BABEȘ-BOLYAI UNIVERSITY
FACULTY OF GEOGRAPHY
DOCTORAL SCHOOL OF GEOGRAPHY

PHD THESIS

USE OF REMOTE SENSING APPLICATIONS IN DETECTING AND ANALYSIS OF WINDTHROW IN THE APUSENI MOUNTAINS AREA

Scientific coordinator:
Prof. Univ.Dr. IRIMUS Ioan-Aurel

Candidate:
FURTUNĂ (DUMA) Paula-Roxana

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SUMARY

The presence of forests has been known since man made his presence felt on the surface of the earth. The role and importance of forests have been recognized since the beginning, but their importance has been perceived differently over time, in close dependence on socio-economic development. Occupying most of the land area, these forests have lost continuously, but at different rates, from the spatial distribution. Of all the terrestrial ecosystems, the forest achieves the most imposing and greatest aspect. Forests are an extremely important natural resource that can be managed sustainably given the structural and functional complexity, determined by the populations of trees, shrubs, herbaceous plants, animals and decomposers that make it up.

The increasing frequency of windthrow in the Apuseni Mountains and the intensification of extreme weather events leading to their production were a motivation in carrying out this study. From the beginning of this paper, in 2013, there were more and more meteorological phenomena that caused significant damage, throughout Romania, not only in the area studied. Their effects are primarily related to the pressure exerted by the wind on the trees and the amount of precipitation that fell during the meteorological phenomenon.

The main motivation of this work is given primarily by the desire to deepen the issue of wind blows in Romania and in the Apuseni Mountains.

The purpose of this study is to use spatial analysis methods (GIS and remote sensing) in order to detect and evaluate windthrow in the Apuseni Mountains. At the same time, the applicability and efficiency of Landsat data in felling detection and the development of a methodology to analyze in a short time the forest areas affected by storms are pursued.

The paper is structured on 6 chapters, each of these chapters corresponds to the objectives proposed in the elaboration of the paper.

Chapter 1 is an introductory chapter which provides general information on windthrows importance and their impact on forest ecosystems. Also, in this chapters are presented the objectives and purpose of this paper. Geographical location and a brief characterization of the Apuseni Mountains.

Chapter two presents the issue of deforestation, by presenting the notional aspects that will be operated during the work and the classification of deforestation caused by wind. After consulting the many types of windthrow classifications, based on different criteria for windthrow classification and damaged classification, worldwide was adopted the classification proposed by

Miller in 1985. Thus, the windthrow were divided into 2 large groups, respectively windthrow with catastrophic effects and endemic windthrow.

Also, in this chapter is presented a brief history of windthrow in the Apuseni Mountains. The oldest windthrow records related in the Apuseni Mountains area are from 1962, when two windthrow were mentioned, one during 1939-1941 being affected 650 m 650 of trees and the other during 1958-1969 when they were affected 500 m^3 of trees.

The main steps and methods used in windthrow analysis research both in Romania (national) and international level are detailed.

Chapter 3 presents the main data used in the elaboration of the study. A number of 15 sets of images, with 210 spectral bands in total were used. The images used in this study were chosen to be for the vegetation season (mid-May - early September) to reduce the impact of vegetation in different seasons.

Data from the Bobohalma WSR-98D Doppler radar were used for meteorological analysis. Because, in the literature, it is mentioned that the trees are felled by strong gusts, over 90km/h, for the analyzed period, the maximum gusts equal to or greater than 90km h (25m/s) were considered. The maximum bursts were only available for the period 2004-2014.

Also, in chapter 3 are presented the methodological steps taken. The stages of preparing the satellite images as well as the preprocessing steps in order to detect and analysis of the windthrow within the Apuseni Mountains are presented. In order to obtain the forest areas, the images were classified, highlighting 2 classes, forested areas (forest) and non-forested areas (other land cover classes, other than forests). This step was performed following two steps:

- automatic extraction of forest pixels based on the histogram
- supervised classification of satellite images

The next step was to use the supervised classification. After running the classification algorithm, the images obtained were reclassified into forested areas and non-forested areas.

At the end, the two images with the forest areas (obtained by using the respective histogram following the supervised classification), were superimposed and the pixels that were classified incorrectly in the two images were excluded from the analysis.

Chapter 4 is dedicated for presentation and interpretation of obtained results. The windthrow will be called the areas where we detected a decrease in vegetation from one image to another and where we could confirm with official data or meteorological data indicating that the area was affected by strong gusts.

First analysis was made on Normalized Vegetation Differentiation Index (NDVI) which was used to mask water and dark surfaces.

After calculating the NDVI to delimit the land cover classes, a threshold must be set for masking areas covered with water and soil. In this study the thresholds used are 0.3, which helped to mask the areas with water and soil. This step made it possible to identify and remove pixels that may be problematic in the next steps.

For forest vegetation extraction we used the supervised classification method. The result obtained after classifying the images for each year allowed us a visual analysis of changes that occurred in the study area.

Studies based on satellite maps require a step to validate the results obtained. The most commonly method used to assess the accuracy is the calculation of the error matrix, that has been used in many land classifications studies and has become a crucial component of this research. The accuracy assessment was applied: a) the supervised classification and b) the image classification in three categories (forest areas, forest loss and other classes).

Having in mind that Apuseni Natural Park is located in the Apuseni Mountains area, we tried to make a separate analysis.

