Stability models at wind action for trees and stands

Summary

The natural mountainous forest ecosystems are characterised by a high structural diversity and they impress by their stability. In the last decades in the mountainous ecosystems have been frequently reported ecological unbalances with thoughtful consequences upon their productivity and their capacity to meet multiple functions they have been assigned. Promoting an environmentally sound silviculture, supported by ecological bases, preserving and developing on sustainable tenets these complex ecosystems represent the most important problems the modern forest management is facing with.

Combining knowledge provided by physics, mathematics, statistics and modelling, the spatial and temporal analysis of the stability of trees, stands and forest as a whole generates a new level of the integration of the observations and data gathered by classical research methods and a condition of understanding the windthrow.

On the base of Gumbel's model we have found that the most likely number of windthrows with a damaged volume over 1 million m^3, at European level, varies between 3 wind damages in a ten year period to 14 wind damage in 50 years. The likehood of a windthrow affecting a volume larger than 20 million m^3 is one of 20 years. The return period, respectively the time between two windthrows having a *k* intensity varies between 3.6 years for a windthrow exceeding 1 million m^3 to 8.5 years for a damaged volume larger than 10 million m^3, and it is 72 years for a windthrow with a damaged volume over 30 million m^3.

Applying the Weibull probabilistic model to model the frequencies of having catastrophic wind damages at the European level we have found similar results with the Gumbel model, and we can state, having the statistical support, with a likehood of error lower than 30%, that at every ten years at the European level might occur a windthrow with a damaged volume exceeding 1 million m^3, and the likehood to repeat the event is more 50%. At the Romanian level in base of Weibull model we can forecast that the probability to occur massive wind damage within a ten-year period is 0.55, while the likelihood to have a second windthrow is 0.33.

Applying the stochastic modelling and simulation techniques to figure out the number of windthrows within a period and the time interval between two consecutively wind damage, at European and national level, the results show that:

- the likehood of not having windthrow within a ten year period in very low: 5.7% for the European level and 8.9% for Romania;
- the likehood of having one windthrow within a ten year period is 21.6% at Romanian level and 16.4% at European level;
- the most likely time interval between two subsequent windthrows is 1 year with a likehood of 19% at Romanian level and 21.5% at European level;
- the informational characteristics, respectively the information energy and the entropy of the system, have an aleatory dynamics in the case of simulation with constant number of events, and a progressively diminishing with the augmentation of simulation size, in the case of simulation with variable number of events.

Applying the modern techniques for analysis the seasonality of windthrow, respectively the autocorrelation function, partial autocorrelation function and spectral analysis, we have found that the dynamics of wind damage at European level shows a seasonality with a return period of 3-4 and 9 years for an damaged volume over 1 million m^3, respective 3 and 15 years for the windthrow more 20 millions m^3. At our national level the return period of strong wind damage is 3-4 years, and 56 years.

Using the methods and techniques specific to mathematical modelling and simulation, taking advantage of the facilities provided by information technology, we have elaborated a theoretic model of stability of tree at wind action, in static regime, and in dynamic regime respectively. Having the outcome of the simulation, the following conclusions have been drawn:

- the tree stability expressed by the risk coefficient increases with the height, tendency accentuated by a high value of the slenderness coefficient (the ratio between tree height and DBH diameter);
- the risk coefficient increases with slenderness coefficient, and this is obvious when tree is very high;
- the higher risk occurs when the height exceeds 20 m and the slenderness coefficient is greater than 120;
- small crown diameter, that is small crown-ratio, the risk coefficient increment plotted against slenderness coefficient is low; for crown-ratio greater than 0.2 the risk increment follows an exponential shape;
- trees with a very long or very short crowns have a high stability;

The aims of simulations made on the theoretic model are to emphasize the way and the direction of the influence of biometric parameters over tree stability.

The mathematical modelling of wind effects on the tree has been carried out considering an ideal study subject, with parameters following mathematical laws. The results hold out from theoretic viewpoint, but their *ad literam* application in practice is not advisable. The phenomenon of windthrow is more complex, involving o series of factors that cannot be captured within mathematical models. So, the influence of local terrain conditions, of biotic factors (rotten), cannot be quantified with actual mathematic apparatus. Embodying these qualitative factors into the mathematical model is possible due to the statistic methods. For statistic modelling of tree stability at wind action we have acted to quantifications, in base of real data, two statistics stability models, respective discriminator model and logit model.

After this statistic modelling we have take the follows conclusions for the vulnerability of trees at wind actions, expressed by critic height:

- the critic height decrease with the decrease of wreath length;
- the increasing of the rapport height / diameter on registry the decreasing of critic height;
- the present of any type of defect go to a significant decreasing of the critic threshold of windthrow appearance.

The results are conform to them obtained by mathematical modelling, confirming the validity of the conclusions obtained by simulation make on the theoretic models.

The validating of stability models at tree level was making by the methods of uniform couple, capable to surprise, by reduced costs, a large scale of stations conditions and stands. The basic principle of uniform couple method is given by the uniformity of stations conditions, of soils characteristic, of general and local topography, of stands conditions and in special of the atmospheric conditions. The statistic analyses was confirmed the validity of the theoretic models proposed.

The theoretic landing of stands stability at wind action is extremely complex. The interactions between the factors that intervene in the stability process of stands are very complex, that make that, the quantification mathematic of them to be extremely difficult with the actually mathematics apparatus. The grand variability of the factors that intervene in system impose the adopting and building the probabilistic models for analysis and forecast by short and long term of windthrow. The scope of modeling of stability of stands is to offer an adequate and efficient instrument for measuring the susceptibility of station and stand to the risk of appearance of windthrow and also for estimating the likehood of future perturbations.

The spatial and temporal analysis of wind damage, also of the complex of factors that intervene in the system have permit the synthesizing of the likehood of the windthrow in a probabilistic relation compose by the probability of appearance of wind damage – p – and the percentage of windthrow – Pdv – expressed by the percent of volume of accidental products of the volume existent at ha.

The likehood of appearance of windthrow was quantified by statistic models with two factors, respective the age and the stand density. In case of production unit I Demacuşa we have realized the stratification of the model in rapport with the spruce percent of the stand composition.

Beginning of the general form of the logit model we have proposed for the estimating the percent of wind damage, a model modified by the introduction of a correction factor k, determined after the quantification of statistic parameters.

In case of production unit VII Izvoarele Bistriței the stability parameters adopted, after the regressive analysis in step, are the exposition, the altitude, the age, the type of structure, the stand density, the height, the class of production and the rapport height / diameter. For the production unit I Demacuşa the stability factors included in the model are; the slope, the altitude, the spruce percentage, the stand density, the age, the height and the rapport height / diameter.

The final scope of the modeling of tree and stands stability is the obtaining the efficient and realistic criteria for mapping the windthrow risk.

In this research we have proposed three methods for building the windthrow hazard classification systems:

- the method of testing the statistically significance of mean difference;

- the method of probabilistic models;

- the method of discriminant analysis.

The present thesis don't resolve all the problems that the wind damage involve in the forest ecosystem, she is a new and modern landing this stress factor.