Application of LiDAR and aerial photography data for assessment of forest management risk

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1. Introduction

This article describes systematic approach for risk assessment and data retrieval by using LiDAR and aerial photography data methods for estimating indicators that can be used to analyze risk scenarios, and their subsequent use in context of Forest Management Plan (FMP). All forest owners are recommended to have FMP to ensure the sustainable use of resources, and to fulfil other targets. According to publications this plan consists of three sections- aims, baseline data and economic orders.

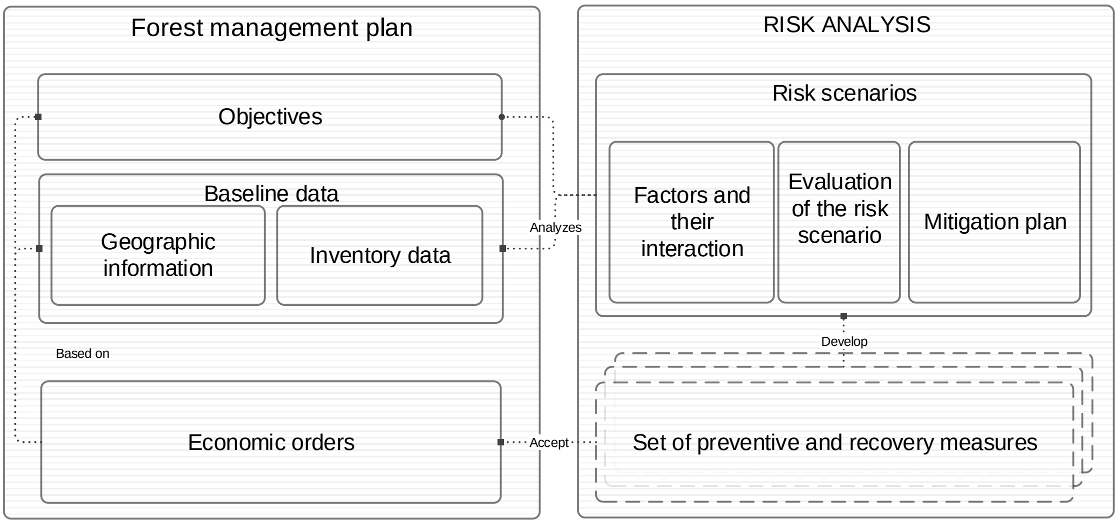


Figure 1: FMP structure

Plan of forest management activities is prepared during the development of FMP (Fig. 1) it is based on underlying data and previously stated objectives. It describes a set of actions that must be performed to achieve stated objectives. In simple terms FMP development is process that starts with objective statement and baseline data collection, and ends with the preparation of the economic order. Unfortunately, it may be impossible to realize such a simplified FMP version in practice, as any human intervention in natural processes of forest growth or failure to act can lead to a variety of unplanned changes, that may interfere in the achievement of the stated objectives. Therefore the forest owner must be aware of the risks factors that have undermined his property and where possible, he should be able to reduce or eliminate the impact by taking appropriate preventative measures. To be able to prepare for such situations risk analysis must be done. Within process of risk evaluation, conformity assessment of inventory data and geographic information to previously examined risk scenarios consisting of factors and their interactions must be performed. In order to assess which of these factors describes hazard situations, a qualitative base line information that sufficiently describes the planning area must be available and collection of such information usually is the most problematic phase of FMP development. Nowadays, there are various methods that can provide information for planning operators and the appropriate choice of options is usually associated with issues such as data quality, cost, speed of data collection. Traditionally, data collection methods can be classified in to three different groups - field measurements, statistical data extension and remote sensing data processing. Each of them has its own advantages and disadvantages. For example, field measurements are able to provide the widest range of information, but they are expensive and time consuming for relatively large territories. In contrast, remote sensing methods provide less information, but in a shorter period of time. Sometimes fastest method is not the preferable one, because it doesn't measure all needed stand parameters so many researchers find that the best results may come from the combination of methods from more than one group. Different sensors or methods that encompass certain levels of observation should not be taken as exclusionary alternatives (Korpela et al., 2007). In a result of such combinations method that is capable to achieve higher data quality and measure more parameters in a shorter time could be developed.

2. Methods

Subsequent chapters examine ways of using LiDAR and aerial photography in process of data acquisition, as well as conceptually describes risk analysis method, that is based on such data.

