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Neyman type A distribution for the natural disasters and related casualties in Turkey

Gamze Ozel[1*], Semra Turkan[1]
[1] *Department of Statistics, Hacettepe University*

Abstract: The statistical modeling of natural disasters is an indispensable tool for extracting information for prevention and risk reduction casualties. The Poisson distribution can reveal the characteristics of[1] a natural disaster. However, this distribution is insufficient for the clustering of natural events and related casualties. The best approach is to use a Neyman type A (NTA) distribution which has the feature that two or more events occur in a short time. We obtain some properties of the NTA distribution and suggest that it could provide a suitable description to analyze the natural disaster distribution and casualties. We support this argument using disaster events, including earthquakes, floods, landslides, forest fires, avalanches, and rock falls in Turkey between 1900 and 2013. The data strongly supports that the NTA distribution represents the main tool for handling disaster data. The findings indicate that approximately three earthquakes, fifteen landslides, five floods, six rock falls, six avalanches, and twenty nine forest fires are expected in a year. The results from this model suggest that the probability of the total number of casualties is the highest for the earthquakes and the lowest for the rock falls. This study also finds that the expected number of natural disasters approximately equals to 64 per year and inter-event time between two successive earthquakes is approximately four months. The inter-event time for the natural disasters is approximately six days in Turkey.

Key words: Natural hazards; earthquake; landslide; avalanche; flood; forest fire; rock fall; recurrence time; Neyman type A distribution.

1. Introduction

A natural hazard is an event of unusual magnitude that people do not expect and cannot control. They threaten people's lives and can forever change their ways of living. The natural hazard can become a natural disaster due to the destruction of people's property or their injury and/or death (Shield 2008). Nowadays, natural disasters are becoming more frequent, expensive and threatening worldwide. Massive flooding from extreme precipitation, raging forest fires

[*] Corresponding author.

from prolonged droughts; monster hurricanes or super tsunamis or giant earthquakes all seem to have become much more common.

Large numbers of casualties that can result from natural disasters are a difficult challenge for the individuals, communities and governments (Webster al. 2005). Perhaps it is difficult but it is not impossible to predict the occurrence of most natural disasters. It is possible to take action before emergency events happen to plan for their occurrence and, in this way, to mitigate their potential effects.

The study of distribution for different natural disasters (earthquakes, floods, forest fires, landslide, etc.) is necessary not only for the risk assessment, but it is also for understanding the physical natural of the underlying processes (Emanuel 2005). The earthquake statistics are the best-studied case among disasters and the distribution laws for the other kinds of natural disasters are much less known. The classical distributions frequently encountered for the occurrence of the natural hazards are the Gaussian and Poisson distributions. Each of these distributions occurs under some sets of conditions that are fairly clear and wide-spread in natural systems. One obvious advantage for the use of these classical distributions is the possibility of physical interpretation of the results. The empirical distributions for the disasters have not been sufficiently studied because of the shortage of the statistical data for corresponding kinds of natural disasters. Some natural disasters, such as earthquakes, forest fires and landslides and related losses, can follow the NTA distribution.

Turkey has always been vulnerable to various kinds of natural hazards, on account of its orogenic system, geology, topography and condition. These hazards, coupled with high physical and social vulnerability, have caused unacceptable losses of life, injury, and damage to property (JICA 2014). The country has 81 provinces with a total population over 70 million people. Earthquake occurrence is the leading hazard in Turkey, as the Northern Anatolian fault crosses the country east to west, and the Anatolian fault spans the country north to south. 92% of the country's, 780,580 km^2, and area is prone to earthquakes due to these active faults. More importantly, 75% of the countries industry is located in this active earthquake zone. The second leading hazard in Turkey in terms of economic loss is floods. The Black Sea, Mediterranean and Western Anatolian regions of the country are at most risk, as seen from historic records. The Black Sea region has secondary hazards of landslides that occur due to earthquakes and flooding. Therefore, our purpose is to analyze natural disasters in Turkey using the NTA distribution.

The rest of the paper is structured as follows. In Section 2, the NTA distribution is introduced to analyze the natural disasters and casualties. Section 3 describes study area and includes natural disasters in Turkey. In Section 4, the results are obtained applying the NTA to the natural hazards occurred in Turkey. The conclusion is given in Section 5.

2. Probability function and moment characteristics

Since natural disasters are extreme occurrences (earthquake or/and tsunami of high intensity, landslide of a great amount of soil, karsts crater of a large diameter), their statistics have the character of "statistics of rare phenomena". The Poisson distribution is not sufficient for the clustered natural disasters. The NTA distribution can be used but the explicit probabilities and statistical properties of this distribution have not been obtained in the literature. Therefore, moments, skewness, kurtosis, unimodality, coefficient of correlation, survival function of the NTA distribution are derived in this study.

