6

exhibit differences and similarities with regard to accident rates. The reliability, frequency, and continuity of the data were the most important factors in the clustering analysis stage. The clusters created for the countries varied depending on a number of similarities and differences among them. The reasons for the differences and similarities between the countries studied could be related to proactive measures and legislation regarding

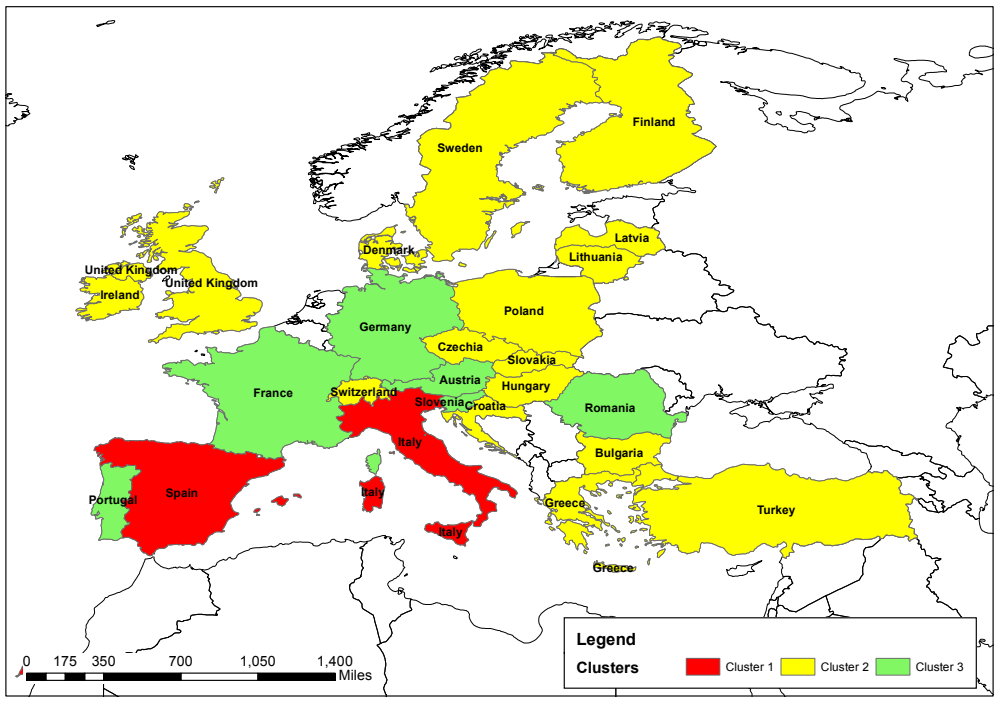

Figure 3. Geographical distribution of the countries according to clusters.

Table 9. Final cluster centers.

Variables	Number of clusters		
	1	2	3
Nonfatal male accident incidence rate	0.85	0.16	0.48
Nonfatal female accident incidence rate	0.62	0.04	0.16
Total (male + female) nonfatal incidence rate	0.95	0.14	0.48
Total (male + female) fatal accident incidence rate	0.29	0.20	0.73

Table 10. Descriptive statistics on the clusters.

Variables	Cluster 1	Cluster 2	Cluster 3	23 EU countries and Turkey
Mean nonfatal male accident incidence rate	11,620.40	2246.10	6656.71	4129.45
Mean nonfatal female accident incidence rate	13,212.23	944.72	3509.29	2608.16
Mean total (male + female) nonfatal accident incidence rate	11,682.37	1886.83	5960.61	3721.57
Mean total (male + female) fatal accident incidence rate	27.55	20.46	65.9	32.43

Table 11. Distances between the final cluster centers.

Cluster no	1	2	3
1	-	1.212	0.872
2	1.212	-	0.711
3	0.872	0.711	-

Table 12. Results of ANOVA for clustering analysis.