2.1 Risk assessment

Risk assessment is a complicated process because it's performer basing on knowledge of past events, analogous situations or matters of common knowledge facts must be able to predict the future development of activities. In FMP case, these developments may be main reason for the failure to achieve previously stated objectives.

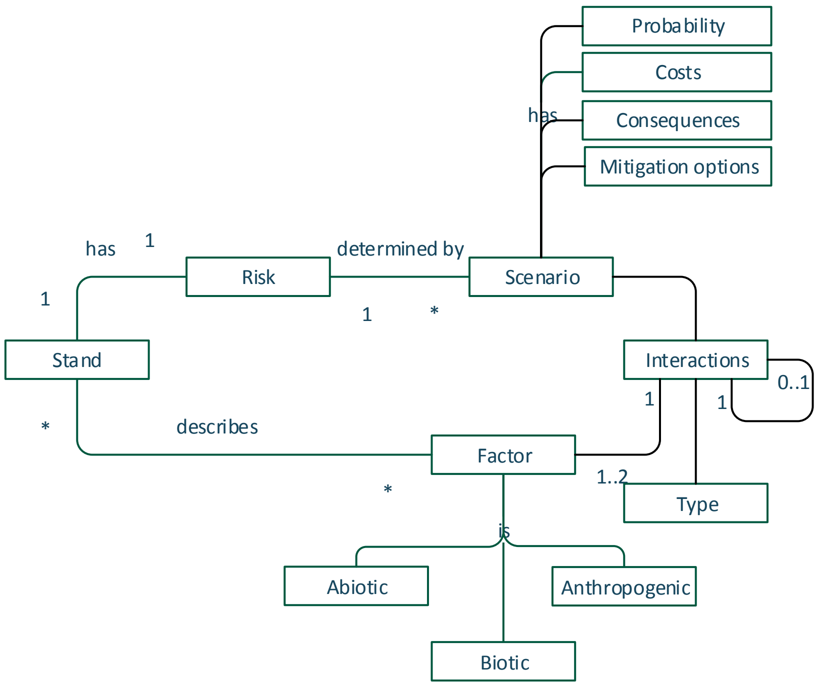


Figure. 2. Conceptual model of FMP risk management

There are several different definitions, which indicates that each risk has a consequences and probability. For example, J. Kaktiņš I. Arhipova and (Kaktiņš J and I. Arhipova 2002). define that risks are possible losses which arises in a result of random set or interrelated causal set of occurrences . For simplicity, the MAP risk can be defined as the possibility of failing to meet stated objectives, as well it can be assumed that there is only one risk with different scenarios.

And that each scenario has a certain probability, consequences, cost, mitigation options, factors and their interactions set. Probability indicates the likelihood of the risk occurring at the selected scenario, consequences characterizes changes that will take place, or reality deviations from the plan.

Mitigation options are a set of measures designed to reduce the likelihood of the risk occurring.

