ProtectBio - Evaluation of the effects of protection forests on natural hazards due to gravity

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ABSTRACT

Assessing the impact of biological protective measures is a major challenge. The project "PROTECT" of the National Platform for Natural Hazards (PLANAT) defines principles and processes to evaluate the impact of technical protection works. Within the framework of "ProtectBio", the methodology of PROTECT was adapted to biological measures, notably protection forests. This article shows that the principles for technical measures according to PROTECT are applicable to protection forests if some peculiarities of biological systems are considered. Thus, the impact of protection forests is comparable with the effects of technical protection works with the same objectives. The assessment of biological protection measures include several steps: the preparation, the rapid assessment, the evaluation of measures and the evaluation of effects. Some open questions remain concerning the quantification of the impact of the forest on medium and deep landslides as well as on floods. Notwithstanding these limitations, the here presented approach enables the quantitative assessment of the protection forests' effect and, thus, allows including biological measures in the integrated risk management.

KEYWORDS

Protection forest; Evaluation of Protection Measures; Natural Hazard Management; Risk Management

INTRODUCTION

The Federal Council mandated the national platform for natural hazard (PLANAT) to establish the strategy "Protection against Natural Hazards" (PLANAT 2004) which required as a core element the application of an integrated risk management.

Integrated means that

- all natural hazards are considered
- all stakeholders are involved in the planning and implementation
- all types of measures are included
- all aspects of sustainability are taken into account

Including all types of measures means that the protection against natural hazards is assured with both measures of prevention (spatial planning, technical and biological measures,

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preparedness measures) as well as measures of response (warning, rescue, damage protection, emergency measures) and measures of recovery. Integrated risk management is based on a comprehensive hazard and risk assessment and on an active communication about risk, which enables the community to correctly assess the risks and to act accordingly. An important bases of this comprehensive risk assessment is an in depth hazard and risk analysis which enables to quantify natural hazards and determines its process area. Moreover, the reliability and the effect of existing protection measures must be assessed.

At a workshop of experts in natural hazards (FAN) in 2002 it was found that – depending on the hazard process – protection measures are considered very different (Romang et al. 2003). Therefore, PLANAT launched the project "Assessment of the effect of protection measures against natural hazards as a basis for their integration in spatial planning" called "PROTECT" (Romang et al. 2008). In the framework of this project, an evaluation method was developed, which includes nine principles to be tested in a four step procedure (Figure 1).

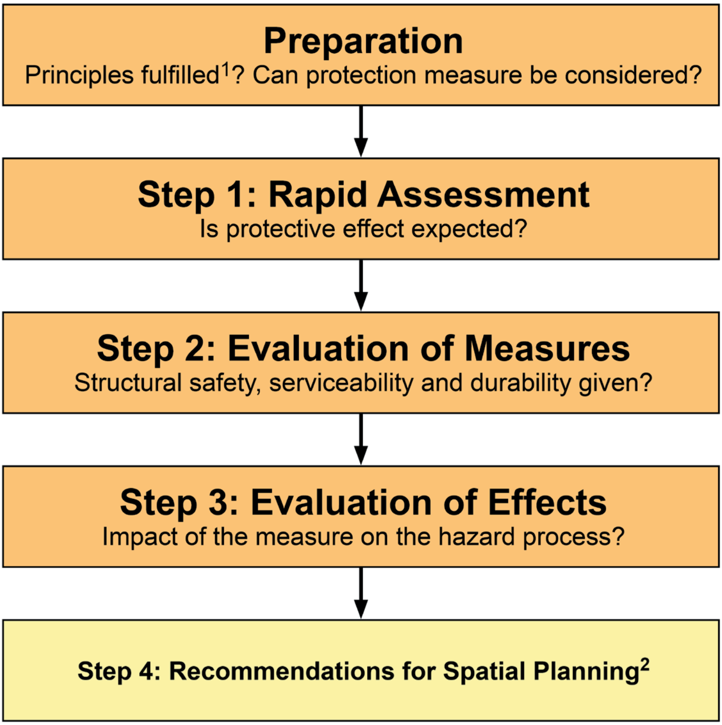

Figure 1: Procedure to assess technical protective measures according to PROTECT. [1]: see Table 1. [2]: Recommendations for spatial planning are not considered in ProtectBio

However, PROTECT uses test criteria derived from civil engineering and designed for technical protection measures (as e.g. structural safety, serviceability, durability). Thus, a common basis for a comprehensible assessment of protective measures was created. It must therefore be examined whether and how these criteria can be applied to other protective measures such as protection forests.