Let N be a Poisson random variable with parameter $\lambda > 0$ and let Y_i , $i = 1, 2, 3, \ldots$ be i.i.d. Poisson distributed random variables with parameter $\mu > 0$, independent of N. Then, Neyman (1939) defined the NTA distributed random variable X as

$$X = \sum_{i=1}^{N} Y_i \quad (1)$$

Let $E(Y_i) = \mu$, $V(Y_i) = \sigma^2$, $i = 1, 2, 3, \ldots$, be the expected value and variance of Y_i , $i = 1, 2, 3, \ldots$, respectively. The expected value and variance of *X* are respectively given by $E(X) = \lambda\mu$ and $V(X) = \lambda(\sigma^2 + \mu^2)$. The probability function (pf) of *X* in (1) is given by

$$p_X(k) = P(X = k) = \sum_{n=0}^{\infty} \exp(-\lambda)\frac{\lambda^n}{n!}\exp(-n\mu)\frac{(n\mu)^k}{k!}, \; k = 0, 1, \ldots \quad (2)$$

This formula needs long and tedious operations since some terms could be out of the machine range and set to zero (Martin and Katti, 1962). So, the probability generating function (pgf) of *X* in (3) can be used to obtain the pf of *X*:

$$g_X(s) = \exp[\lambda(\exp(\mu(s-1)) - 1], \; \lambda > 0 \quad (3)$$

Let define the parameters , Then, the pgf of X in (3) is also given by

$$g_X(s) = \exp[\lambda(\exp(-\mu) - 1]\exp(\lambda_1 s + \lambda_2 s^2 + \ldots) \quad (4)$$

Differentiating the pgf in (4) and substituting in $p_X(0) = g_X(0)$,

$$P(X = k) = \frac{\left.\frac{\partial^k}{\partial s^k} g_X(s)\right|_{s=0}}{k!}, \; k = 1, 2, \ldots,$$

after some algebraic manipulations, a general formula for the probabilities $p_X(k) = P(X = k)$, $k = 0, 1, \ldots$ is obtained by

$$p_X(0) = e^{\lambda(e^{-\mu}-1)},$$

$$p_X(1) = e^{\lambda(e^{-\mu}-1)}\frac{\lambda_1}{1!},$$

$$p_X(2) = e^{\lambda(e^{-\mu}-1)}\left[\frac{\lambda_1^2}{2!} + \frac{\lambda_2}{1!}\right],$$

$$p_X(3) = e^{\lambda(e^{-\mu}-1)}\left[\frac{\lambda_1^3}{3!} + \frac{\lambda_1\lambda_2}{1!1!} + \frac{\lambda_3}{1!}\right],$$

$$p_X(4) = e^{\lambda(e^{-\mu}-1)}\left[\frac{\lambda_1^4}{4!} + \frac{\lambda_1^2\lambda_2}{2!1!} + \frac{\lambda_1\lambda_3}{1!1!} + \frac{\lambda_2^2}{2!} + \frac{\lambda_4}{1!}\right], \quad (5)$$

$$\vdots$$

Similarly, moments of the NTA distribution are considered using the moment generating function (mgf) of X as

$$M_X(s) = \exp[\lambda(\mu-1)]\exp[\lambda_1\exp(s) + \lambda_2\exp(s^2) + \ldots] \quad (6)$$

where $\lambda_j = \lambda p_j$, $j = 0, 1, \ldots$

The rth general moment of the NTA distribution is obtained by differentiating (6) with respect to s and substituting in $\mu'_r = E(X^r) = \frac{d^r}{ds^r} M_X(s)\Big|_{s=0}$, $r = 1, 2, \ldots, n$. Let $\xi_r = E(Y^r)$, $r = 1, 2, \ldots, n$, be the *r*th general (non-central) moment of Y_i, $i = 1, 2, \ldots$ Since the moments of Y_i , $i = 1, 2, \ldots$, are $\xi_1 = \mu,$, $\xi_2 = \mu + \mu^2$, $\xi_3 = \mu + 3\mu^2 + \mu^3$, $\xi_4 = \mu + 7\mu^2 + 6\mu^3 + \mu^4$, the first four general moments of the NTA distribution are given by

$$\mu'_1 = (\lambda\xi_1),$$
$$\mu'_2 = (\lambda\xi_1)^2 + (\lambda\xi_2),$$
$$\mu'_3 = (\lambda\xi_1)^3 + 3(\lambda\xi_1)(\lambda\xi_2) + (\lambda\xi_3),$$
$$\mu'_4 = (\lambda\xi_1)^4 + 6(\lambda\xi_1)^2(\lambda\xi_2) + 4(\lambda\xi_3)(\lambda\xi_1) + 3(\lambda\xi_2)^2 + (\lambda\xi_4). \quad (7)$$

Let μ_r , $r = 1, 2, \ldots, n$, be the central moments of the NTA distribution. If the *r*th central moment exists, then, the generating function $G_X(s)$ of μ_r , is defined by the relation

$$G_X(s) = E[\exp(s(X - \lambda\mu))] = \exp(-s\lambda\mu)M_X(s), \quad (8)$$

where $\mu'_1 = E(X) = \lambda\xi_1 = \lambda\mu$. Then, *r*th central moment of X is obtained by

$$\mu_r = E(X - \lambda\mu)^r = \frac{d^r}{ds^r} G_X(0) = \frac{d^r}{ds^r}\exp(-s\lambda\mu)M_X(s)\Big|_{s=0}. \quad (9)$$

