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

INTRODUCTION

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) (Figure1).

It may be impossible to realize 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 risk factors that have undermined his property and where possible, he should be able to reduce or eliminate the impact by taking appropriate preventative measures.

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.

LiDAR and aerial photography is a potential source of data needed for development of FMP.

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.

For simplicity, the FMP 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.

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.

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.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.

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 by using the Fourier transform process. Figure (Fig. 3b) shows main steps used in local maximum method for tree identification from ADS data. 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.

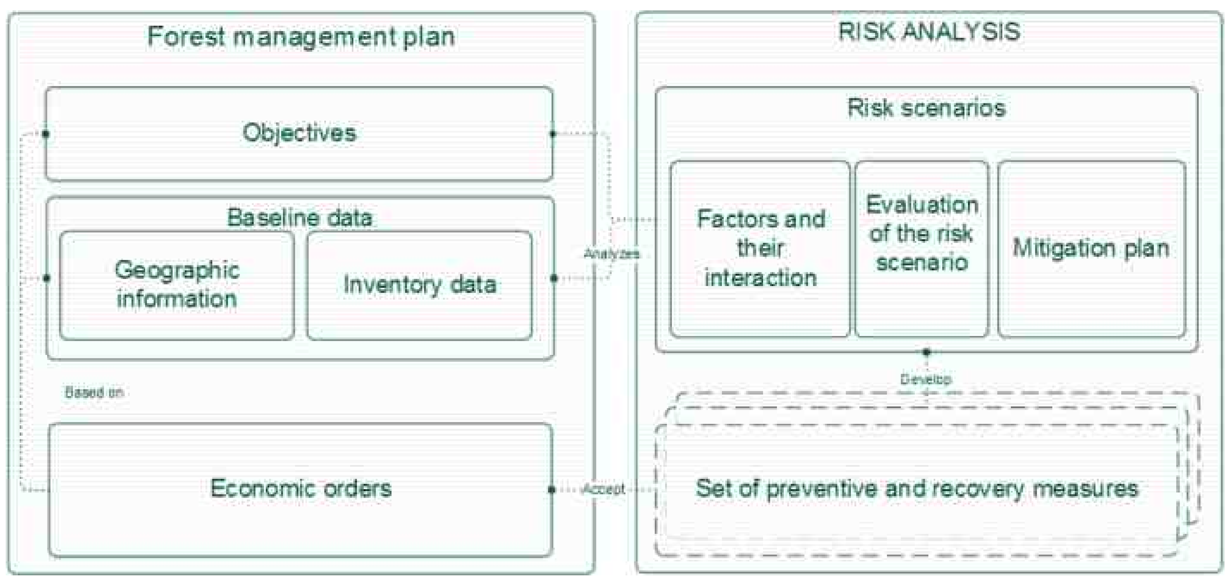

Figure 1: FMP structure with risk managment

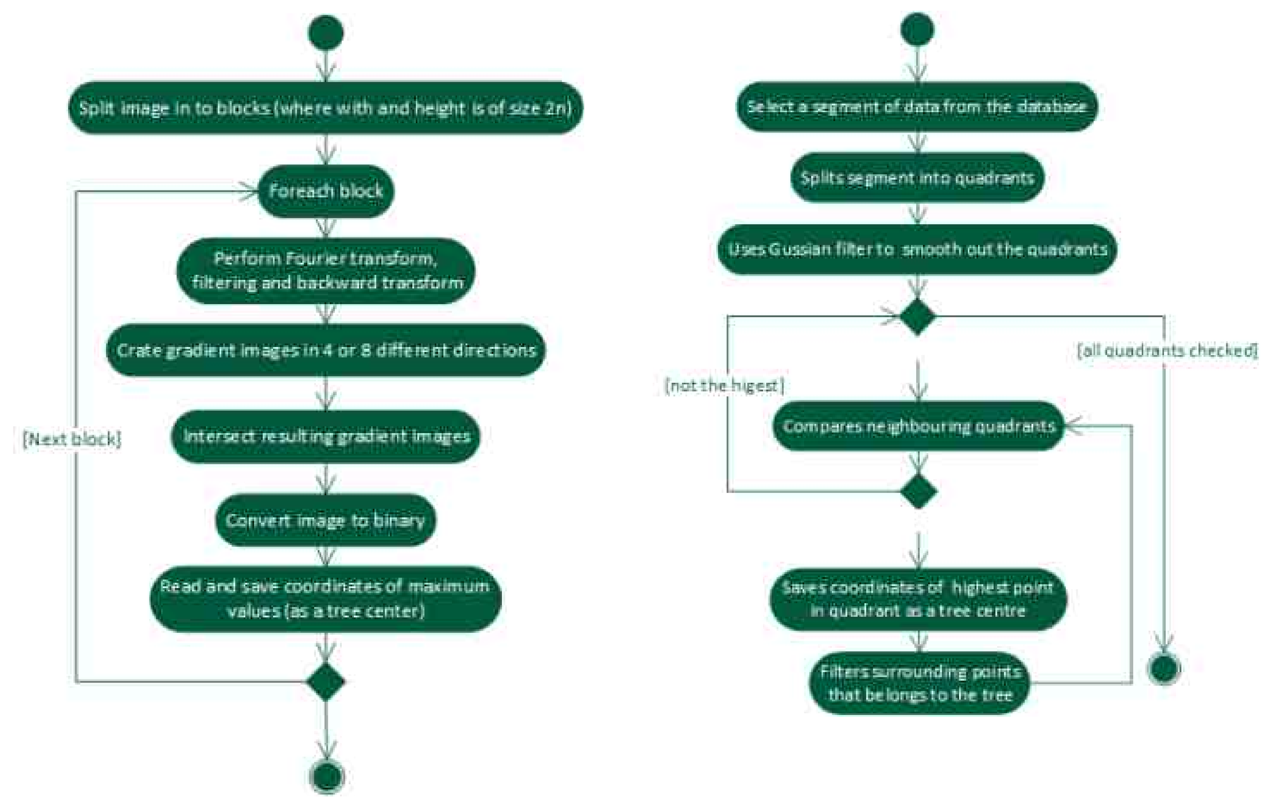

Figure 2: Conceptual model of FMP risk management

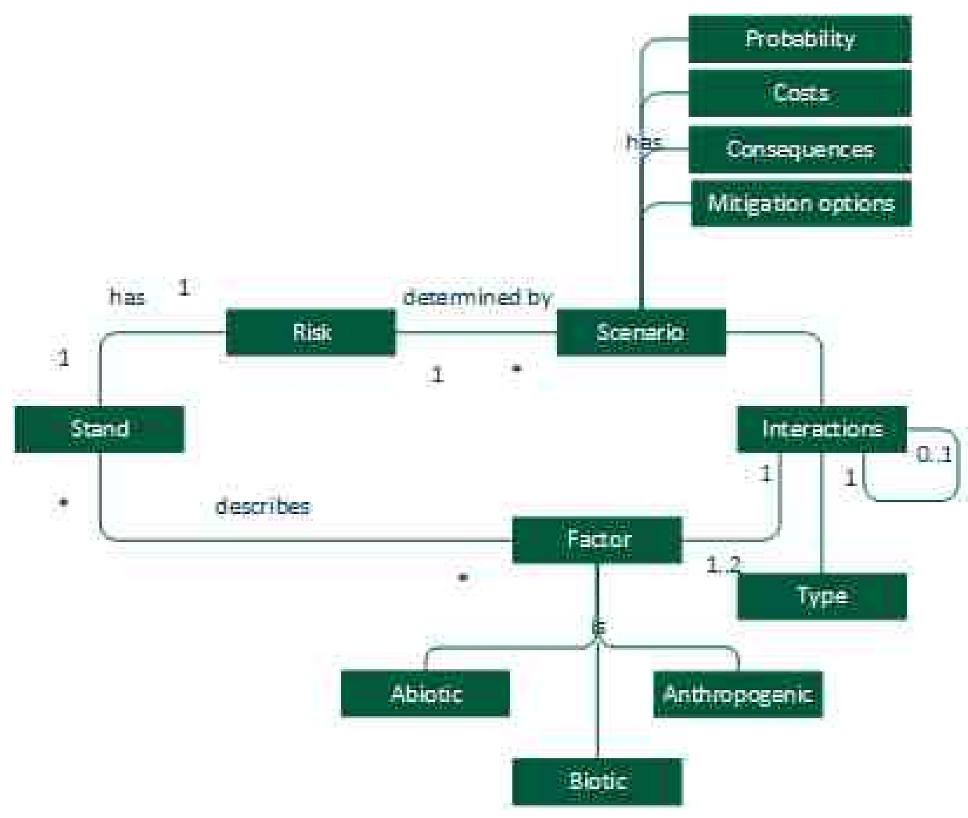

Figure 3: Local maximum algorithm for LiDAR and ADS data

