QUANTIFYING THREATS ALONG TOURIST TRAILS: AN INITIAL APPROACH.

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ABSTRACT:
The current information society permits but also forces new techniques in hazard calculus. Outdoor activities, hiking became has increasing popularity. The tourist of our days also wants to know as much as possible regarding the trail what he will go to. Current information regarding these trails doesn't contain a hazard along the trails. In our research will started to develop a methodology to can assess hazard levels to each tourist trails identifying the threat sources and categories and developing quantitative methods for calculating it.

Key-words: *tourist trails, hazard, threat, R system, quantitative analysis, algorithm development*

1. INTRODUCTION

In recent years, in tourism development in Harghita county a prominent role was to secure mountain tourism. To achieve this, - in addition to the instrument development - one of the first steps was re-trace of the existing hiking trails by the local mountain rescue associations influence. After that quantitative parameters of the trails were calculated using a unified methodology. The quantitative values were the trail length, hiking time, minimum, maximum altitude, maximum altitude difference, burned calories. From the mountain rescue team we obtained data about the seasonality and viability of these trails in different seasons, and if they are easy or hard to go through.

However, to determine and indicate the degree of hazard of hiking trails also can be very important and needs a common method to determine. At present, tourists can find information about the difficulty of the trail, but this characteristic to doesn't take into account external factors juts the parameters of the route. In my view, it would be useful to provide information to tourist regarding, how dangerous is the route to take and where he can expect different types of hazards along the path.

The aim of this research is to try to develop a starting point for a unified methodology for classifying the tourist trails hazardous category by evaluating each hazard category along the trail's sections.

2. METHODOLOGY

The scientific literature is poor in scientific research, which would apply to the hazards of hiking trails (Tropan, Moldovan, 2013). However, there are numerous (especially on the Internet) sources which lists the risks of hiking and outdoors, and GIS proved to be an important tool in tourist related activities (Stankov et al., 2012) Based on these sources, which are mostly mountain rescue organizations or authorities of conservation areas, national parks, the existing threads can be determined and can be observed their categorization (Brandolini et al., 2006). In summary, the threats that appear on these sites, can be grouped as follows:

- based on the parameters of the path
- based on the tourist/hikers characteristics

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- based on the characteristics of the environment

The listed hazard categories will represent a real hazard through their interaction. Thus, for example the length of the trail will represent a true a hazard correlated with the health and fitness of a person. Of course, this also means that in some ways the hazard category of a trail depends on person characteristics. In our research, the development of a standard methodology was not intended to take account of these individual characteristics, so this type of interaction has not been included in the analysis.

The parameters of the trail which can indicate hazard, and which indirectly help to evaluate the hazard category of the trail are the hiking time and the length of extreme slopes.

The characteristics of the environment can be divided into several sub-categories, natural phenomenon plays an important role as the availability of help or the presence or absence of wildlife. Analyzing the sub-categories, we have observed that some of the natural phenomenon vary slowly like the slump or collapse. Others like storm, heavy rain or wind can rapidly change and that’s why static, forward modelling is not possible for them. For these dynamic phenomenon modelling, however, it is not necessary to use meteorological forecasts, it cannot be done in Harghita county, as the region has no local or zonal meteorological forecasts. In such situations, the systematic observations along the hiking trails can provide a great help to determine the likelihood of appearance of the phenomenon. This statement applies equally to the spatial spread of wildlife hazards as well, in this case an actualized observation database may help.

Based on the above-mentioned ideas the following hazardous elements can be taken into account:

- estimated hiking time
- the length of extreme slopes
- surrounding extreme slopes along the trail positions
- rain, fog, wind, storms presence
- presence of wild animals
- mobile service coverage along the route

On this basis, we believe that the definition of hazard category is not based only on a preliminary static analysis, but after the determination of certain basic values, using a well-defined methodology, in fact is a dynamic assessment. This assessment needs a well-defined evaluation system in which each input data from the users themselves, the hikers should be integrated.

3. DATA AND ALGORITHMS

In our view the hazard categories attached to the trails should not be too detailed, it should follow the following rating categories: safe, low-hazard level, moderate hazard level and high hazard levels. For numerical evaluation of these we used the 0-3 closed interval divided in sub-intervals with the following meanings:

- safe: [0.0-0.5]
- low hazard (0.5-1.5]
- moderate hazard (1.5-2.5]
- high hazard (2.5-3]

For each hazard categories mentioned this evaluation criteria was used. For assessing a single value to the whole trail the average of the obtained hazard values was determined.