For this reason, the Federal Office for the Environment FOEN has initiated the project "ProtectBio" which is presented in this paper. The main objective of this paper is to show whether and how the principles and procedures of PROTECT are adaptable to biological protective measures in order to assess and compare their reliability and effects to technical protective measures.

METHODOLOGY

According to PROTECT, the assessment of technical protection structures includes the preparation and four consecutive steps: the rapid assessment to evaluate if there is an impact of the measure on the hazard process, the evaluation of measures to assess its reliability, the evaluation of the effects of the measures to quantify its impact and recommendations for spatial planning (Figure 1). Opposed to PROTECT, recommendations for spatial planning were not discussed within the framework of ProtectBio. Thus, step 4 is not elaborated. PROTECT defines nine principles for the assessment according to Figure 1. Table 1 explains these principles for technical measures.

Table 1: Nine principles to prove the general suitability of technical protective measures according to PROTECT

Principles	
1	**Quantifiable Effect:** the effect on the hazard process can be quantified or is at least discernible
2	**Uncertainties:** the quantified impact of the measure on the hazard process exceeds the uncertainties in the assessment
3	**Scenarios:** the assessment considers usual scenarios
4	**System Delimitation:** the measure is assessed both with regard to the individual system and to the entire process area
5	**Permanent Availability:** the protective effect is ensured for at least 50 years
6	**Monitoring and Surveillance:** the monitoring, the surveillance and in case of defects, the replacing is ensured
7	**Temporary Measures:** temporary measures are not considered.
8	**Planned Measures:** after a measure is realized, it is verified if the realization is according to the planning
9	**Time**: since both protective measures and processes change in the course of time, the hazardous situation is verified periodically

The preparation serves as a rough assessment to clarify whether these principles may be fulfilled and detailed analyses are appropriate. In-depth assessments of the nine principles are subsequently conducted in the framework of steps 1-3. One of the main goals of ProtectBio was to verify whether these principles and the procedure defined for technical protection structures are also usable for biological measures. In the context of this verification, some peculiarities of biological systems should be considered:

1. Protection is a free service provided by the nature but only one of the functions of forests.
2. Humans can influence the forest, but natural cycles and specific forest stand characteristics have to be considered. Forests cannot be planned to resist a specific impact of a certain event.
3. The impact of the protection measure depends on natural cycles.
4. The effect is area-wide.
5. Forests and hazard processes interact with each other.

Thus, due to these peculiarities, some deviations with regard to the interpretation of the principles are necessary when protection forests are assessed according to the procedure defined in PROTECT:

Principles 1 and 2 (Quantifiable Effect and Uncertainties)
It depends on the process to what extend the impacts of protection forests are quantifiable and whether the quantified impact exceeds the uncertainties. For avalanches, fall processes and shallow landslides, these principles are normally fulfilled.

Principle 3 (Scenarios)
Scenarios refer to events with differing probabilities of occurrence. The risk for an overload in forests may exceed that of technical measures since a forest is not planned to resist an event of a certain return period.

Principle 4 (System Delimitation)
The entire system includes the whole process area including forest and technical measures. Single systems describe a certain forest stand in a subterritory, e.g. the forest in the starting zone of an avalanche.

Principle 5 (Permanent Availability)
According to PROTECT, the protective effect should be ensured for at least 50 years (on condition that the measure is maintained). The return period of damages relevant to protection as storms, harmful organisms or forest fires at a specific site exceed 50 years even on pessimistic assumptions. Thus, permanent availability can be assumed. This does not mean that relevant damages never occur, but relevant events are rare and the protective functions do not disappear completely after a damage since laying wood and resilience (ability for

regeneration of protection forests in case of damaging events) is often able to compensate the damage partially.

Principle 6 (Monitoring and Surveillance)

The guideline "Sustainability and success monitoring in protection forests" (Frehner et al. 2005) is a tool that enables the monitoring and surveillance of protection forests at minimal costs. The need for action is derived from comparing the current state of the forest with the target profile, taking into account natural forest development. Local experts are responsible for both monitoring and surveillance which are a part of the forest planning.

