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> Sustainability and success monitoring in protection forests

Guidelines for silvicultural interventions in forests with protective functions

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Project part-financed by the European Union

Published by the Federal Office for the Environment FOEN
Bern, 2007

Impressum

Significance of this publication

This publication is a partial translation of the implementation guide „Nachhaltigkeit und Erfolgskontrolle im Schutzwald NaiS" published by the Federal Office for the Environment (FOEN). The translation has been realised in the frame of the Interreg III C project „Network Mountain Forest", and with its financial support.

Issued by

Federal Office for the Environment (FOEN), CH-3003 Bern
www.umwelt-schweiz.ch
FOEN is an office of the Federal Departement of Environment, Traffic, Energy and Communications (DETEC)

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Suggested form of citation

FREHNER, M.; WASSER, B.; SCHWITTER, R., 2007: Sustainablity and success monitoring in protection forests. Guidelines for managing forests with protective functions. Partial translation by Brang, P.; Matter, C. Environmental Studies no. 27/07 Federal Office for the Environment (FOEN), Bern, 29 p. + 26 p. Appendix.

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www.environment-switzerland.ch
Order number and price:
UW-0727-E/CHF 10.– (incl. VAT)
The original publication is available in German, French and Italian.
(Order number VU-7005-D/F/I)

Contents

Abstract

This publication is a partial translation of the implementation guide *Nachhaltigkeit und Erfolgskontrolle im Schutzwald NaiS.* This guide is a practical tool intended to ensure a permanently effective protection forest at a minimum cost. The partial translation is intended to promote the basic principles of silvicultural decision-making in protection forests. These principles are explained in the first section. Based on the assumption that the state of a forest is crucial to its ability to provide effective protection against natural hazards, silvicultural target profiles are described for different site types and natural hazards. The target profiles for natural hazards are explained in some detail in Appendix 1. The profiles for the site types have not been translated since they are very specific for mountain forests found in Switzerland. The procedure for determining the need for action in indicator plots can also be used as an aid in the planning of protection forest management. Success monitoring includes an effectivity analysis on indicator plots to test silvicultural interventions as well as a target review to ensure that new insights from research and practice are included in the target profiles.

Keywords: Sustainability, protection forest management, natural hazards, risk management, success monitoring, controlling

Preface

This publication is a partial translation of the implementation guide *Nachhaltigkeit und Erfolgskontrolle im Schutzwald NaiS* (Sustainability and success monitoring in protection forests) that has been realised within the frame of the Interreg project III C Network Mountain Forest. The partial translation is intended to promote the basic principles of silvicultural decision-making in protection forests as described in the implementation guide.

The NaiS system conveys current knowledge about forest effects and the protection from natural hazards provided by forests, in a form suitable for practical use. It was developed in close collaboration with researchers and practicioners.

Success monitoring in a protection forest is difficult because growth processes in mountain forests are slow and natural hazards have irregular frequencies. The NaiS system recommends a form of success monitoring based on three aspects. These are: an implementation assessment, an effectivity analysis on indicator plots to check the long-term effects of silvicultural measures, and a target review. With these tools, it should be possible to demonstrate the effects of protection forest management and the efficient use of public funding, thus justifying better the need for such funding. However, the guidelines function only if implemented on site by trained individuals. They cannot replace know-how, observation, professional judgment and decision-making skills.

Many thanks to all the authors, those working in the field, in research, in teaching, in administration as well as other areas, for contributing to these farsighted guidelines. I also wish to thank those who carefully translated these guidelines into English to make them available to an international audience.