As follows, we present the hazard assessment for every hazardous elements mentioned before, together with their calculation methodology and necessary data. The described methodology is completed with the calculation function developed in R analysis software (Teetor, 2011).

a) ***Hiking time.*** As these trails are marked and partially arranged this factor should not touch the high hazard level. For calculation of the hiking time the Naismith-Langmuir rule was applied completed with Tranter correction using fourth fitness category (Naismith 1892, Langmuir, 1984). The necessary data is the 3D geometry of the trail. The rating bounds are the following (Tranter time [min] – associated hazard value): 0 – 0 / 300 – 1.5 / 870 – 2.5 / too much to attempt – 3.0

```
Naismith.time<-function(l,coord=TRUE,type="langmuir",
                  corrected=TRUE,fc=3,experience=NA,agecat=NA,fittime=NA)
{
  n=length(l[[1]])
  if (coord==TRUE)
  { dx=sqrt((l$X[2:n]-l$X[1:(n-1)])^2+(l$Y[2:n]-l$Y[1:(n-1)])^2) }
  else { dx=l$X[2:n]-l$X[1:(n-1)] }
  dz=l$Z[2:n]-l$Z[1:(n-1)]
  z=sum(dz*(dz>0))
  ll=sum(dx)
  if (type=="base")
  { time=ll*60/5000+z*60/600 }
  else
   if (type=="langmuir")
   {
    s=100*dz/dx
    gs=abs(sum(dz*((s<(-11.1))&(s>(-26.6)))))
    es=abs(sum(dz*(s<=(-26.6))))
    time=sum(dx)*60/4000+z*60/600-gs*10/300+es*10/300
   }
  if(corrected==TRUE) time=Tranter(time,fc,experience,agecat,fittime)
  return(time)
}
```

Fig. 1 – R function for calculating hiking time based on Naismith rule

For determining the estimated hiking time, we developed an R function (fig. 1), which parameters are: a list of three vectors representing the X, Y, and Z coordinates, the possibility to choose between base or Langmuir versions. It's also possible to apply Tranter correction for which the person's fitness class can be specified (Magyari-Saska, Dombay, 2012).

The returned time is expressed in minutes or a -1 value is returned if the Tranter correction calculates a time value which is too much to attempt for a person.

```
shp.getTime<-function(name_in)
{
  t=c();
```

```
  s=read.shp(name_in);
  n=length(s[1]$shp);

  for (i in 1:n)
    {
      l=list(X=s[1]$shp[[i]]$points$X,Y=s[1]$shp[[i]]$points$Y,
             Z=s[1]$shp[[i]]$points$Z);
      t[i]=Naismith.time(l,fc=4)
   }
  return(t);
}
```

Fig. 2 – R function calculating hiking time for all trails from an ESRI shape file

For easy usage we also created a function (fig. 2) which reads all lines form an ESRI shapefile, construct the necessary list structure and invoke the time calculation function. The resulted values are put in a list which is the final return value. As described before the rescaling of the calculated values to 0-3 interval is also has been made automatically by a proper function

b) ***Extreme slopes length.*** This component is based on the length of the steep slopes, as follows. The length extreme slope from 50 degrees were calculated based on the hiking trails 3D geometry. Tens slope length intervals were used, it's arithmetic means square were multiplied with the obtained length, and the value thus obtained were rescaled on the 0-3 interval as follows (calculated value – associated hazard value): 0 – 0 / 10 000 – 1.5 / 150 000 – 2.5 / over 1500000 – 3.0

```
slopeCat<-function(l,coord=TRUE,mi,ma)
{
  n=length(l[[1]])
  if (coord==TRUE)
  {
    dx=sqrt((l$X[2:n]-l$X[1:(n-1)])^2+(l$Y[2:n]-l$Y[1:(n-1)])^2)
  }
  else dx=l$x
  dz=l$Z[2:n]-l$Z[1:(n-1)]
  slp=abs(dz*100/dx*45/100)
  poz=which(slp>=mi&slp<=ma)
  s=sum(dx[poz])
  return(s);
}
```

Fig. 3 – R function calculating the length of trail segment between given slope values

The extreme slope calculation function (fig. 3) is a general function which admits the slope limits between which the length is calculated. Similarly as for the hiking time calculus, we also developed an auxiliary function (fig. 4) to automatize the process reading ad processing all line features from a shapefile. The considered extreme slope categories are from 50 to 90 degrees with a step of 10.

```
shp.getSlope<-function(name_in)
{
```

```
  s=read.shp(name_in);
  n=length(s[1]$shp);
  t=rep(0,n);
  for (i in 1:n)
  {   l=list(X=s[1]$shp[[i]]$points$X,Y=s[1]$shp[[i]]$points$Y,
      Z=s[1]$shp[[i]]$points$Z);
    for (j in 5:8)
     {
       t[i]=t[i]+slopeCat(l,mi=j*10,ma=(j+1)*10)*(j*10+5)^2;
     }
  }
  return(t);
}
```