Principle 7 (Temporary Measures)

Temporary measures are not considered when assessing the impact of protection forests. In the event of damages relevant to protection, temporary measures as laying wood may gain in importance.

Principle 8 (Planned Measures)

With the exception of reforestations, planned measures are of no significance.

Principle 9 (Time)

Changes in both the protective measures and hazard processes are considered by updating the target profiles for hazard processes in the guideline NaiS (Frehner et al. 2005) periodically.

Table 2: Relevance of the protection measure „forest" and its assessability. Green: relevance is possible and assessable. Yellow: relevance is only partially possible or relevance is only partially assessable. Red: no relevance or relevant, but not assessable.

Natural hazard process		**Relevance of protection measure "forest"**	
		possible	**assessable**
Avalanches	● Flowing avalanche	yes	yes
	● Powder avalanche	yes	yes
	● Snow glide	yes	yes
	● Ice avalanche	no	-
Fall	● Rock fall	yes	yes
	● Rock slide	yes (only small events)	yes
	● Rock avalanche	no	-
	● Ice fall	yes	yes
Water	● Flooding	yes	rarely
	● Debris flow	yes	yes
	● Erosion	yes	yes
Spontaneous landslides	● Shallow	yes	yes
	● Intermediate	yes	no
	● Deep	yes	no
Permanent landslides	● Intermediate	yes	no
	● Deep	yes	no
Sinkhole / Subsidence	●	yes	no

To sum up, the principles of PROTECT are applicable to protection forests when some peculiarities of biological measures are taken into account. Thus, the procedure for technical measures according to Figure 1 (steps 1-3) is in principle transferable to protection forests. Furthermore, it was evaluated for which gravitational natural hazards a relevance of forests can be expected and, additionally, if this relevance is assessable. Table 2 gives an overview of this evaluation.

RAPID ASSESSMENT

The rapid assessment, as the first step after the preparation according to Figure 1, aims at giving a first overview of the situation and includes an estimation of the relevance of the protection measure. This evaluation reveals whether the measure has a relevant impact on the hazard and whether a more detailed investigation is appropriate.
Thus, the rapid assessment should be practicable with minimal effort, i.e. as far as possible without fieldwork and complex calculations. Criteria used for the rapid assessment of a forest are, for example, the percentage of forest cover and its location in the process perimeter, stand characteristics like the canopy cover and the differentiation between stands that effectively have a protective effect and such which are presumably ineffective (e.g. young forests).

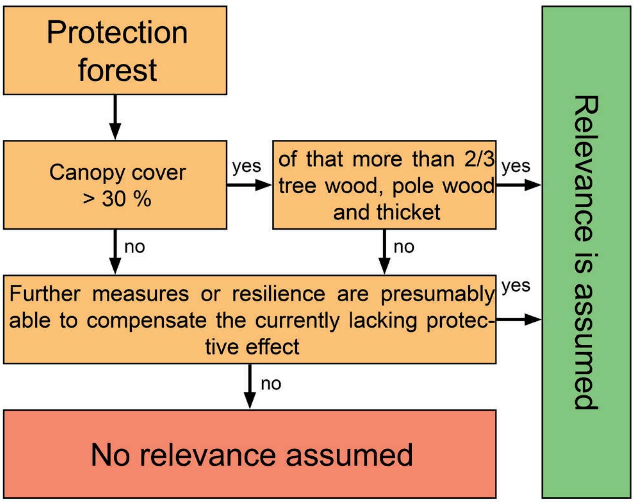

Figure 2: Approach for the rapid assessment of protection forest in the starting zone of avalanches

Within the framework of ProtectBio, decision schemes for frequent natural hazard processes were developed to simplify the rapid assessment. An example of such a scheme, concerning the relevance of the forest in starting zones of avalanches, is shown in Figure 2.

EVALUATION OF MEASURES

In this step, the reliability of protective measures is assessed with regard to their impact on the hazard process. According to PROTECT, the reliability depends on the structural safety of the measure, its serviceability and durability. The structural safety is the ability to resist an impact. As an example, a forest in an avalanche starting zone should resist a certain snow load. Thus, tree species and the coefficient of slenderness determine the structural safety in this case.

The serviceability is the capacity of a forest to guarantee its protective function and depends on both the protection aim for the damage potential and the resulting state of the forest. It is assumed that serviceability is given if the condition of the forest fulfills the minimum target profile according to the guideline "Sustainability and success monitoring in protection forests (NaiS)" (Frehner et al. 2005).