Variables	Cluster		Error			
	Mean Square	df	Mean Square	df	F	Significance
Nonfatal male accident incidence rate	0.570	2	0.033	21	17.215	0.000*
Nonfatal female accident incidence rate	0.307	2	0.027	21	11.514	0.000*
Total (male + female) nonfatal incidence rate	0.706	2	0.029	21	24.270	0.000*
Total (male + female) fatal accident incidence rate	0.599	2	0.027	21	21.828	0.000*

*p<0.05

Table 13. Minimum and maximum averages in the clusters.

Variables	Min/max value	Clusters					
		1		2		3	
Mean nonfatal male accident incidence rate	Min	9605.20	Italy	152.88	Bulgaria	597.20	Romania
	Max	13,635.60	Spain	5964.30	Switzerland	8,737.17	Portugal
Mean nonfatal female accident incidence rate	Min	5269.35	Spain	28.637	Bulgaria	32.141	Romania
	Max	21,155.11	Italy	4577.07	Ireland	11,657.31	Germany
Mean total (male + female) nonfatal accident incidence rate	Min	11,021.53	Italy	126.04	Bulgaria	259.47	Romania
	Max	12,343.22	Spain	4705.59	United Kingdom	8305.88	Portugal
Mean total (male + female) fatal accident incidence rate	Min	22.14	Italy	2.62	Finland	39.79	Portugal
	Max	32.95	Spain	40.45	Greece	89.72	Romania

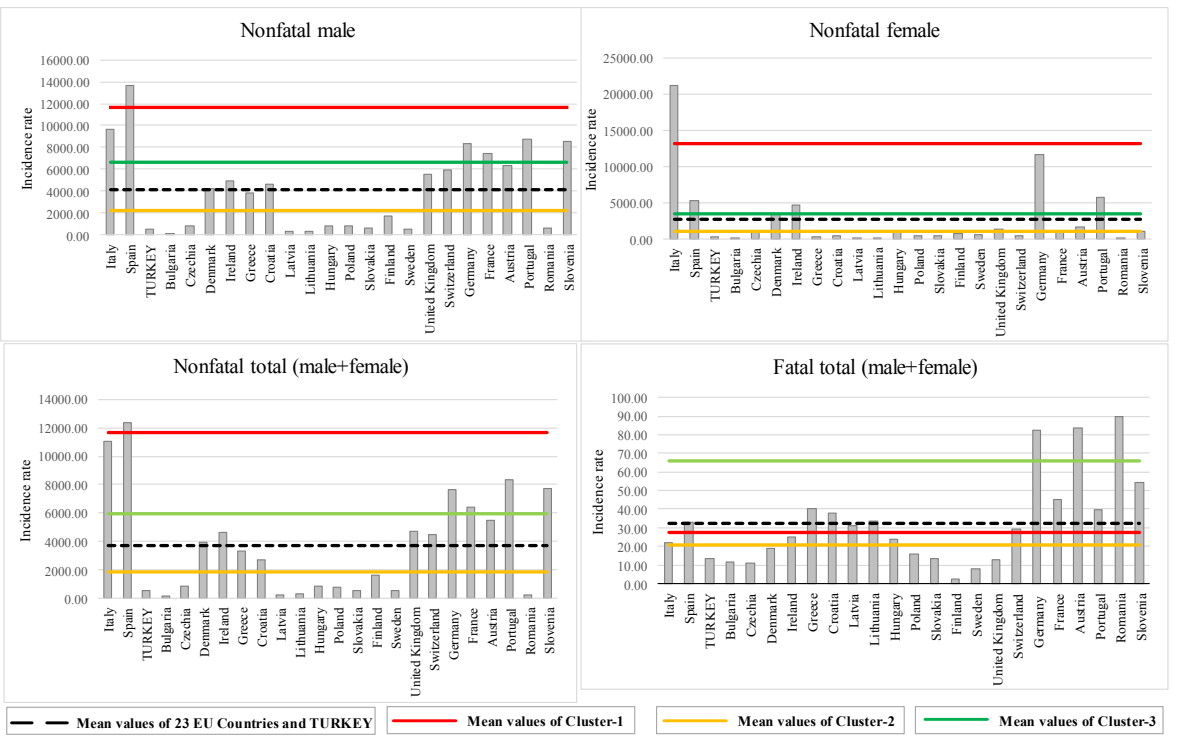

Figure 4. Relationships and differences among countries with respect to the mean values of each cluster as well as the 23 EU countries and Turkey.

occupational health and safety, degree of mechanization, the education level of the workers, and the socioeconomic and cultural structures of the countries. Studies similar to this one but on an intercontinental basis will provide a foundation for improving work health and safety legislation in forestry and logging on a global scale. Also, evaluation of occupational safety performances of countries in terms of forestry and logging, according to clustering results will be beneficial for comparing countries and self-evaluation.