From (6) and (9), the first four central moments of X are obtained as

$$\mu_1 = 0,$$
$$\mu_2 = \lambda\xi_2,$$

$$\mu_3 = \lambda\xi_3,$$
$$\mu_4 = 3(\lambda\xi_2)^2 + \lambda\xi_4. \tag{10}$$

Similarly, let κ_r, $r = 1, 2, ..., n$, be cumulants of X. Then, cumulants of X are given by

$$\kappa_r = \lambda\xi_r \tag{11}$$

where $\xi_r = E(Y^r)$, $r = 1, 2, ..., n$, is the *r*th general moments of Y_i, $i = 1, 2, ...$

We now discuss the skewness and kurtosis of the NTA distribution. From (7), the skewness and kurtosis are given by, respectively,

$$\sqrt{\beta_1} = \frac{\xi_3}{\sqrt{\lambda}(\xi_2)^{3/2}} = \frac{\mu + 3\mu^2 + \mu^3}{\sqrt{\lambda}(\mu + \mu^2)}, \quad \beta_2 - 3 = \frac{\xi_4}{\lambda(\xi_2)^2} = \frac{\mu + 7\mu^2 + 6\mu^3 + \mu^4}{\lambda(\mu + \mu^2)^2}. \tag{12}$$

The mgf of N and X is defined as $M_{N,X}(u,v) = E[\exp(uN + vX)] = E[E(\exp(uN + vX) \mid N)]$ which leads us to the following result:

$$M_{N,X}(u,v) = E[\exp(uN + v\sum_{i=1}^{N} Y_i) \mid N = n) = E\left[\exp(uN)\left(\prod_{i=1}^{n} M_Y(v)\right)\right] = E\left[\exp(uN)M_Y^n(v)\right] \tag{13}$$

where $M_Y(v)$ is the mgf of Y_i, $i = 1, 2, 3, ...$ Since N is a Poisson distributed random variable, we get

$$M_{N,X}(u,v) = \exp(-\lambda)\sum_{k=0}^{\infty} \frac{[\lambda M_Y(v)\exp(u)]^k}{k!} = \exp[\lambda(M_Y(v)\exp(u) - 1)]. \tag{14}$$

In order to complete the derivation of the covariance of N and X, we need to evaluate

$$E(NX) = \left.\frac{\partial^2 M_{N,X}(u,v)}{\partial u \partial v}\right|_{u=v=0}$$

The derivative of $M_{N,X}(u,v)$ with respect to u is

$$\frac{\partial M_{N,X}(u,v)}{\partial u} = \lambda M_Y(v) M_{N,X}(u,v)$$

and the derivative of the latter with respect to v is

$$\frac{\partial^2 M_{N,X}(u,v)}{\partial u \partial v} = \lambda M_{N,X}(u,v) M'_Y(v)[M_Y(v)\lambda \exp(u)+1] .$$

It follows that

$$\left.\frac{\partial^2 M_{N,X}(u,v)}{\partial u \partial v}\right|_{u=v=0} = \lambda(\lambda+1)E(Y).$$

Therefore,

$$E(NX) = \lambda(\lambda+1)E(Y)$$

and the covariance of N and X is given by

$$\mathrm{Cov}(N,X) = \lambda E(Y) = \lambda \xi_1 .$$

Hence, the coefficient of correlation between N and X is given by

$$\rho = \mathrm{Corr}(N,X) = \frac{\mathrm{Cov}(N,X)}{\sqrt{\mathrm{Var}(N)\mathrm{Var}(X)}} = \frac{\xi_1}{\sqrt{\xi_2}} , \qquad (15)$$

where $\mathrm{Var}(N) = \lambda$ and $\mathrm{Var}(X) = \lambda E(Y^2) = \lambda \xi_2$.

3. Distributional Properties

Unimodal probability distribution is a distribution which has a single mode. Let $(p_x)_0^\infty$ be a distribution on the non-negative integers with pgf $g_X(s)$ satisfying

$$\frac{\partial}{\partial s} \ln g_X(s) = R(s) = \sum_{k=0}^{\infty} r_k s^k \text{ ,where } r_k \text{ is non-negative.}$$

Then, $(p_x)_0^\infty$ is unimodal if $(r_k)_0^\infty$ is non-increasing and $(p_x)_0^\infty$ is non-increasing if and only if $r_0 \le 1.$ From (6), R(s) can be written as

$$\frac{\partial}{\partial s} \ln g_X(s) = R(s) = \sum_{k=0}^{\infty} \frac{\mu\lambda e^{-\mu}\mu^k}{k!} s^k \text{ , where } r_k = \mu\lambda e^{-\mu}\mu^k / k! \text{ is non-negative.}$$

Therefore,

$$\frac{r_k}{r_{k-1}} = \frac{\mu}{k} \text{ and } \lim_{k\to\infty}(\mu/k) \to 0.$$

Hence $(r_k)_0^\infty$ is non-increasing, and so the NTA distribution is unimodal for all values of μ and λ. When $r_0 = \mu\lambda e^{-\mu} \le 1$, $(p_x)_0^\infty$ becomes non-increasing which means that the NTA distribution is unimodal for all values λ.