We performed 2 error matrices, one for the Apuseni Mountains area and another for the Apuseni Natural Park area. The overall accuracy obtained for supervised classification is 82.21% for Apuseni Mountains and 80.23% for Apuseni Natural Park. Kappa coefficient 0.88 - Apuseni Natural Park while for the Apuseni Mountains it was 0.79.

At the same time, in order to obtain a better understanding of accuracy assessemnt, we calculated the error matrix for each annual classification in the three categories: constant forest-CF; forest loss-FL and constantly non forest-CNF. Thus, for this matrix were used 1524 random points (110 points for each year), 560 on the territory of the Apuseni Natural Park.

Constant forest area is considered by those areas that were represented by the forest in both image 1 and image 2, and the areas that show disturbances are those areas that in image 1 have been classified as forest and in image 2 are no longer classified in the forest class.

In the subchapter Spatial-temporal variability of forest areas in the Apuseni Mountains 2001-2014 period, we analyzed the spatial and temporal variability of forested areas within the Apuseni Mountains.

In order to obtain a better understanding of forest distribution within the Apuseni Mountains, previously classified maps in forested areas and non-forested areas were used, for each year. Using these maps, differences and ratios were made between the classified images, obtaining areas with forest gained or loss from one year to another. Most of the changes took place in the Apuseni Natural Park area, where being a protected area, the vegetation management norms are different from the rest of the forest areas

Analyzing obtained data shows that years 2002 recorded the lowest values. Percentages up to 5% were recorded in several years, 2004, 2005, 2006, 2008, 2009, 2011, 2013 and 2014. For year 2004 we have officially recorded 2 affected areas without having the affected areas so we cannot compare the result obtained in this study. For 2005, we did not find data on the production of windthrow.

The highest percentage was registered in 2007 (22.58%). According to data received in 2007, 437.56 hectares were affected by windthrow in Apuseni Mountains. Following the calculations performed in this study, we obtained an affected area for 2007 of 762.93 hectares. The place of these windthrow is located in the mountain area, Beliș and Padiș Plateau but also on the area of Turda Forest District.

The following analysis refers to forest vulnerability to windthrow. Given the fact that the vulnerability is influenced by many factors directly or indirectly, in this subchapter we calculated the vulnerability of trees to the action of the wind considering morphometric factors. We considered 5 morphometric factors that were classified into 5 risk categories. The highest vulnerability class overlaps the areas with altitude between 1400-1600, where conifers are found especially, and the slopes have a steep slope. We have superimposed over the vulnerability map and the relief units so that the valleys, depressions and corridors where we meet the lowest vulnerability classes can be located very well. In addition to all the natural factors that contribute to increasing the vulnerability of forest areas to the action of the wind, another factor that cannot be quantified is the anthropogenic factor.

The examination of relationship between morphometric factors and disturbances in the Apuseni Mountains complements the previous subchapter where we analyzed the vulnerability of trees to windfalls and observed the close connection between these elements. At the same time, the connection between the main elements of geographical space in differentiating the production of damages on a local scale is pursued. The most affected areas are between 1400-1600 altitudes, with a percentage value of 36%, the area over 1600 altitudes by 20%. The areas between 1200-1400 also have a high percentage (15%). Analyzing the graph with land cover classes, the most significant decreases were registered in the areas classified with forests, the highest percentages belonging to the class of coniferous forests (35.05%). The deciduous forests were classified with vegetation decreases by a percentage of 24%, higher than the mixed forests that totaled a percentage of 10.55%.

The next morphometric element analyzed is the slope. The windthrow were concentrated on slopes with values corresponding to the classes moderately inclined (5 ° -15 °) and inclined (15 ° -25 °). After the analysis of the slope classes, another important factor is the slope exposure. Areas with decreasing vegetation were concentrated in the North (12.15%), North-East (14.07%) and East (12.77%).

The triggering factor for windthrow occurrence, namely wind, was analyzed in the subchapter Influence of meteorological factors. Analyzing the factors that led to wind gusts production over 90km/h in the studied area we considered, first, the type of air mass circulation. The tropical maritime mass circulation was the basis of 45.24% of the summer storms in the analyzed area, while the blocking mass circulation caused only 7.14%.

If we refer to storm genesis, those analyzed in this paper, a mixed origin in proportion of 33.33%. And the fewest come from the occluded front, 2.38%. Cyclones of Icelandic origin influenced the air masses in a proportion of 60.71%, followed by cyclones of Mediterranean origin (25%).

Also, in this subchapter, a case study was carried out on the Felling of July 20, 2011 in the localities of Cîmpeni, Bistra and Vidra in Alba County.

Chapter 5 presents a Comparative Study: Apuseni Mountains (Romania) and Vosges Mountains (France). The results emphasized that both areas were affected in the area of coniferous forests, at different altitudes 1447m in Romania and 950m in France. This altitudinal difference is due to the lower altitudes in the Vosges Mountains where coniferous forests can be found at an attitude of 800-900m. The analysis shows that over 80% of the affected area had conifers in the composition in Romania while for France we obtained a percentage 75% for conifers forest.

An analysis in terms of areas affected was performed, dividing the affected areas into three categories, the smallest of one hectare, those between one hectare and five hectares and those exceeding five hectares affected. The French area was affected in a higher proportion, the areas exceeding 5 hectares occupy a percentage of 51.12% compared to 43% for the Romanian territory. The affected areas exceeded 100 hectares in Apuseni and over 200 in Vosges, with the exposure of the eastern and southeastern slopes in Romania and the northern and northeastern ones in France.

The paper ends with a chapter in which the general and specific conclusions of this study are presented, which highlights the importance of this study.