Fig. 4 – R function calculating hiking time for all trails from an ESRI shape file

c) ***Surrounding extreme slopes.*** Extreme slopes are considered over 60 degrees. For the calculation the trails 2D geometry and the DEM of the region is needed. For each point the extreme off road slope value is calculated, and its value is summed if reach over 60 degrees. The conversion to hazard values is as follows (calculated value – hazard value): 0 – 0 / 300 – 1.5 / 800 – 2.5 / over 1500 – 3

```
perpSlope<-function(l,demname)
{
  mycalculus=function(x)
  {
    if (x[5]<0)
    {
      y=x[-(which(x<0))]
      return ((((-1)*x[5]-min(y))*100)/r)
    }
    else return(0)
  }
  dem=raster(demname)
  prj=CRS("+init=epsg:31700")
  projection(dem)=prj
  trackPart=extent(min(l$X)-200,max(l$X)+200,min(l$Y)-200,max(l$Y)+200);
  dempart=crop(dem,trackPart);
  xy=cbind(l$X,l$Y)
  dm=rasterize(xy,dempart,-1,background=1)
  r=res(dm)[1]
  dm2=dm*dempart;
  dm3=focal(dm2,w=matrix(c(1,1,1,1,1,1,1,1,1),nrow=3),fun=mycalculus)
  return(sum(dm3@data@values>70,na.rm=TRUE)*r)
}
```

Fig. 5 – R function calculating surrounding extreme slopes

Calculating the highest slope which surrounds every position of a trail (fig. 5), needs in addition to the trail location the digital elevation model of the region. In our function to get an efficient calculus time, after attaching the Stereo70 projection system, we cropped the DEM to the surrounding rectangle of the trail. The next step is the rasterization of the trail on a new layer with a background value of 1, and -1 for trail positions. By multiplying the newly created raster with the original DEM, we can regain all the height values, which is very important at the third step. To achieve a fair computation time a sliding window technique was applied. Having negative values on trail position we can easily identify them and determine the highest height difference between current and surrounding off trail positions. The returned value of the function is the total length of position which has at least 70 degrees surrounding slopes. The length calculation is based on the raster resolution. To have an easy calculation a new function (fig. 6) process all lines from a give shapefile.

```
shp.getPSlope<-function(name_in,dem_name)
{
  t=c();
  s=read.shp(name_in);
  n=length(s[1]$shp);
  for (i in 1:n)
   {
     l=list(X=s[1]$shp[[i]]$points$X,Y=s[1]$shp[[i]]$points$Y,
            Z=s[1]$shp[[i]]$points$Z);
     t[i]=perpSlope(l,dem_name)
   }
  return (t);
}
```

Fig. 6 – R function calculating surrounding extreme slopes for every line in a shapefile

d) ***The presence of rain, wind, fog and wild animals.*** Although these represents different types of threats their data handling follows the same principle, namely the observation. The threats represented by these factors can be assessed and updated periodically based on the observed data by tourists. The assessment procedure should take into account both situations if a hiker encountered one of these hazard types or not. Considering the wild animals habitat and the observer extent of the phenomenon the threat represented by them can be spatialized and so the dangerous trail sections can be identified. The hazard evaluation for the entire trail is based on the empirical probability of a discrete probability distribution function. The applicability of the method, however, needs at least 15 to 20 years of observed data. The evaluation should be done separately for natural phenomena and the occurrence of wild animals. Hazard factor for the entire day hiking trip to the back divided on the basis of probability reaching and surpassing value of 1 for the following (calculated value - hazard value: 0-0 / 0.05-1.5 / 0.1-2.5 /> 0.1-3

e) ***Mobile service coverage along the hiking trail.*** Hazard ratings for GSM service coverage as an extremely important factor, as with any dangerous situation the possibility of getting help means very much. This is true even if other hazard factors are not present along the trail, as a sprained ankle due to a bad step can rise major threat on time. Of course it is more dangerous, in case on any other threats and there are no possibility to call emergency services. For calculating the hazard caused by this factor we need the 2D geometry of the trail, the mobile services coverage maps, and the locations of threads discussed at b) to d) along the trail. In the hazard evaluation procedure the mobile service coverage appears as an enhancing factor. For those sections which has no GSM signal coverage the originally calculated value originally will be doubled. For evaluating the hazard represented just by the lack of GSM signal we calculated the percentage of signal lack along the trail and the resulted value is classified as follows (percentage – hazard value: 0 – 0 / 50 – 1.5 / 85 – 2.5 / 100 – 3.