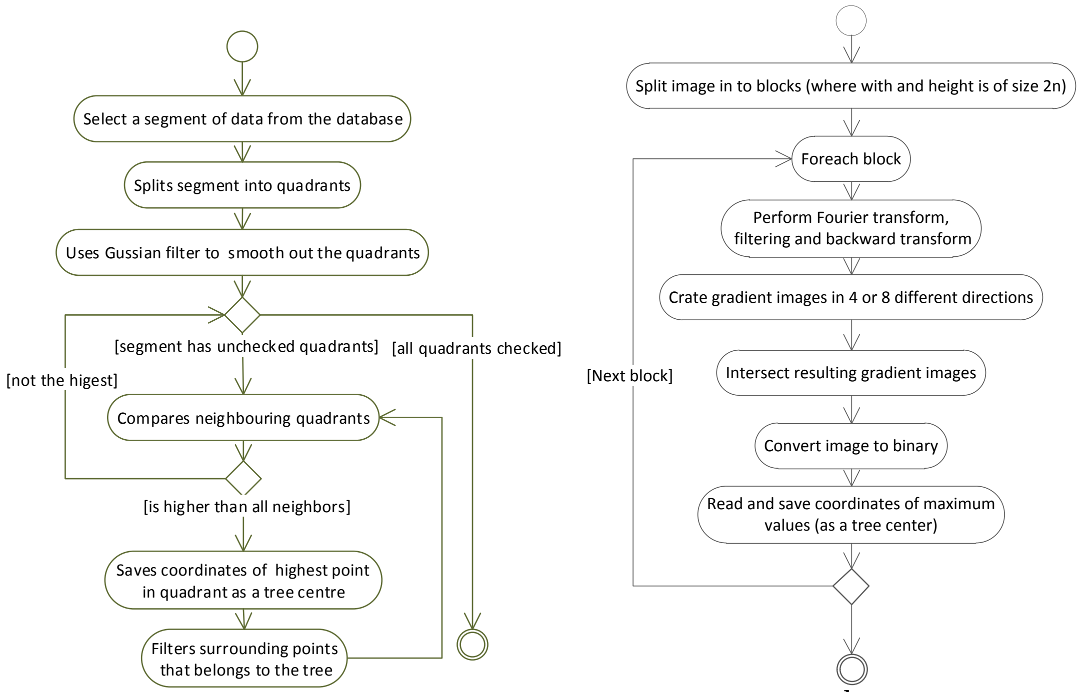
For example, the mitigation options for risk scenario of wind damage are: evolution and selection of potential planting sites for low wind conditions, species selection, planting aged cuttings to reduce sail area, correcting toppling, avoiding late heavy thinning, avoiding excessive edge effects, normalising age class distribution, utilizing timely, avoiding clearfelling exposure. (Arbez et.al., 2002). Most significant part of the model displayed in Figure 2 is risk factors and their interaction that are included in the scenario. There are three groups of factors - abiotic, anthropogenic and biotic.

Two major obstacles is preventing from the practical implementation of risk analysis in FMP. First - researchers engaged in the study of FMP risk must describe the factors and interactions between them in the way that it's possible to carry out a systematic selection of eventually affected stands and to perform an automatic risk probability estimation. The second obstacle is related to the source of data - part of the information is available in the standard inventory database or obtained by previously developed methods of data processing, however, many important factors that characterize stand must be collected separately. The results section of this publication outlines an approach of systematic description of risk factors and their interactions.

2.1 Processing LiDAR and Aero data

As mentioned above an important risk scenario section are made from factors that describes different parameters of stand or individual tree. A small set of the parameters that can be acquired using LiDAR or aerial photo was estimated during this research, and it is given in result section. This section provides an insight into couple of methods that can be used for such purposes and is practically validated.

First method is used to estimate tree height, position and number of trees in stand from LiDAR data. It's main idea is searching for local maximums on height axis of LIDAR data collection. Usage of this method is based on the assumption that tree top centre is highest point in data set which is not always the case. For better results before location of maximums data set is smoothed by using Gaussian mask. As closest point of such mask has bigger affect than the ones on the border. It can be stated that this filter evaluates interactions between data points. After calculating the Gaussian mask the highest segment points above the surface are searched and compared with adjacent cells independently for each segment. If the selected cell is higher than the adjacent - then there is the tree top. Tree top is not always the centre of the cell, so the tree is found by determining the highest cell. Tree recognition algorithm is shown in figure (Fig. 3a.) The described local maximum approach is one of the most widely used methods of tree identification, and determination of the crown canopy and tree height (Pikanen et al., 2004; Popescu, 2002; Korpela, 2006; Korpela, 2007).



a. b.

Figure. 3. Local maximum algorithm for LiDAR and ADS data

Second method is used to estimate tree position and number of trees in stand from aerial photographs. It is based on the local maximum approach (Rossmann, et al., 2007), where using the Fourier transform process that consists of several stages- image preparation, image processing and compilation of results- is performed.

Figure (Fig. 3b) shows main steps used in local maximum method for tree identification from ADS datat. It begins with image division into several sub images of size 2n. Main reason for such deviation and size restrictions is dictated by fast Fourier transformation algorithm used in next steps. After Fourier transformation each subimage is filtered and transformed back to spatial domain. In a next step gradient images in 4 or 8 different directions are calculated and intersected with each other. Then the binary image is created, by using results of previous steps such that maximal values show only local maximum points. Main reason for choosing Fourier transformation and performing filtering in frequency domain instead of simple Gaussian filtering is speed of used methods and descriptions of successful usage found in publications. Fourier transformation is described as a method of choice for tree identification (Vaughn et al., 2011; Vaughn et al., 2012; Edwards and Nesbitt, 2002), and it is also tested in tree species identification tasks (Nicholas et al., 2012). Usage of Fourier transformation is studied both for tree position (Vaughn et al., 2011; Vaughn et al., 2012; Edwards and Nesbitt, 2002), and species identification (Nicholas et al., 2012). Composition of species in stand is derived from RGB, NIR imagery and LiDAR crown shape data. Many other parameters can be obtained using previously mentioned measures in regression models describing the relationships between different indicators. For example, a lot of researches describes models for estimation DBH from parameters acquired using LiDAR and Aero photo data.

