Evaluation of the Effect of Forest Input Data on Rockfall Simulations

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INTRODUCTION

The protective effect of trees against rockfall hazards has been known for a long time. However research on the interactions between tree stands and falling blocks only dates back to the 1980's. Thank to the knowledge based on field experiments and on the increased processing power of computers, numerical models have been developed to simulate the trajectory of falling rocks and the possibility of impacts with trees. Using such models in real case-study requires high resolution input data regarding the topography and the forest cover. Airborne laser scanning (ALS) provides metric digital terrain models and is also used to estimate forest characteristics at the single tree or forest stand levels. However, the errors in these forest predictions are likely to propagate in rockfall simulations and result in erroneous forest protection quantification. The objective of this study is to compare the results of rockfall simulations with a forest patch whose characteristics are derived from two types of data: field inventory or ALS remote sensing.

MATERIAL AND METHODS

The software RockyFor3D is used for rockfall simulations. The topography is a simulated slope of 35 degrees of compact soil with rock fragments but low rugosity. Spherical blocks with a volume of two cubic meters and of 2600 kg/m^3 density are released from five meters height along a contour line (fig. 1). Their velocity increases across an unforested area of 50 m. Then they enter a forest patch where impacts on trees might stop some blocks. The kinetic energy of remaining blocks is recorded when the contour line immediately below the forest patch is attained. The forest input data for Rockyfor3D is either a file with the trees positions and diameters, or files describing the tree density and diameters (mean and standard deviation). In the latter case trees positions are simulated by the software. Another important input is the proportion of coniferous stems which is provided in a separate file.

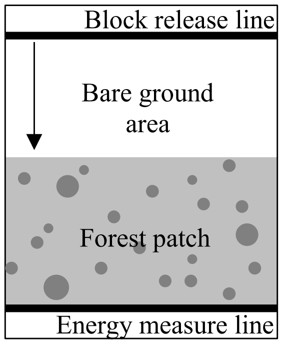

Fig. 1 Simulation scheme

Two forest stands located in the French Alps are used to produce the input data for the forest patch. The high forest of Saint Agnan is dominated by Silver fir (*Abies alba*) and European beech (*Fagus sylvatica*), with a size of 125x80 m^2. The coppice forest of Saint Paul is dominated by Italian mapple (*Acer opalus*), with a size of 50x50 m^2. All trees with a diameter at breast height (DBH) above respectively 7.5 and 5 cm were inventoried and georeferenced. For these two forests, five scenarios are compared:

- "real" scenario: the mapped tree positions and diameters are used as input data.
- "inventory" scenario: mean and standard deviation of DBH, stem density and mean coniferous proportion are calculated from the field data in grid cells.
- "stand estimation" scenario: mean and standard deviation of DBH, stem density are estimated from ALS data for the same grid cells. Mean coniferous proportion is

calculated as the mean proportion of the whole field data.

- "tree detection" scenario: tree positions and heights are detected in the ALS data. DBH are calculated from an external height to DBH relationship and mean coniferous proportion is calculated as the mean proportion of the whole field data.

For comparison purpose a "none" scenario with no forest cover is also simulated. Grid size are respectively 20 and 16.7 m for the high and coppice forests.

RESULTS AND DISCUSSION

For the coppice stand, the "real" and "inventory" scenarios yield almost the same results (Tab. 1) The difference might be explained by two facts. First the diameters distribution simulated from the input data in the "inventory" scenario is different from the "real" distribution as it is sampled from a gamma distribution. Second the clustered pattern of coppice trees in the "real" stand disappears when positions are simulated with a uniform distribution by the software. In the "stand estimation" scenario almost all blocks pass through the forest and they have higher energies. The forest protection effect is under-estimated, probably because the ALS prediction models under-estimate the mean diameter in most grid cells, while the number of stem is correctly predicted. The energy dissipation during an impact is indeed proportional to $DBH^{2.31}$ in the model.

Tab. 1 Proportion of passing blocks, mean and standard deviation of kinetic energy for the two forest stands (row) and the five scenarios for input data generation (column)

	Real	**Inventory**	**Stand estimation**	**Tree detection**	**No forest**
Coppice forest	82.6% 369±189 kJ	81,5% 357±186 kJ	97,5% 392±174 kJ	not relevant	100% 529±167 kJ
High forest	53.2% 426±246	63.0% 422±234 kJ	47.9% 368±223 kJ	71.4% 368±223 kJ	100% 641±205 kJ

For the high stand, the mean energy of passing blocks is similar between the "real" and "inventory" scenarios but their number is different, which might be explained by the proportion of coniferous and broadleaved trees. The energy dissipation for an impact on a broadleaved tree is around 1.5 times higher for a given DBH. In the "real" scenario, the largest trees are mostly conifers. In the "inventory" scenario, coniferous trees are randomly sampled among the simulated diameters. In the "stand estimation" scenario, the over-estimation of the protection effect is probably due to the higher stem density predicted by the ALS model. On the contrary, the "tree detection" scenario under-estimates the protection effect. Indeed mainly dominant trees are correctly detected so that smaller trees are not taken into account in the propagation mitigation.

CONCLUSION

This study points out the fact that the errors in forest inputs will propagate into rockfall simulation results. Tree detection is a simple way to extract forest information from ALS data but will generally lead to the under-estimation of the protection function. Stand estimation may lead to large errors locally but as it is theoretically unbiased for larger areas the results should be more robust. Besides some improvements are possible regarding the algorithms of tree positions, diameter and coniferous character sampling, within the simulation sofware.

Keywords: Rockfall, Forest protection function, Airborne laser scanning