3.1 Derivation of survival function for NTA distribution

Survival analysis is dealing with deterioration and failure over time and involves the modelling of the elapsed time between an initiating event and a terminal event (Hintze 2006). The survival function is a property of any random variable that maps a set of events onto time. It captures the probability that the system will survive beyond a specified time. The survival function of a nonnegative discrete random variable X is defined as

$$S(x) = 1 - P(X \le x). \tag{16}$$

Using the definition $P(X \le x) = \sum_{n=0}^{\infty} P(X \le x \mid N = n)P(N = n)$, $x = 0,1,\ldots$, we have

$$P(X \le 0) = e^{\lambda(e^{-\mu}-1)}, \quad P(X \le x) = \sum_{n=0}^{\infty} \exp(-\lambda)\frac{\lambda^n}{n!}\sum_{k=0}^{x}\exp(-n\mu)\frac{(n\mu)^k}{k!} \tag{17}$$

From (16) and (17), the survival function of the NTA distribution is given by

$$S(0) = 1 - e^{\lambda(e^{-\mu}-1)}, \quad S(x) = 1 - \sum_{n=0}^{\infty} \exp(-\lambda)\frac{\lambda^n}{n!}\sum_{k=0}^{x}\exp(-n\mu)\frac{(n\mu)^k}{k!}, \ x = 1, 2, \ldots \tag{18}$$

Frailty models are often used to model heterogeneity in survival analysis. The distribution of the frailty is generally assumed to be continuous. In some circumstances, it is appropriate to consider discrete frailty distributions. Note that unlike the standard continuous frailty distribution, X allows a positive probability for the risk to be zero and shows the cumulative damage of failures or damages in a system. Survival function of the NTA distribution for the frailty model has not been studied yet. The unconditional survival function for a discrete frailty distribution can be written as

$$S(t) = \sum_{x=0}^{\infty} S(t \mid x)p_X(x) = E[S(t \mid X)] = M_X[S_0(t)], \tag{19}$$

where X is a discrete random variable with the probability function $P(X=x)=p_X(x)$. $M_X(s)$ is the mgf of X and $S_0(t)$ is the baseline survival function. From (19), the unconditional survival function can be written as

$$S(t)=E\{\exp[-X\Lambda(t)]\} = E\left(\sum_{x=0}^{\infty}\exp[-x\Lambda(t)]P(X=x)\right), \qquad (20)$$

where the baseline survival function $S_0(t)$ equals to $\exp[-\Lambda(t)]$. Here, $\Lambda(t)=\int_0^t \lambda(u)du$ is a cumulative hazard function. Then, the unconditional survival function with the NTA distribution is derived as

$$S(t)=\sum_{n=0}^{\infty}\sum_{x=0}^{\infty}\exp[-x\Lambda(t)]\exp(-n\mu)\frac{(n\mu)^x}{x!}\exp(-\lambda)\frac{\lambda^n}{n!}. \qquad (21)$$

From (21), we obtain

$$S(t)=\exp(-\lambda)\sum_{n=0}^{\infty}\exp(-n\mu)\frac{\lambda^n}{n!}\sum_{x=0}^{\infty}\frac{\left(n\mu\exp[-\Lambda(t)]\right)^x}{x!} = \exp\left[\lambda\left(\exp(\mu\{\exp[-\Lambda(t)]-1\})-1\right)\right], \quad (22)$$

where $\Lambda(t)=\int_0^t \lambda(u)du$ is a cumulative hazard function.

It is well known that entropy and information can be considered as measures of uncertainty of probability distribution. The entropy $H(X)$ of a discrete random variable X is defined by

$$H(X)=-\sum_{k=0}^{\infty}p_X(k)\log p_X(k).$$

For the NTA distribution, we have

$$\log p_X(k)=\sum_{n=0}^{\infty}\log\left[\exp(-\lambda)\frac{\lambda^n}{n!}\exp(-n\mu)\frac{(n\mu)^k}{k!}\right]=\sum_{n=0}^{\infty}\left(\frac{n\log\lambda}{n!}+\frac{k\log n\mu}{k!}-(\lambda+n\mu)\right) \qquad (23)$$

Then, the entropy function of the Neyman A distributed random variable X is given by

$$H(X)=-\sum_{k=0}^{\infty}\sum_{n=0}^{\infty}\frac{e^{-(\lambda+n\mu)}}{n!k!}\lambda^n(n\mu)^k\left[\frac{n\log\lambda}{n!}+\frac{k\log n\mu}{k!}-(\lambda+n\mu)\right]. \qquad (24)$$

4. Application on the Natural Disasters in Turkey.

In this study, natural disaster data of Turkey is derived from the EM-DAT International Disaster Database maintained by the Center for Research on Epidemiology of Disasters (CRED) in cooperation with the United States Office for Foreign Disaster Assistance (OFDA). The database defines a disaster as meeting at least one of the following criteria: 10 or more deaths, 2000 or more affected people, a government disaster declaration. Using this data, the number of disasters and casualties in Turkey by the natural disasters between the years 2000 and 2013 are presented in Fig. 1. As seen from Fig. 1, during the past ten years, the most of the casualties have been occurred in Van-Ercis earthquake in 2011. The number of disasters is very low between 2012 and 2013. Although the number of disasters is moderately high, the number of loses are very low from 2000 to 2001. The numbers of the casualties in Turkey by the natural disasters between 1990 and 2013 are presented in Fig. 2.