Acknowledgments
The authors thank the editor and the anonymous reviewers for their constructive comments that helped us improve the manuscript.

References

Acar H, Senturk N (1999). Artvin yöresindeki orman işçilerinde işçi sağlığı üzerine bir araştırma. İstanbul Üniversitesi Orman Fakültesi Dergisi 49 (1): 25-40.

Aggarwal CC, Reddy CK (2014). Data Clustering Algorithms and Applications. Boca Raton, FL, USA: CRC Press.

Albizu PM, Tolosana-Esteban E, Roman-Jordan E (2013). Safety and health in forest harvesting operations. Diagnosis and preventive actions. A review. Forest Systems 22 (3): 392-400. doi: 10.5424/fs/2013223-02714

Alguwaizani A, Hansen P, Mladenović N, Ngai E (2011). Variable neighborhood search for harmonic means clustering. Applied Mathematical Modelling 35 (6): 2688-2694. doi: 10.1016/j.apm.2010.11.032

Ambrosio Y, Tolosana ES Vignote M (2001). Análisis de la seguridad y salud laboral en los aprovechamientos forestales de cortas de claras en España.

Revista Chapingo Serie Ciencias Forestales y del Ambiente 7 (1): 55-65 (in Spanish).

Bentley TA, Parker RJ, Ashby L (2005). Understanding felling safety in the New Zealand forest industry. Applied Ergonomics 36 (2): 165-175. doi: 10.1016/j.apergo.2004.10.009

Berg S, Fischbach J, Brüchert F, Poissonnet M, Pizzirani S et al. (2012). Towards assessing the sustainability of European logging operations. European Journal of Forest Research 131 (1): 81-94. doi: 10.1007/s10342-011-0561-x

Bernik R, Jeroncic R (2011). The comparison of number of deaths in accidents with the agriculture and forestry tractors among European countries. Acta Agriculturae Slovenica 97 (3): 213. doi: 10.2478/v10014-011-0015-7

Dalton L, Ballarin V, Brun M (2009). Clustering algorithms: on learning, validation, performance, and applications to genomics. Current Genomics 10 (6): 430-445. doi: 10.2174/138920209789177601

Dhillon IS, Modha DS (2001). Concept decompositions for large sparse text data using clustering. Machine Learning 42 (1): 143-175. doi: 10.1023/A:1007612920971

Enez K, Topbas M, Acar HH (2014). An evaluation of the occupational accidents among logging workers within the boundaries of Trabzon Forestry Directorate, Turkey. International Journal of Industrial Ergonomics 44 (5): 621-628. doi: 10.1016/j.ergon.2014.07.002

Engsaas J (1993). Accidents in small-scale forestry. Department of Operational Efficiency, Swedish University of Agricultural Sciences, Research Note 251. Uppsala, Sweden: Swedish University of Agricultural Sciences.

Eurostat (2013). European statistics on accidents at work (ESAW) Summary methodology. 2013 ed. Luxembourg: Eurostat European Commission.

FAO (2018). Accident reporting and analysis in forestry guidance on increasing the safety of forest work. Rome, Italy: Food and Agriculture Organization of the United Nations.

Gellerstedt S, Dahlin B (1999). Cut-to-length: the next decade. Journal of Forest Engineering 10 (2): 17-24.