Durability means that the structural safety and the serviceability of a protective measure are ensured for at least 50 years (on condition that the measure is monitored and maintained). Crucial is the current condition of the protection forest and the probable development over 50 years according to NaiS (Frehner et al. 2005) as well as the probability of relevant

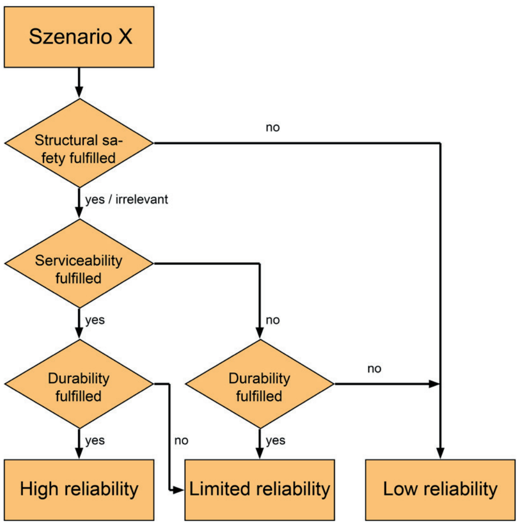

Figure 3: Evaluation of measures: determination of the reliability based on structural safety, serviceability and durability (according to Wasser & Perren 2014)

damages. Moreover, regeneration is of large importance and, thus, ungulate browsing as a factor that affects tree establishment, growth and mortality.
To sum up, the reliability of a protection forest is determined according to Figure 3 based on the assessment of its structural safety, its serviceability and durability. Currently, the reliability is determinable for hazard processes whose relevance is assessable according to Table 2.

EVALUATION OF EFFECTS

The evaluation of effects quantifies the significance of the protection measure to the hazard process and therefore to the risk for the damage potential. Stand characteristics that cause protective function are natural hazard specific. Consequently, parameters allowing the quantification of the protective function of a forest such as canopy cover (avalanche) or basal area (rockfall) have to be known and methods to quantify this influence must be available. These methods range from physically or probabilistic based models to expert evaluations and calculations and indirect evaluations.

Existing approaches evolve and new methods are developed. Thus, the here presented statements about the quantifiability of the forests' protective function represent the current state of the art. Usable to good quality quantifications are possible for hazard processes whose relevance is assessable according to Table 2.

Open questions remain especially regarding landslides and floods. Even though there is an impact of forests to the water cycle and therefore to flood protection, it is rarely possible to quantify this connection. In hydrological models the forest is sometimes incorporated by adjusting the discharge coefficient or discharge measurements in forested watersheds include the impact of the forest implicitly. For shallow landslides, there are some efforts to include the influence of roots on the stability of slopes into models (e.g. Schwarz et al. 2012). Thus, significant improvements to validate the impact of the forest on soil stability are expected in the near future.

CONCLUSIONS AND OUTLOOK

ProtectBio shows that the procedure for assessing the effect of technical protection measures is in principle applicable to biological measures such as protection forests.
Wherever hazard and risk assessments are made, the protective effects of forests should be adequately addressed in the future. As part of a comprehensive variant study of different protection measures, biological systems should be considered as possible alternatives to technical measures. Often, the variant studies do not lead to a clear preference of either a technical or biological solution but rather an optimal combination of both. For example, the better the effects of rock fall protection forests are assessable, the more accurate additional rock fall protection nets can be planned and designed. This combination suits therefore the demands of the integrated risk management.

ProtectBio is not suitable for an area-wide application. The associated effort would be disproportional high. However, it makes sense to use it wherever detailed risk assessments and planning of protection measures are made. So far, ProtectBio has not been applicable as an automated processes, e.g. in a GIS, since georeferenced data of forest characteristics are rarely available. Moreover, the effect of protection forests on intermediate and deep landslides as well as on flooding is hardly quantifiable with existing approaches. Consequently, more research is needed in these areas. Furthermore, there are still open questions regarding the influence of gaps, openings and gullies in the forest cover. Not only size and number of openings and gullies are crucial for the resulting risk, but also their location in the transit area. Again, further work is necessary to gain simply applicable criteria. But overall, Protect-Bio enables the evaluation of the reliability and effectiveness of protection forests and their inclusion in the integrated risk management.

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