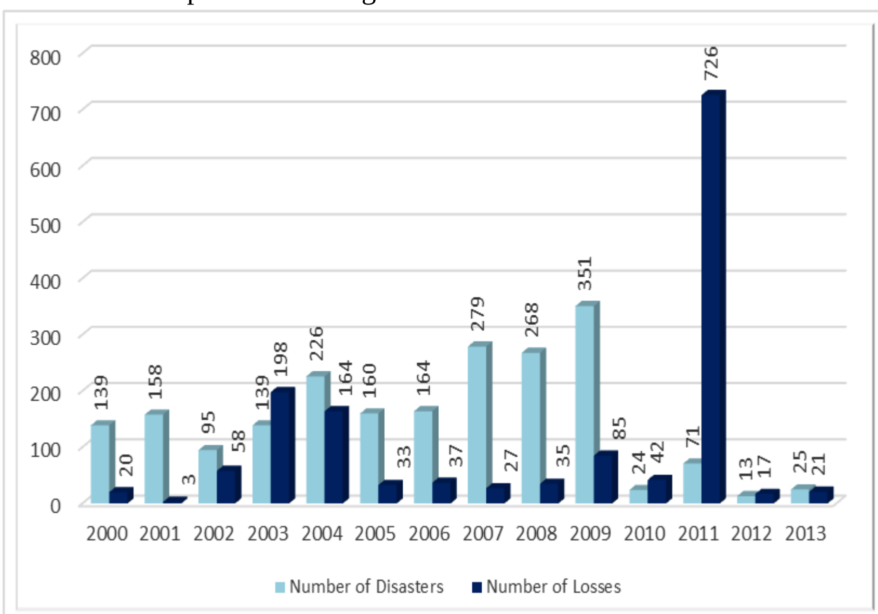

Figure 1: The number of disaster and casualties in Turkey reported between years 2000 and 2013

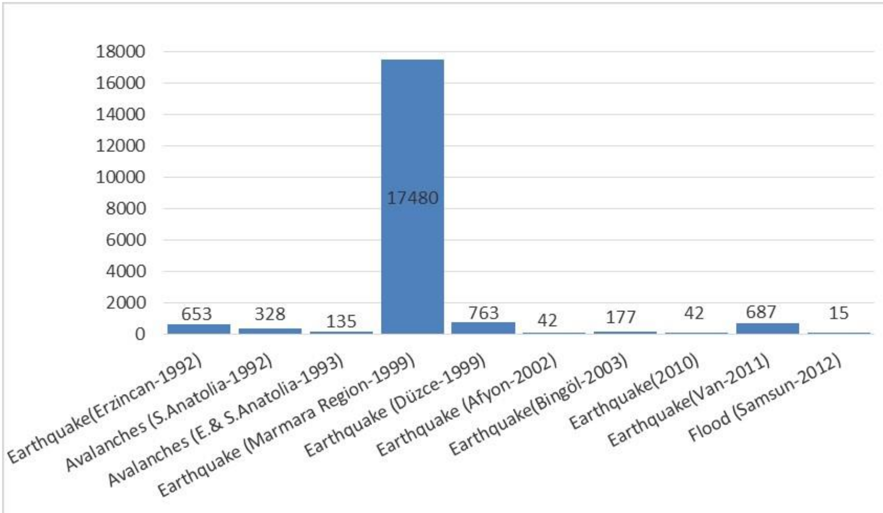

Figure 2: The numbers of the casualties in Turkey by the natural disaster between 1990 and 2013

As seen from Fig. 2, particularly, over the past two decades Turkey faced several moderate and large earthquakes that resulted in significant loss of life and property. The number of loses is very high as we compared earthquakes with other disasters. The most destructive earthquake was occurred in Marmara Region in 1999. The second and the third destructive earthquakes were occurred in Van in 2011 and in Erzincan in 1992, respectively. Final losses were recorded for floods in Samsun in 2012. The natural disasters and the casualties between years of the 1900 and 2013 in Turkey are presented in Table 1.

Table 1: Type of natural disasters and the number of people killed by natural disasters in Turkey during the period 1900-2013.

Event	Number of Disasters	Percent of Disasters	Number of Casualties	Percent of Losses
Earthquake	239	0.6	91959	98.30
Landslide	975	24.0	834	0.89
Flood	245	0.6	512	0.55
Avalanche	220	0.5	201	0.21
Rock Fall	308	0.8	26	0.03
Forest Fire	2082	51.0	20	0.02
Total	4069	100	93552	100

As seen from Table 1, Turkey is prone to mainly six types of natural disasters. Earthquake is the most dangerous natural disaster for Turkey among others. It is located in one of the most seismically active regions of the world. It lies within the Mediterranean sector of the Alpine-Himalayan orogenic system. The Alpine orogeny is produced due to the "compressional" motion between Europe and Africa, whereas the Himalayan orogeny has resulted from the India-Asia collision (JICA 2014). 66% of the surface area of Turkey lies on Zones 1 and 2 levels of seismic hazard, and the fraction of the population living in these risk areas is 7% (Turkan and Ozel 2014). In Turkey, the most of earthquakes happen on the North Anatolian Fault Zone (NAFZ) which can damage to many constructions (Sengor et al. 1985). It is an active right-lateral system about 1500 km long which bounds to the North Anatolian block (Ozel 2011). It represents a transform margin that mainly follows a pre-existing zone of crustal weakness: a suture zone inherited from an earlier collisional phase (Batuk 2005).