Grzywiński W, Skonieczna J, Jelonek T, Tomczak A (2020). The influence of the privatization process on accident rates in the forestry sector in Poland. International Journal of Environmental Research and Public Health 17 (9): 3055. doi: 10.3390/ijerph17093055

Gumus S, Okan SU, Hatay TY (2019). Analysis of work accidents in wood harvesting: a case study of the East Black Sea region. Forestist 70 (1): 1-7. doi: 10.5152/forestist.2020.19008

Hartigan JA, Wong MA (1979). Algorithm AS 136: A k-means clustering algorithm. Journal of the Royal Statistical Society Series C (Applied Statistics) 28 (1): 100-108.

Jain AK (2010). Data clustering: 50 years beyond K-means. Pattern Recognition Letters 31 (8): 651-666. doi: 10.1016/j.patrec.2009.09.011

Jankovský M, Merganič J, Allman M, Ferenčík M, Messingerová V (2018). The cumulative effects of work-related factors increase the heart rate of cabin field machine operators. International Journal of Industrial Ergonomics 65: 173-178. doi: 10.1016/j.ergon.2017.08.003

Javadi S, Hashemy SM, Mohammadi K, Howard KWF, Neshat A (2017). Classification of aquifer vulnerability using K-means cluster analysis. Journal of Hydrology 549: 27-37. doi: 10.1016/j.jhydrol.2017.03.060

Kijewska A, Bluszcz, A (2016). Research of varying levels of greenhouse gas emissions in European countries using the k-means method. Atmospheric Pollution Research 7 (5): 935-944. doi: 10.1016/j.apr.2016.05.010

Klun J, Medved M (2007). Fatal accidents in forestry in some European countries. Croatian Journal of Forest Engineering: Journal for Theory and Application of Forestry Engineering 28 (1): 55-62.

Krishna K, Murty MN (1999). Genetic K-means algorithm. IEEE Transactions on Systems, Man, and Cybernetics 29 (3): 433-439.

Li C, Sun L, Jia J, Cai Y, Wang X (2016). Risk assessment of water pollution sources based on an integrated k-means clustering and set pair analysis method in the region of Shiyan, China. Science of the Total Environment 557-558: 307-316. doi: 10.1016/j.scitotenv.2016.03.069

Li B, Fan ZT, Zhang XL, Huang DS (2019). Robust dimensionality reduction via feature space to feature space distance metric learning. Neural Networks 112: 1-14. doi: 10.1016/j.neunet.2019.01.001

Lilley R, Feyer AM, Kirk P, Gander P (2002). A survey of forest workers in New Zealand: Do hours of work, rest, and recovery play a role in accidents and injury? Journal of Safety Research 33 (1): 53-71. doi: 10.1016/S0022-4375(02)00003-8

Lindroos O, Burström L (2010). Accident rates and types among self-employed private forest owners. Accident Analysis & Prevention 42 (6): 1729-1735. doi: 10.1016/j.aap.2010.04.013

MacQueen J (1967). Some methods for classification and analysis of multivariate observations. In: Proceedings of the Fifth Berkeley Symposium on Mathematical Statistics and Probability; Oakland, CA, USA. pp. 281-297.

Marola KV, Kbnt J, Bibly JM (1979). Multivariate analysis. AcadeInic Press, Londres.

Mauro R., De Luca, M, Dell'Acqua G (2013). Using a k-means clustering algorithm to examine patterns of vehicle crashes in before-after analysis. Modern Applied Science 7 (10): 11. doi: 10.5539/mas.v7n10p11

Mitchell R, Driscoll T, Healey S, Mandryk J, Hendrie L et al. (2001). Fatal injuries in forestry and logging work in Australia, 1989 to 1992. Journal of Occupational Health and Safety-Australia and New Zealand 17 (6): 567-577.

Montorselli NB, Lombardini C, Magagnotti N, Marchi E, Neri F et al. (2010). Relating safety, productivity and company type for motor-manual logging operations in the Italian Alps. Accident Analysis & Prevention 42 (6): 2013-2017. doi: 10.1016/j.aap.2010.06.011

Nikooya M, Naghdi R, Nouroozıa Z (2012). Analysis of forest logging work accident case study, west forest of Guilan province. Journal of Forest and Wood Products (Jfwp) (Iranıan Journal of Natural Resources) 64 (4): 475-486.