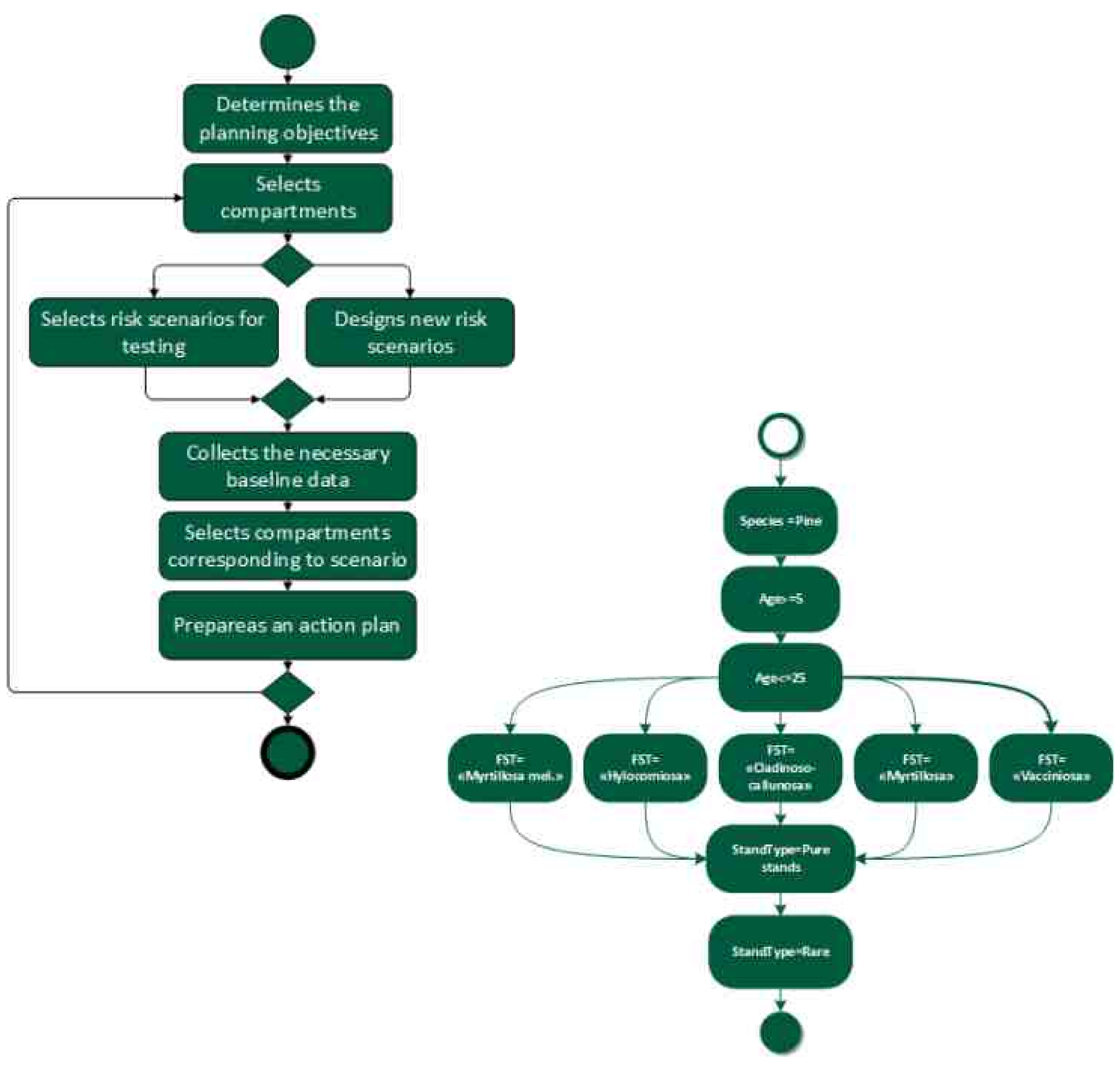

Figure 4: (a) Workflow of Risk assessment system, (b) factor interaction diagram

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

Workflow given in Figure 4a. 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. Graphical tool that allows to describe visually a sophisticated scenarios can be included in solution for FMP preparation to solve this problem.

Figure 4b. 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 (R^2 = 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.

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

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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