Landslides are significant natural hazards in Turkey. 25% of country area is exposed to landslide hazard and 11% of total population is located in landslide areas. From 1955 to 2007, landslides affected 4500 settlements and killed 200 people and 65000 dwelling units were relocated to safer places in this period. Landslides frequently affect inner Anatolia, eastern Anatolia and particularly the Black Sea regions in Turkey. The West Black Sea region of Turkey is known as one of the most landslide-prone regions in the country (Ercanoglu and Gokceoglu 2002). Table 1 shows that 24% of total disaster casualties are due to landslides.

Flooding is a serious natural disaster in Turkey similar to rest of the world causing significant economical damage and loss of lives every year. Table 1 shows that in Turkey, after the landslides, flooding is the third important natural disaster in terms of life losses and economical damage. Flood events can be predicted and modeled so the damage due to the flood can be prevented or minimized through a proper planning. On the other hand, detailed flood modeling and mapping are not common in Turkey and general specifications document for the flood studies is not available.

Avalanches are also seen in Turkey. Although they are not as much as in the other countries, they cause loss of life and property with great damages. Snow avalanches affecting the highways and settlements directly in Turkey are mostly seen in Eastern Anatolian Region, Black-Sea Region and in the upper Kizilirmak section of Central Anatolia Region. The snow-fall here is between the months of October and May and the snow cover stays on the ground more than 40 days in a year, and the snow thickness is around 20-22 cm in many places.

Large fires are a dominant disturbance in boreal ecosystems and exert significant effects on carbon cycling, vegetation dynamics, and the climate system. Turkey is located in Mediterranean climate region. The forests located at the coastal band areas are under severe risks of fire threats. The average annual number of forest fires and burned forest areas are 1096 and 23477 hectares, respectively.

Rock fall in this study refers to the movement of loosened rock blocks on steep slopes under the effect of gravity by free fall, rolling down the slope, and/or bouncing (Keskin 2013). The rock fall causes loss of life and property because of its very rapid movement (Topal et al. 2012). As seen from Table 1, although rock fall has smaller volumes, it has destructive effects. It is one of the major hazards cuts for highways and railways in Turkey.

We both aggregate all disaster types and separately analyze them during the years 1900-2013. For the construction of a model to explain the total number of the natural disasters using the NTA distribution, the following random variables are defined: N is the number of natural disasters that occurred in Turkey between 1900 and 2013; is the number of the casualties of ith disaster; and

X is the total number of the casualties. If the following conditions hold, X has the NTA distribution:

Condition 1: *Fit of the Poisson distribution to the natural disasters:* The Kolmogorov-Smirnov (K-S) goodness of fit test is performed to compare the observed frequency distribution with the theoretical Poisson distribution. The results are presented in Table 2.

It means that the expected number of natural disasters approximately equals to 64 per year. The results in Table 2 also suggest that three earthquakes, fifteen landslides, five floods, six rock falls, six avalanches, and twenty nine forest fires are approximately expected for a year in Turkey.

Condition 2: *Fit of the Poisson distribution to the number of casualties:* After obtaining K-S test results in Table 2, it is seen that the numbers of casualties Y_i, $i = 1, 2, \ldots$, has a Poisson distribution with parameter at the level of 0.05. The results in Table 2 indicate that the expected number of casualties equals to 1451 per year. Table 2 also shows that approximately 1121 people in earthquakes; fourteen people in landslides; ten people in floods; two people in rock falls; six people in avalanches and one person in forest fires are expected to die in Turkey for a year.

Since all conditions are hold, now it can be written as $X = \sum_{i=1}^{N} Y_i$ and suggested that X has the NTA distribution. The probabilities $P(X = k)$, $k = 0, 1, \ldots$, are computed from (5) and presented in Fig. 3.

Table 2: Kolmogorov-Smirnov goodness of fit test results.

Type	λ	K-S statistics	p-value	μ	K-S statistics	p-value
Earthquake	2.91	0.212	0.006	1121.5	0.829	0.044
Landslide	15.98	0.129	0.001	13.67	0.867	0.046
Flood	4.80	0.255	0.008	10.04	0.755	0.035
Avalanche	6.47	0.474	0.013	5.91	0.211	0.006
Rock Fall	6.04	0.264	0.009	1.91	0.600	0.025
Forest Fire	29.28	0.465	0.012	0.98	0.685	0.026
Total	63.92	0.699	0.025	1451	0.794	0.042