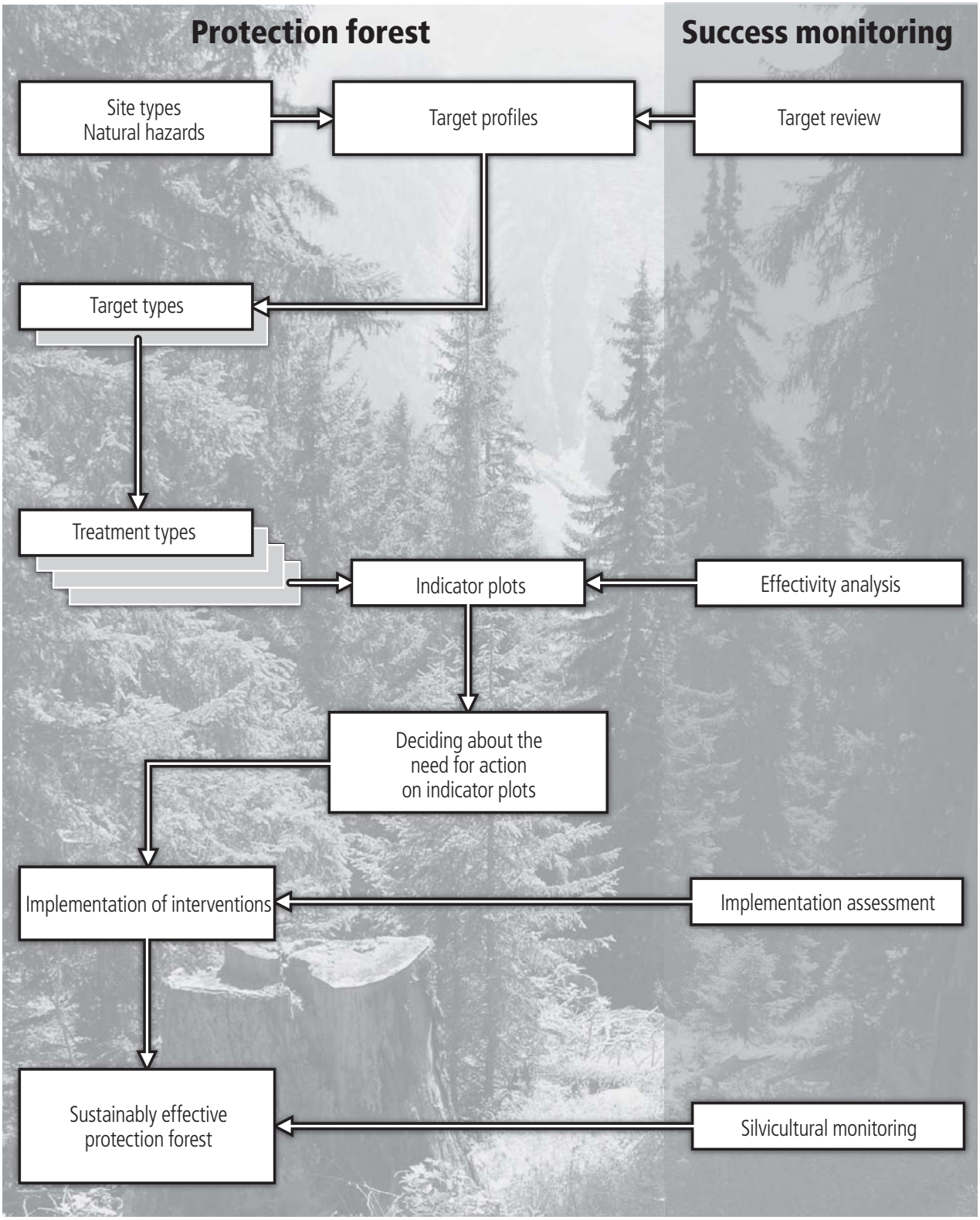
Federal Office for the Environment
Andreas Götz
Deputy director

Acknowledgements

The project *Sustainability and success monitoring in protection forests* has been carried out at the request of FOEN with support from the Cantons and the Centre for mountain forest management. The resulting guide became possible through extensive teamwork involving many experts and institutions during four years. Colleagues working in the field, administration, education and research have attended conferences, workshops and field excursions, with the aim to draw from practical experience and research and develop a product for practical use. The editor would like to thank all those who have contributed to this project, in particular:

- the project team:
  Dr. Monika Frehner, Brächt Wasser and Raphael Schwitter
- the advisory working group:
  Prof. Dr. Harald Bugmann, Werner Frey, Dr. Walter Schönenberger, Jean-Jacques Thormann and Jürg Walcher
- many experts and colleagues from administration and practice:
  Dr. Frederic Berger, Dr. Uehli Bühler, Dr. Jacques Burnand, Gabriele Carraro, Dr. Hansueli Frey, Heinz Nigg, Dr. Dani Rüegg, Dr. Reinhard Schnidrig and Kaspar Zürcher
- many researchers at WSL and SLF, in particular:
  Dr. Peter Bebi, Albert Böll, Dr. Peter Brang, Marco Conedera, Dr. Philippe Duc, Werner Gerber, Dr. Peter Lüscher, Christian Rickli and Dr. Josef Senn
- those responsible for the case studies in Amden-Weesen and Ritzingen:
  Dr. Rolf Ehrbar and Fredy Zuberbühler
- the members of the Swiss Mountain Forest Management Group (Schweizerische Gebirgswaldpflegegruppe GWG)
- the members of the Jura Mountain Silviculture Group (Groupe Jurassien de Sylviculture GJS)
- the members of the Expert Group for Natural Hazards (Fachgruppe für Naturgefahren FAN)
- the members of the Swiss Working Group for Forest Planning (Schweizerischer Arbeitskreis für Forsteinrichtung SAFE)
- the forest rangers and forest engineers who supported the field workshops.

Sustainability and sucess monitoring in protection forests



1 Introduction

1.1 Overview

These guidelines are intended to help practitioners interested in ensuring that **protection forests** are sustainably effective at minimal cost.	Chapter 2
Protection forest management is based on the assumption that there is a direct link between the state of the forest and the level of risk. Therefore, depending on the natural hazards and on the local site conditions, **target profiles** for forests are defined to provide the best possible protective effect.	Chapter 3.2 Natural hazards, Appendix 1 Site types, Appendix 2[1]
All stands with the same target profile belong to the same **target type**. Target types are subdivided into **treatment types** according to the current state of the forest. An **indicator plot** is a forest area representative of a treatment type.	Chapter 3.3
The **need for action is derived on indicator plots** from comparing the current state of the forest with the target profile, taking into account natural forest development.	Chapter 3.4 Forms, Appendix 4[1]
Interventions are implemented according to the results of the assessments of the indicator plots. Goal-oriented protection forest management requires a network of indicator plots and basic information from forest planning.	Chapter 4 Use of timber, Appendix 7[1]
The aim of **success monitoring** is to make a protection forest sustainably effective as efficiently as possible.	Chapter 5
The **implementation assessment** ensures that the planned measures have been professionally carried out at the right sites.	Chapter 5.2 Implementation assessment, Appendix 3[1]
The **effectivity analysis** uses the indicator plots to check how the measures implemented and the intentional omissions have affected the state of the forest. This is therefore a form of process control.	Chapter 5.3 Effectivity analysis, Appendix 3[1]
Silvicultural monitoring checks to what degree the state of the forest meets the target profile.	Chapter 5.4
The **target review** helps to clarify whether the target profiles used are appropriate or not.	Chapter 5.5

[1] Appendices 2–7 are unavailable in English.

1.2 The project *Sustainability and success monitoring in protective forests – NaiS*[1]

These guidelines are intended to help practitioners interested in ensuring that protection forests are sustainably effective at minimal cost. Forest managers and authorities should be able to use these guidelines as an instrument for employing public funding efficiently.

The Swiss Law on Forests (Waldgesetz, WaG) enacted in 1991 obliges the Cantons to ensure that forests with a protective function are managed to guarantee protection (Article 20, § 5 WaG). According to Art. 19, § 4 of the Ordinance on Forests (Waldverordnung WaV), minimal interventions are those limited to conserving the protective function and to ensuring permanent stand stability. To implement this, FOEFL (Federal Office of Forests, Environment and Landscape, now the Federal Office for the Environment) issued the guidelines *Minimal forest management for forests with a protective function* in 1996. These guidelines were well received, and increasingly used for planning and implementing silvicultural projects. In the meantime this publication has gone out of print. This new edition is an extended and improved version of the previous guidelines and follows the same principles. The project *Sustainability and success monitoring in protection forests – NaiS* paid particular attention to the following aspects in the revised edition:

- The guidelines were originally developed for application in Alpine regions. However, the methods are in principle applicable everywhere, and can be directly adopted. In the revised edition, many additional site types have been added so that the guidelines are now applicable to protection forests throughout the whole of Switzerland.
- When managing mountain forests, issues related to regeneration usually have most priority. Reference values need to be established for sustainable levels of regeneration to determine silvicultural targets. The target profiles have therefore been extended to include measurable regeneration values.
- Basic principles for dealing with natural hazards have been considerably improved in recent years. These have been incorporated in the new guidelines with supplementary explanatory text.
- The importance of timber as a resource cannot be ignored even in protection forests. While where possible advantage should be taken of economically viable solutions, sometimes at least some of the cut trees must be left in the stand for ecological and protective reasons. In such situations, the guidelines offer improved decision-making support.
- Establishing forest reserves (protected forests) in protection forests may give rise to conflicts. The guidelines show for which site types ecological objectives are consistent with protection forest requirements.
- Silvicultural monitoring can play a decisive role in managing protection forests efficiently and effectively. This section of the guidelines has been considerably improved and supplemented. The procedure has been tested by many forest managers and found very suitable for application in mountain forests.
- The guidelines specify the requirements for forest planning. They overlap in ways with forest planning and are compatible, for instance, with the Forest Development Plan, the management plan and with inventory methods.

The aim of the revised guide is to provide an update on the relevant issues based on new findings and recent experience. It is the result of close cooperation with both researchers and practitioners. The resulting guidelines are therefore up-to-date and have already met with high acceptance.

The guidelines are extensive and informative, but at the same time user friendly. The main part provides an overview of the main goals and principles, and explains the most important steps in managing protection forests sustainably and effectively. The more applied section has been divided into 10 appendices so that practitioners can quickly find the relevant information for specific problems in the area they are managing. Only Appendix 1 has been translated into English.

[1] NaiS in German stands for *Nachhaltigkeit im Schutzwald*

2 What does sustainable management of protection forests mean?

2.1 Forest management and protective effect

Forests often protect people and material assets from natural hazards, by preventing hazards or by reducing their impact. Protection forests are delineated on the basis of an assessment of the hazard potential, the damage potential and the potential effect of the forest. Deciding on the protective status of a forest is up to the authorities and not dealt with in these guidelines.

Protection forest management is based on the assumption that there is a direct link between the level of risk and the state of a forest. The goal of protection forest management is to ensure a forest is as effective as possible in reducing potential damage due to hazards.

The state of the forest aimed for is defined in so-called target profiles which are based on what is known about natural hazards and the local site conditions. These profiles describe stand conditions which should have a strong protective effect (Fig. 1). The target profiles incorporate the attributes tree species composition, stand structure, stability carriers and regeneration.