The last two factors could are not considered in the present paper as the necessary data are not available yet.

4. RESULTS AND DISCUSSION

The described methodology was applied onto 55 tourist trails in Harghita county, covering the four regions of the county: Ciuc, Odorhei, Gheorgheni and Toplita.

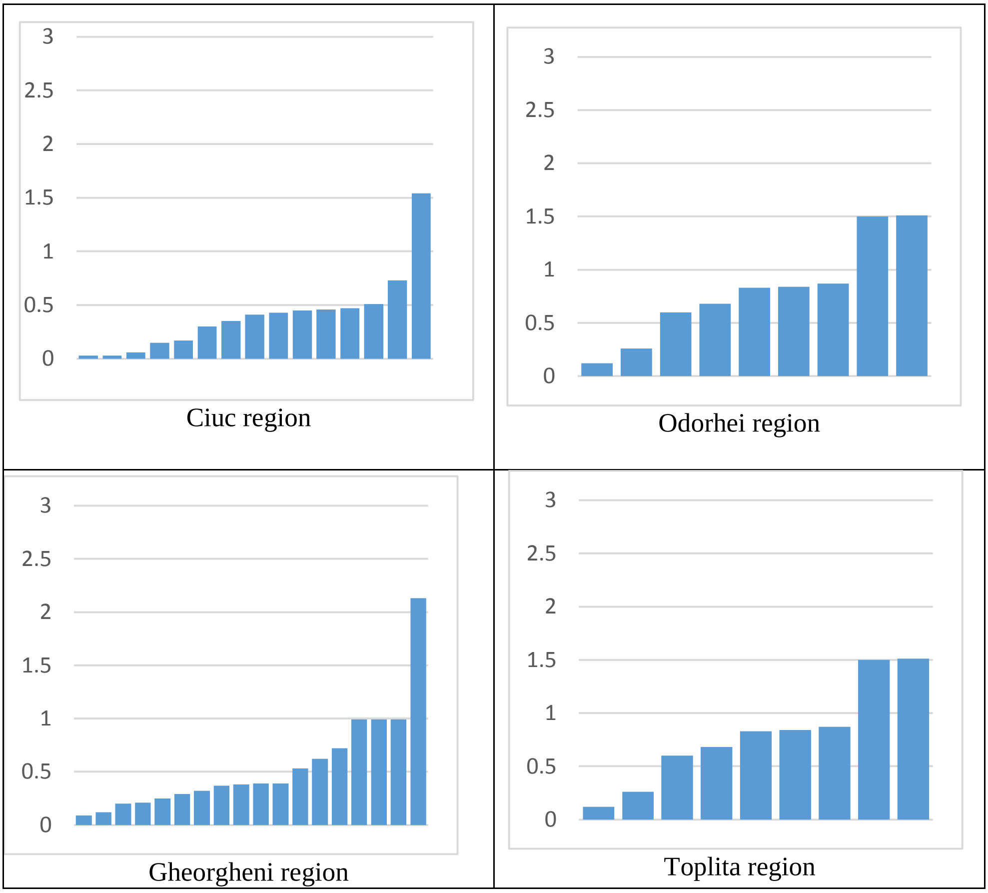

Fig. 7 – Hazard values for tourist trails based on trails length

The hazard factor represented by the trails length indicates that majority of the tourist trails indicates a low hazard value. Only on trail in Gheorgheni region has a moderate hazard classification (fig. 7). Looking at the mean values Ciuc and Toplita region has the highest values. We have to mention that averaging these values doesn't reflect the reality as not all trails data are available at this moment, because the remarking and data analysis is an ongoing process.