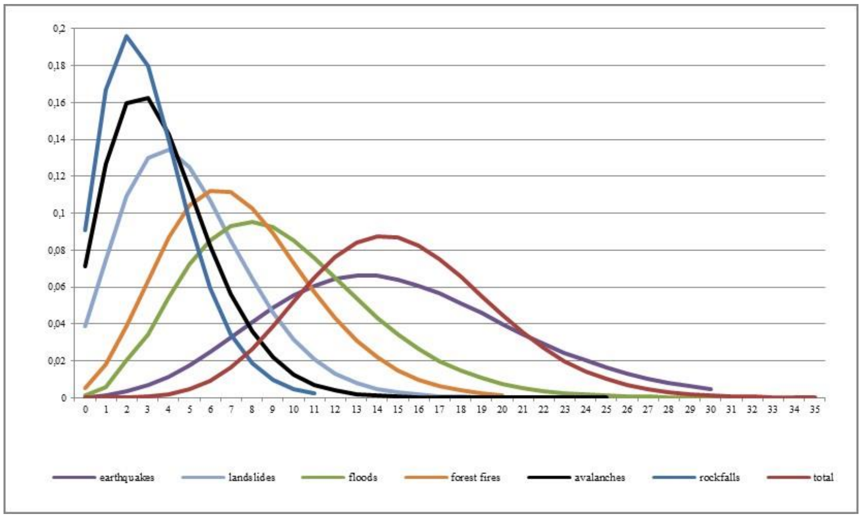

Figure 3: The NTA distributions of the total number of casualties for natural disasters.

Fig. 3 shows that the NTA distribution is unimodal for all values of λ related with the natural hazards. It can be concluded from Fig. 3 that the probability of the total number of casualties is the highest for the earthquakes and the smallest for the rock falls in Turkey. The probability of 14 casualties is the highest for the earthquakes whereas the probability of 6 casualties is the highest for the forest fires in Turkey.

The non-central, central moments, and cumulants of the NTA distribution are computed from (9), (10), and (11) respectively. The results are presented in Table 3. It is found that approximately 28,828 people die in all natural disasters every year in Turkey. The majority of deaths is caused by earthquakes. On average, 3269 people die because of the earthquakes in Turkey.

The coefficient of correlation between N and X is calculated and presented in Table 3. The value for the coefficient of correlation between N and X is found as $\rho = 0.99$ when all disasters are aggregated. This finding indicates that the number of the natural disasters is highly correlated with the number of casualties in Turkey. Table 3 also shows that the numbers of the rock falls and forest fires are not highly correlated with the number of casualties.

Table 3: Moments, correlation, skewness and kurtosis by types of natural disasters in Turkey during the period 1900-2013.

Event	Central Moments		Non-Central Moments		Kumulants		Corr (N, X)	Skewness	Kurtosis
Earthquake	μ_1	0	μ_1'	3268.724	κ_1	3263.56	0.99	658.087	0.344
	μ_2	3669143	μ_2'	14353699	κ_2	3663352			
	μ_3	$4.12\text{x}10^9$	μ_3'	$7.50\ \text{x}10^{10}$	κ_3	4115772385			
	μ_4	$4.50\text{x}10^{13}$	μ_4'	$4.48\ \text{x}10^{14}$	κ_4				
Landslide	μ_1	0	μ_1'	218.533	κ_1	218.45	0.97	3.903	0.08
	μ_2	3206.32	μ_2'	50963.1	κ_2	3204.61			
	μ_3	50030.91	μ_3'	12588538	κ_3	49997.82			
	μ_4	31666175	μ_4'	$3{,}27\ \text{x}10^9$	κ_4	824068.23			
Flood	μ_1	0	μ_1'	48.226	κ_1	48.19	0.95	5.451	0.287
	μ_2	532.371	μ_2'	2858.152	κ_2	532.04			
	μ_3	6360.985	μ_3'	195547.8	κ_3	6357.57			
	μ_4	931647.7	μ_4'	14997040	κ_4	81354.73			
Rock Fall	μ_1	0	μ_1'	3.079	κ_1	3.08	0.58	0.752	0.892
	μ_2	4.648	μ_2'	14.127	κ_2	4.65			
	μ_3	8.588	μ_3'	80.705	κ_3	8.59			
	μ_4	84.096	μ_4'	544.072	κ_4	19.29			
Avalanche	μ_1	0	μ_1'	38.252	κ_1	38.24	0.92	3.053	0.251
	μ_2	264.396	μ_2'	1727.68	κ_2	264.22			
	μ_3	2053.598	μ_3'	88370.21	κ_3	2051.76			
	μ_4	227262.6	μ_4'	5004008	κ_4	17526.77			
Forest Fire	μ_1	0	μ_1'	14.824	κ_1	14.93	0.52	0.263	0.162
	μ_2	20.418	μ_2'	240.164	κ_2	20.60			
	μ_3	33.717	μ_3'	4199.203	κ_3	34.10			
	μ_4	1318.097	μ_4'	78525.97	κ_4	68.38			
Total	μ_1	0	μ_1'	28828,37	κ_1	28827.92	0.99	56.65	0.016
	μ_2	13030424	μ_2'	$8.44\ \text{x}10^8$	κ_2	13030220			
	μ_3	$5.90\ \text{x}10^9$	μ_3'	$2.51\ \text{x}10^{13}$	κ_3	5902660760			
	μ_4	$5.12\text{x}10^{14}$	μ_4'	$7.57\ \text{x}10^{17}$	κ_4	$2.68\text{x}10^{12}$			