3. Results

Main result of this research is proposal to combine described remote sensing data acquisition methods and risk analyze approach in to single automated system that can be used to identify different risk types and that has an open framework for definition of such a risk scenarios

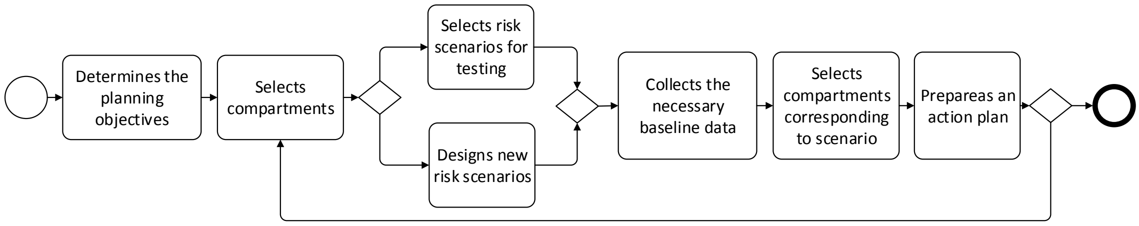


Figure 4. Main workflow of Risk assessment system.

Workflow given in Figure 4. describes such a FMP system, where main process begins with definition or FMP aims, than continues with selection of analyzed risk scenario types and territorial data. Risk scenarios is formed form factors and interactions that indicates their relationships, for example statement - "Species=Pine and Age>=5 and Age<=25 and (FST=Hylocomiosa or FST=Cladinoso-callunosa or FST=Vacciniosa or FST=Myrtillosa or FST=Myrtillosa mel.) and Stand Type=pure stands and Density=6" defines favourable scenario for the pine bark bug spread. Main drawback of such statement that defines factors and their interactions is opacity. Graphical tool that allows to describe visually a sophisticated scenarios can be included in solution for FMP preparation to solve this problem.

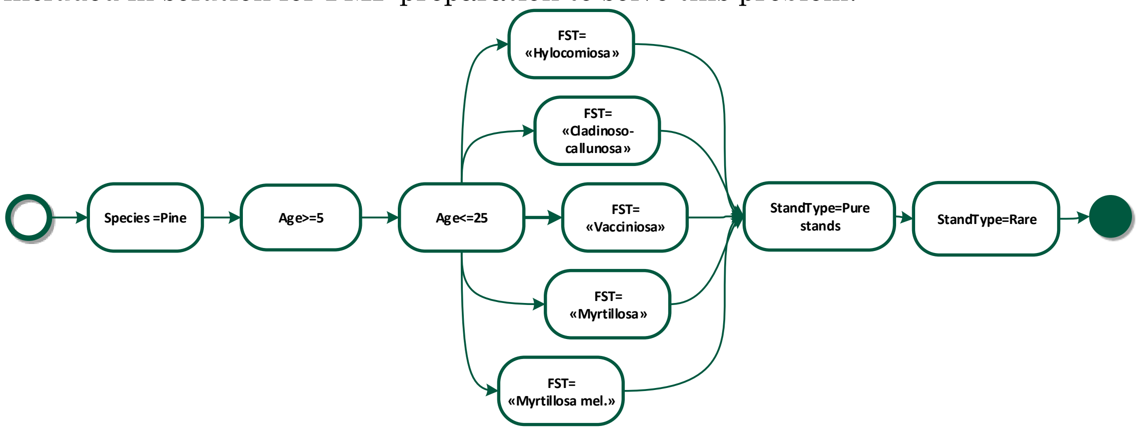


Figure. 5. Factor interaction diagram

Figure 5. shows graphical representation of previously described pine bark bug spreading scenario where each rectangle indicates a particular factor and its value, but the arrow and its placement notes an interaction type. If rectangles are arranged in sequence it means that there is AND-type relationship between factors, while parallel placement indicates OR-type interaction. Such models can be used to describe a wide variety of risk scenarios.

