Mountain geoecosystems. GIS modelling of rockfall and protection

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FINAL SYNTHESIS

8.1 GIS modelling of rockfall and protection forest structure

The main objective of this study is to develop an efficient and scientific method for assessing the level of protection that mountain forests provide against rockfall at a regional scale, in order to improve the management of those forests. The two silvicultural examples, presented in chapter two, showed that forest authorities are perfectly able to carry out forest rehabilitation projects. But forest management on the whole may be improved if rehabilitation projects would not be necessary at all and attention could be focused on sustaining the functions provided by forest ecosystems, rather than restoring them. Regarding mountain forests that protect against rockfall, this could be achieved by applying the techniques used and developed within this study. Combining these techniques, as illustrated in Figure 8.1, firstly enables the identification of impaired protection forests in larger management areas and secondly, it can be assessed where and which silvicultural interventions have to be carried out so as to safeguard protection against rockfall.

The first step required is to obtain data on the forest structure and coverage at a regional scale. This thesis demonstrated that a Landsat TM image is able to provide forest stand type maps for steep mountainous terrain, but additional stand details like DBH, tree distribution, structure and stability still have to be provided by forest inventories. The combination of forest inventory data and forest stand type maps in a Geographic Information System (GIS) provides a good database for forest management both at a regional scale and at a local scale. The accuracy of information derived from a Landsat TM image depends very much on the used classification technique as well as on the applied statistic for accuracy assessment. The advantage of object-based classification is that the derived map is composed of objects which correspond with forest stands. Such a map with delineated forest stands is a useful basis for setting up a regional forest inventory.
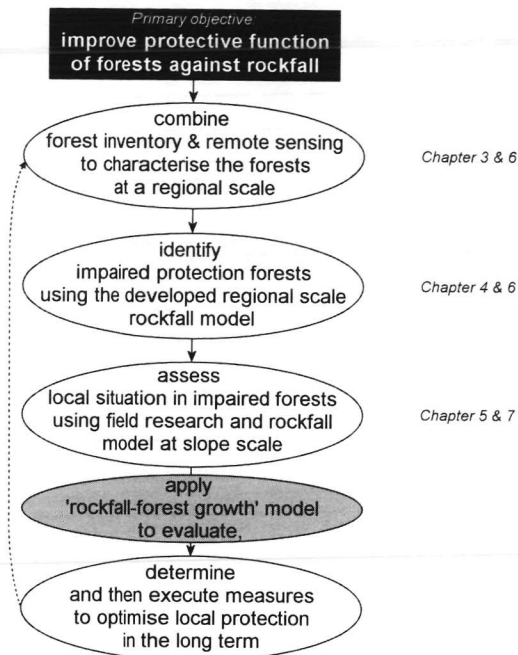
Figure 8.1. Flow diagram showing how the combination of the techniques used and developed within this thesis could contribute to an improvement of the management of mountain forests that protect against rockfall. The step described in the grey ellipse is not covered in this thesis and will be a future research challenge. The dotted arrow refers to monitoring, which focuses at a larger temporal scale.

Apart from the Digital Elevation Model, the obtained forest data combined with forest inventory data is the most important input in the developed GIS-based distributed rockfall model. The literature review included in this thesis concluded that such a model is most appropriate for modelling patterns of rockfall runout zones at a regional scale. Moreover, this thesis demonstrates that the developed model is the most accurate regional rockfall model tested. Furthermore, it is shown that modelling tree damage on the basis of simulated rockfall impacts does not generate accurate results when using the developed rockfall model with input data with a large support. Dynamic modelling of forest development under continuous rockfall disturbance at a regional scale by using a combined rockfall – forest growth model is consequently neither feasible nor realistic. Such a model requires detailed forest characteristics for a large area as well as high quality digital elevation data. Methods to obtain these data other than labour-intensive forest inventories or expensive DEM retrieval techniques are lacking at the moment. As a result, dynamic modelling of the development of forests which protect against rockfall at a regional scale is not possible at this moment.

Fortunately, it is not necessary to model forest development at a regional scale, since at such scales, foresters only need to locate where in the management area protection forests are deteriorating or even impaired. For those forests, detailed silvicultural strategies have to be developed. A combined field and modelling study, as carried out in chapter five, increases insight into a geoecosystem in which rockfall and forest dynamics are interacting and is therefore a prerequisite for developing such a silvicultural strategy. A dynamic combined rockfall-forest growth model could perfectly fulfil the modelling part, since forest authorities indicate that they know how to improve the integrity of a deteriorated protection forest. They do not know, however, the exact effect of their silvicultural measures in combination with the natural disturbances, despite their increasing awareness of forest ecosystem dynamics. Scenario modelling could help foresters not only to evaluate the effect of the measures taken, but also to pinpoint optimal felling or thinning locations in forests. Modelling the effect of both silvicultural measures and rockfall on forest dynamics at stand scale is thus the next step forward to improve management of forests that protect against rockfall. In other words, a start has to be made with modelling the panarchy of such protection forests in mountain geoecosystems. This thesis reveals that the developed rockfall model should be implemented into dynamic forest growth models. This thesis also shows that the slope scale is the most appropriate spatial scale for this, both regarding the support at which rockfall and forest structure are to be modelled, as well as the required data quality.

8.2 Final remarks

On the whole, the method developed within this thesis could contribute to an improvement of the management of mountain forests that protect against rockfall. This can be justified by two arguments. Firstly, the developed method results in a better priority of the implementation of silvicultural measures at regional scale. Subsequently, silvicultural strategies within specific protection forests could be improved on the basis of the increased insight into the interaction between forest structure and rockfall as obtained by combined field and modelling studies.

The developed method could be optimised if the following improvements could be realized. Regarding the regional rockfall model, the rockfall source areas, such as small cliff faces, should be identified better. Furthermore, a better representation of gaps within forest stands at a regional scale is needed. Regarding the slope scale rockfall model, more knowledge of tree-mechanical behaviour as well as knowledge of the resilience of individual trees after rockfall impacts is required. Especially if this model is to be implemented in a

dynamic forest growth model. It would also be interesting to carry out simulation tests with high quality forest cover data and digital elevation data obtained with an airborne laser scanner.

A point which is not addressed in this study is that the developed method could contribute to defining forest functions at a regional scale. Mountain forests provide multiple functions, but they cannot fulfil all the potential functions simultaneously in an optimal way. Traditionally, the main functions of mountain forests were timber production and protection against natural hazards. But depending on the risk posed by natural hazards, forests on steep valley slopes might also be assigned a hydrological regulation function, a biodiversity function, a cultural function or a recreation function. The developed method could assist in identifying suitable forest functions, in the first place regarding the assignment of the protective function against rockfall. As forest functions form the basis of forest management, this is the second justification for the fact that the developed method could improve mountain forest management.

Processes in mountain geoecosystems which affect forest ecosystems are indicative for the function that should be assigned to a certain forest. Processes governing our socio-economic and institutional systems, however, direct the final decision about the assignment of forest functions. This is not a problem as long as functions provided by mountain geoecosystems are used in a sustainable way, so as to maintain ecosystem integrity. To strengthen this process and the underlying line of thinking, scientists have to continue working on understanding geoecosystem functioning. This implies that the interactions between abiotic and biotic factors in our surrounding landscapes, as well as the possible human influence on these, are investigated in integrated research projects. An essential first step in such projects is to improve the communication between scientists by using clear theoretical frameworks and by using plain and simple language. This will eventually improve the communication between 'the scientific world' and society.