Ovaskainen H, Heikkilä M (2007). Visuospatial cognitive abilities in cut-to-length single-grip timber harvester work. International Journal of Industrial Ergonomics 37 (9-10): 771-780. doi: 10.1016/j.ergon.2007.06.004

Ozcan M (2008). Avrupa Birliği ormancılık politikaları ve Türkiye ormancılığının bu politikalara uyumu. MSc, Süleyman Demirel University, Isparta, Turkey (in Turkish).

Pandit YP, Badhe YP, Sharma BK, Tambe SS, Kulkarni BD (2011). Classification of Indian power coals using K-means clustering and self organizing map neural network. Fuel 90 (1): 339-347. doi: 10.1016/j.fuel.2010.09.012

Potočnik I, Pentek T, Poje A (2009). Severity analysis of accidents in forest operations. Croatian Journal of Forest Engineering: Journal for Theory and Application of Forestry Engineering 30 (2): 171-184.

Sangita O, Dhanamma J (2011). An improved k-means clustering approach for teaching evaluation. In: Unnikrishnan S, Surve S, Bhoir D (editors). Advances in Computing, Communication and Control. ICAC3 2011. Communications in Computer and Information Science, Vol. 125. Berlin, Germany: Springer, pp. 108-115. doi: 10.1007/978-3-642-18440-6_13

Shakeel PM, Baskar S, Dhulipala VS, Jaber MM (2018). Cloud based framework for diagnosis of diabetes mellitus using K-means clustering. Health Information Science and Systems 6 (1): 1-7. doi: 10.1007/s13755-018-0054-0

Shi BQ, Liang, J, Liu Q (2011). Adaptive simplification of point cloud using k-means clustering. Computer-Aided Design 43 (8): 910-922. doi: 10.1016/j.cad.2011.04.001

Spinelli R, Magagnotti N, Facchinetti D (2013). Logging companies in the European mountains: an example from the Italian Alps. International Journal of Forest Engineering 24 (2): 109-120. doi: 10.1080/14942119.2013.838376

Suchomel J, Belanová K, Vlčková M (2013). Analysis of work accidents in selected activities in Slovakia, Czech Republic and Austria. Croatian Journal of Forest Engineering: Journal for Theory and Application of Forestry Engineering 34 (2): 311-320.

Thelin A (2002). Fatal accidents in Swedish farming and forestry, 1988–1997. Safety Science 40 (6): 501-517. doi: 10.1016/S0925-7535(01)00017-0

Tsioras PA, Rottensteiner C, Stampfer K (2011). Analysis of accidents during cable yarding operations in Austria 1998–2008. Croatian Journal of Forest Engineering: Journal for Theory and Application of Forestry Engineering 32 (2): 549-560.

Tsioras PA, Rottensteiner C, Stampfer K (2014). Wood harvesting accidents in the Austrian state forest enterprise 2000–2009. Safety Science 62: 400-408. doi: 10.1016/j.ssci.2013.09.016

Ward Jr JH (1963). Hierarchical grouping to optimize an objective function. Journal of the American Statistical Association 58 (301): 236-244.

Wei L, Villemey A, Hulin F, Bilger I, Yann D et al. (2015). Plant diversity on skid trails in oak high forests: A matter of disturbance, micro-environmental conditions or forest age? Forest Ecology and Management 338: 20-31. doi: 10.1016/j.foreco.2014.11.018

Wilhelmson E, Wästerlund DS, Burström L, Bylund PO (2005). Public health effects of accidents in self-employed forestry work. Small-Scale Forest Economics, Management and Policy 4 (4): 427-435. doi: 10.1007/s11842-005-0026-5

Wu X, Wu B, Sun J, Qiu S, Li X (2015). A hybrid fuzzy K-harmonic means clustering algorithm Applied Mathematical Modelling 39 (12): 3398-3409. doi: 10.1016/j.apm.2014.11.041

Yock AD, Kim GY (2017). Using k-means clustering to determine the number and position of isocenters in MLC-based multiple target intracranial radiosurgery. Journal of Applied Clinical Medical Physics 18 (5): 351-357. doi: 10.1002/acm2.12139