Regarding the extreme on trail slopes situation there was just a single trail which received moderate hazard category, the all others has no slopes over 50 degrees. The defined R analysis function emphasizes the hazardous portion (fig. 8)

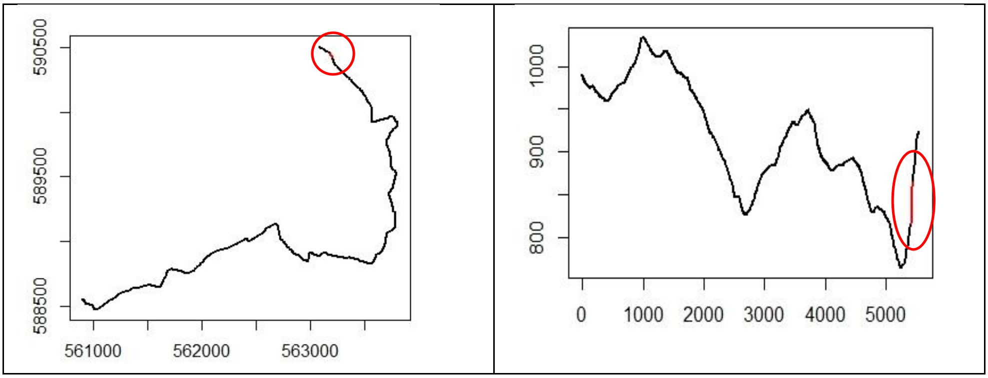

Fig. 8 – On trail extreme slopes location

Regarding the off slope hazard the only region where all the trails has zero hazard value is Odorhei. The Gheorgheni region is the most affected, 73% of the trails contains off trails extreme slope. This value is 40% for Ciuc and 30% for Toplita region. The R system also offers the possibility to plot the obtained rasters (fig. 9), which helps to identify the dangerous portions along the trails.

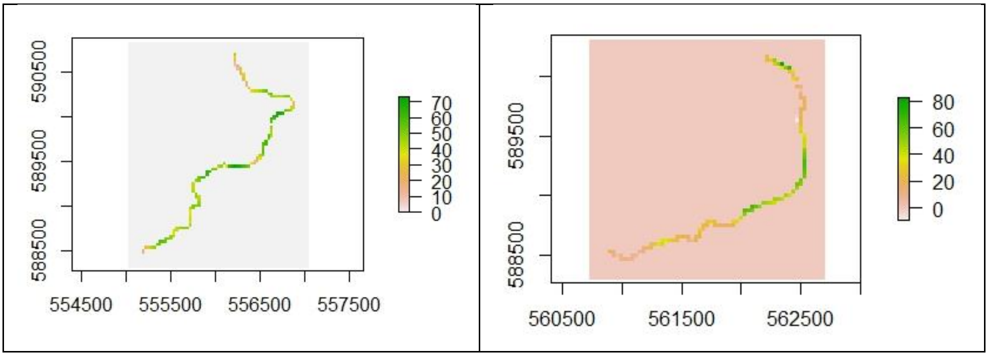

Fig. 9 – Off trail extreme slopes location

We also tried to make a ranking of tourist trails based on our classification system. Using mean values on regions the Gheorgheni region is the most affected, followed by Toplita and then Ciuc and Odorhei region. This can be observed from figure 10, where the most hazardous trails are from Gheorgheni region. We also can observe, that there are two different trends on the chart, showing that about 1/3 of trails has a considerably higher hazard value, than the other 2/3.

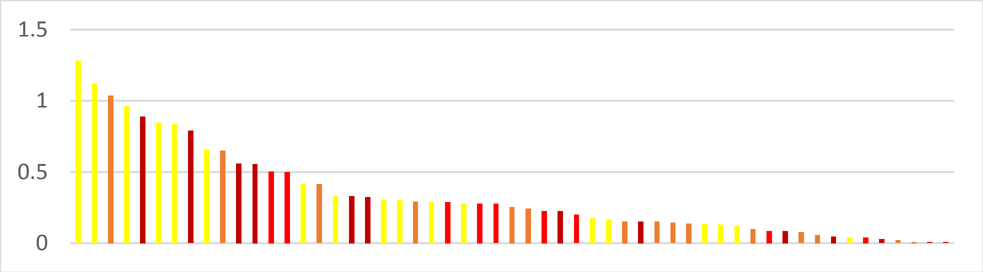

Fig. 10 – Mean hazard values of tracks
(yellow – Gheorgheni, orange – Ciuc, red – Odorhei, dark red – Toplita)

5. CONCLUSIONS

With this research we tried to make the first step in quantifying threats along tourist trails. So far topographical factors were included in the analysis using R multidisciplinary analysis software, developing functions for each considered factors. We observed that R system has a great potential as it can perform efficiently both statistical and GIS operations, handling multiple data formats. These possibilities are present due to the fact that it is a free and freely extensible system.

There is a possibility to evaluate the hazard level of tourist trails even if it has a statically computable and also a dynamically component. Field observations are indispensable to offer actualized information for tourist. Next steps of the research will be to publish an online platform on which tourists can mark their observations for trails offering by this way a starting point for dynamic hazard calculus.

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