The effects of parameters and are also shown by examining the skewness and kurtosis of the NTA distribution. These values are computed from (12) and the results are presented in Table 3. Note that a symmetrical distribution has a skewness of zero. An asymmetrical distribution with a long tail to the right (higher values) has a positive skew and it has a negative skew with a long tail to the left. As seen from Table 3, the NTA distribution is an asymmetrical distribution with a long tail to the right due to positive skewness values and more peaked than a Gaussian distribution. Since the values of skewness for all disaster types are greater than zero, it can be said that most values are concentrated on left of the mean, with extreme values to the right. Hence, the graphs of the NTA distributions in Fig. 3 are flatter than a Gaussian distribution with a wider peak. The probability for extreme values is less than for a Gaussian distribution, and the values are wider spread around the mean. Asymmetrical forms of the NTA distribution are also seen from Fig. 3. Survival functions of the NTA distribution are computed from (17) and (22), respectively. Then, the survival curves are shown in Fig. 4. In this study, the survival function represents the probability that the total casualty number is longer than some specified casualty number.

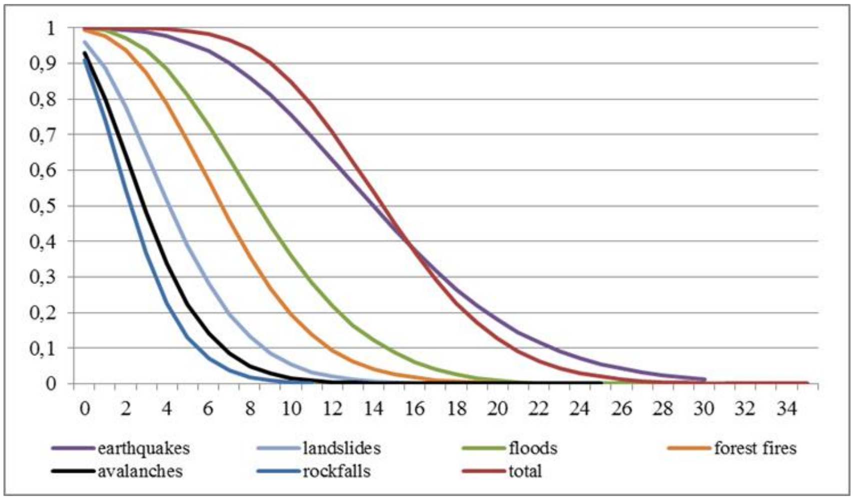

Figure 4: The survival curves of NTA distribution for natural disasters.

The expected recurrence time (year or month) for the natural disasters is estimated using the formula (Expected recurrence year or month = 1/Expected disaster frequency for a year or month) and the results are presented in Table 4.

Table 4: Expected recurrence time of natural disasters in Turkey

Event	Expected recurrence time (year)	Expected recurrence time (month)	Expected recurrence time (day)
Earthquake	0.344	4.128	123.840
Landslide	0.063	0.756	22.680
Flood	0.208	2.496	74.880
Rock Fall	0.166	1.992	59.760
Avalanche	0.155	1.860	55.800
Forest Fire	0.025	0.300	9
Total	0.016	0.192	5.760

As seen from Table 4, inter-event time between two successive earthquakes is approximately four months. The inter-event time of the natural disasters is approximately six days in Turkey.

From (24), the entropy value for the total casualty number is computed as 24.2. The higher value of entropy indicates the greater disorder for the total casualty number.

5. Conclusion

Natural disasters can be defined as temporary events triggered by natural hazards that overwhelm local response capacity and seriously affect the social and economic development of a region. In Turkey, natural disasters, causing serious disruption of normal daily life and causing widespread human, material or environmental losses that exceed the ability of the affected populations. In general, the country is subjected to earthquakes, floods, landslides, avalanches and forest fires, with earthquakes having by far the greatest impact on population and infrastructure.

There has been an increasing interest in understanding the dynamics of a natural disaster using several statistical distributions to determine the human losses. For this reason, a NTA model is proposed in order to gain a good picture of the natural disasters and casualties that occurred in Turkey. Since the number of disasters is described by the Poisson distribution, the resulting distribution of total numbers of casualties is the NTA distribution. We first introduce some characteristics of the NTA distribution such as moments, skewness, kurtosis, and the coefficient of correlation. Then, we obtain survival function of the NTA distribution. We have analyzed Turkish disaster data for the period of 1900-2013 derived from the EM-DAT International Disaster Database. We find that the expected numbers of natural disasters and casualties are 64 and 1451 per year, respectively. The results also show that three earthquakes, fifteen landslides, five floods, six rock falls, six avalanches, and twenty five forest fires are approximately expected for a year. In these disasters, approximately 1121 people in earthquakes; fourteen people in landslides; ten people in floods, two people in rock falls; six people in avalanches and one person in forest fires died. The NTA distribution also suggests that the probability of the total number of casualties is high for the earthquakes and low for the rock falls in Turkey. We also find that the natural disasters are highly correlated with the number of casualties in Turkey and that inter-event time between two successive earthquakes is approximately four months. The inter-event time for the natural hazards is approximately six days in Turkey. The NTA distribution gives us a useful tool for determining the total number of disaster and casualties.

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Gamze Ozel
Department of Statistics
Hacettepe University
Beytepe 06800, Ankara, Turkey.

Semra Turkan
Departmet of Statistics
Hacettepe University
Beytepe 06800, Ankara, Turkey