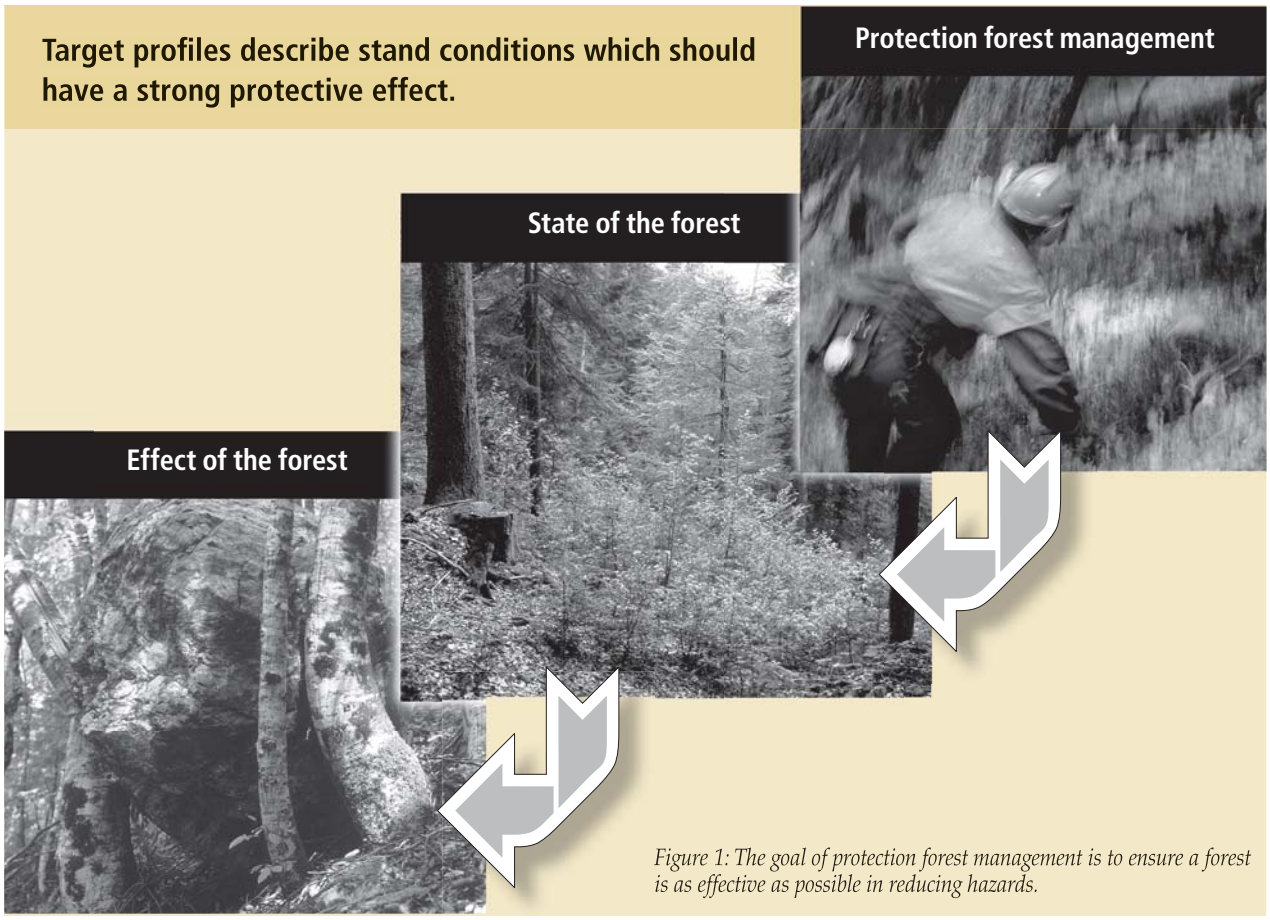


Figure 1: The goal of protection forest management is to ensure a forest is as effective as possible in reducing hazards.

Sustainability in a protection forest implies that the target forest state can be guaranteed in the long term and in the right areas. A rockfall protection forest, for instance, is only effective if it is located directly upslope of the object at risk, and if, in the long term, there are always the required number of stems.

It is difficult to provide direct proof that protection forest management improves safety since it takes considerable time for a silvicultural intervention to affect a forest's state. Moreover, hazard events occur rarely and at irregular intervals. The success of silvicultural interventions is therefore best assessed by monitoring its effects on the state of a forest, and not

directly on hazard occurrence, taking into account what the natural forest development would have been without interventions.

Success monitoring should aim at ensuring that protection forest management is efficient and effective. It should be understood as a monitoring system to help continually improve management practice, and thus steer forest dynamics in the right direction with the least possible effort. Checking the effects of the forest is also part of success monitoring, which thus becomes an instrument for ensuring sustainability in protection forests.

2.2 **Seven principles**

The cantons can prescribe protection forest management if it is in the interests of the public (Chapter 6, legal bases). Any prescribed intervention will be subsidised according to the legislation. However, public funding should be used as efficiently and effectively as possible. Therefore, prescribed silvicultural interventions which are subsidised with public funding must comply with the following seven principles. They must be:

1. **With a focus on the protective target**
   Silvicultural interventions in protection forests serve exclusively to reduce natural hazards.
2. **In the right place**
   Silvicultural interventions are carried out in areas where the forest can prevent or reduce the effects of natural hazards on people and material assets.
3. **At the right time**
   Silvicultural interventions are carried out at that point in time when an optimal effect can be attained with minimal effort.
4. **Consistent with natural life processes**
   Silvicultural interventions are tailored to site conditions to make use of the forces of natural forest dynamics.
5. **Tailored to each stand, transparent, replicable and controllable**
   Silvicultural interventions are determined by experts on the spot. This makes it possible to adapt them to small-scale variation in site factors. A standard decision-making procedure is followed and documented. This makes it transparent, replicable and controllable.
6. **Effective**
   The silvicultural interventions are very likely to lead to the targets.
7. **With reasonable effort**
   The silvicultural interventions have a reasonable cost-benefit ratio.