To be able to select areas with high risk probability it is necessary to estimate different stand indicators that can be used as factors in modelling risk scenario.

Methods described in previous sections of this publication shows fair results in practical usage - tree detection using combined LiDAR and aerial photographic method show that 63 % of all trees were unambiguously found, but 37 % of tree were not identified. The most commonly they file to find shorter and thinner trees, or trees located in 2nd floor, only 15% of the 1st floor trees are not identified. By comparing LiDAR detected height and ground measured total height of the sample trees it can be observed that the bias of height estimates ranges from -1.72 m to 0.26 m, and the average and standard deviation of the absolute bias are -0.75 m and 0.51m.

DBH is an important parameter and it is not measurable it directly from the LiDAR or aerial photo. Possible solution for this problem is to find it by analyzing relationships between different measured factors, height, species, crown width, age and type of growing conditions. By using all of the above factors relatively high coefficient of determination (R2 = 0.872) can

be obtained. If only parameters identified from LiDAR and aerial photo data are used (height, species, crown width) coefficient of determination is reduced to 0.792.
The study site for acquiring described results was forest in middle of Latvia at Jelgava district (56º39' N, 23º47' E). Aerial photography camera (ADS 40) and laser scanner (ALS 50 II) was used to capture the data. A LiDAR data is 5 to 9 p/m2 depending of altitude. Image data is RGB, NIR spectrum with 20 cm pixel resolution. Totally 350 sample plots (0.045 ha) were established during summer 2010.
As can be seen analysis of LiDAR and Aerial photo data gives a good estimation of parameters such as tree height, tree count, position and DBH, but more information is needed for risk assessment. By carrying out a survey of experts and analyzing several real risk scenarios the set of factors and their possible acquisition solutions where created (Table 1.). Its aim is to look at the minimal necessary combination of factors for risk scenario compiling and indicate their role in one of main risk scenarios: pests and diseases(1), fire(2), wind and snow (3) (Arbez et.al., 2002).

Table 1: Set or risk factors and their estimation possibilities

Factor name	**Value type**	**Possible estimation method and risk scenarios**	**1**	**2**	**3**
tree position	*Number*	LiDAR and aerial photography. Local maximum methods	x	x	x
height	*Number*				
count in given stand	*Number*		x	x	x
stand area	*Number, GIS polygon*	LiDAR and aerial photography data can be used to divide territories in subsequent areas that has a common features and its	x	x	x
existence of undergrowth,	*Boolean*	To estimate existence of undergrowth trees and second floor trees methods that analyses point densities at different height can be used	x	x	
existence second floor trees	*Boolean*		x	x	
count of second floor trees	*Boolean*		x	x	
leaf area	*Number*	Methods for processing colour data of aerial photography in combination with LiDAR height information can be used	x	x	x
gaps	*Number*		x		x
species	*Number*		x	x	x
types of adjacent territories	*open spaces, coppices, water reservoirs*	Best solution would be to use stat land and forest inventory data bases if available, because this information is not of fast changing type. If no data available LiDAR height data in cooperation with return type and aerial colour information can be uses.	x	x	x
DBH	*Number*	Alometric equations	x	x	x
site index	*according to the classification*	Databases of forest inventory	x	x	x
H/DBH coefficients	Number	Alometric equations	x	x	x
Age	Number	Alometric equations and if possible, databases of forest inventory	x	x	x
Soil type	*according to the classification*		x	x	x

4. Conclusions

The research showed that least-developed section of forest management planning is risk analysis. Two key areas that are in need of an additional work are - data mining techniques and risk assessment solutions. As well as all process of risks analyses needs an systematic

implementation.
Risk scenarios is formed form factors and interactions that indicates their relationships and can be described by using graphical modelling tools. Such tool would allow to describe visually a sophisticated risk scenarios and can be included in solution for FMP preparation. Evaluation of LiDAR and Aerial photography data shows fair results in estimating different stand parameters. For example, methods described in previous sections where able to identify up to 85% of first floor trees. By combining results of methods that processes LiDAR and Aerial photography data, regression models and previously available data bases baseline information necessary for risk scenario modeling can be obtained.
Separate researches are needed to acquire exact amount, type and methods of data collection of factors that would serve as best indicators in specific risk scenarios.

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