These guidelines describe requirements and suitable instruments for protection forest management to help put these principles into practice.

3 Determining the need for action

3.1 Principles

The assessment of the need for action is based on a comparison of the current state of a forest with the target profile, taking into consideration the natural forest dynamics.

The minimum profile, i.e. the minimum targets related to natural hazards and the site (Chapter 3.2), serves as a benchmark. This is compared with the predicted probable development in 50 years of the stand without interventions, which accounts for the natural forest dynamics. The comparison is conducted for all important stand characteristics.

There is a need for action if the predicted state of the forest does not meet the minimum profile and if it is possible to improve the situation by taking effective and reasonable action. Deciding which measures are adopted requires a profound analysis of the situation. This analysis is carried out on selected, representative areas, i.e. on the so-called indicator plots.

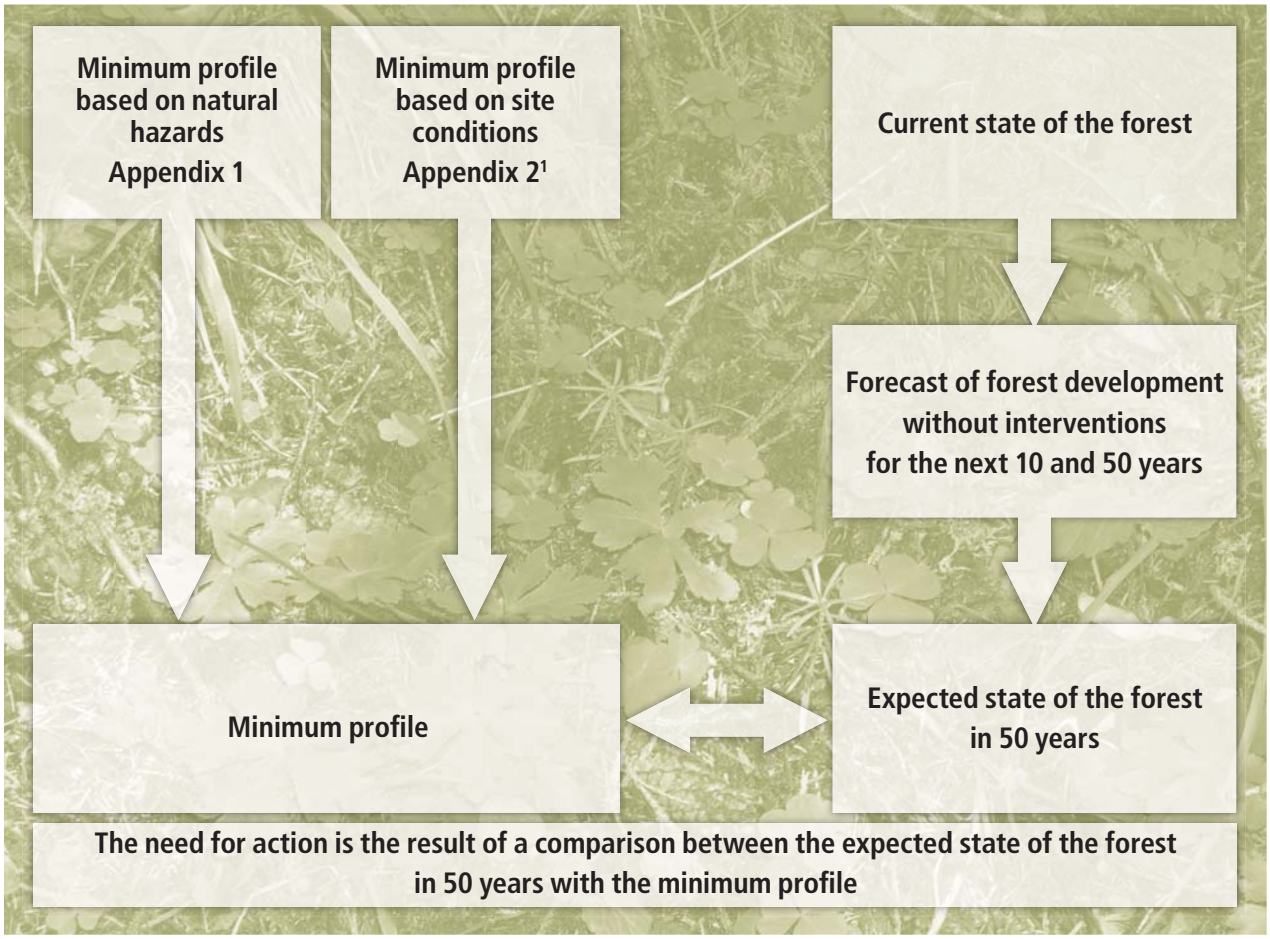


Figure 2: Scheme for deciding about the need for action.

[1] Not translated into English

3.2 **The target profiles**

The target profiles describe the states of the forest that are expected to have a clear protective effect against natural hazards and that can be permanently maintained with minimum effort. The profiles incorporate both site-related targets and targets related to natural hazards. They provide information about the requirements for the stand (mixture, stand structure, stability carriers), the regeneration (new growth, saplings) and the seedbed. There are two target profiles: first, the long-term silvicultural target (ideal profile) and second, the benchmark for the need for action (minimum profile). The target profiles are established mainly on the basis of research results, field observations and practical experience.

Natural hazard:	**Site type:**
Rockfall in the transit zone *Relevant rock size about 50 cm* *Target profile see Appendix 1*	Typical Silver fir-Beech forest on carbonatic bedrock Target profile see Appendix 2B (unavailable in English)

Stand and tree characteristics	**Minimum profile**	**Ideal profile**
Mixture Type and degree	Beech 30–80 % Silver fir 10–60 % Norway spruce 0–30 % Sycamore maple Seed trees	Beech 40–60 % Silver fir 30–50 % Norway spruce 0–20 % Sycamore maple, ash 10–30 %
Structure dbh variation	Sufficient number of trees with development potential in at least 2 different dbh classes per ha	Sufficient number of trees with development potential in at least 3 different dbh classes per ha
horizontal structure	Individual trees, possibly clusters	Individual trees, possibly clusters, canopy closure open
	At least 300 trees/ha with dbh > 24 cm	*At least 400 trees/ha with dbh > 24cm*
	In the case of openings in the fall line, distance between stems < 20 m *Lying logs and high stumps to supplement standing trees, if they are not in danger of falling*	
Stability carriers Crowns	Crown length of silver fir at least 2/3, of Norway spruce at least 1/2	Crown length at least 2/3
Coefficient of slenderness	< 80	< 70
Stand/anchoring	Upright stems, well anchored, few trees leaning at extreme angles	Upright stems, well anchored, no trees leaning at extreme angles
Regeneration Seedbed	Area with strongly competing vegetation < 1/3	Area with strongly competing vegetation < 1/4
Small saplings (10 cm to 40 cm tall)	At canopy closure < 0.6 at least 10 beech/silver fir per 0.01 ha (on average one sapling every 3 m). In openings maple present	At canopy closure < 0.6 at least 50 beech/silver fir per 0.01 ha (on average one sapling every 1.5 m). In openings maple present
Large saplings (40 cm tall to 12 cm dbh)	On each ha, at least 1 group (0.02 - 0.05 ha), on average 1 group every 100 m) or canopy cover at least 4 % Mixture in line with target profile	On each ha, at least 3 groups (0.02–0.05 ha), on average 1 group every 60 m) or canopy cover at least 7 % Mixture in line with target profile

Figure 3: Example for a target profile for rockfall in a typical silver fir-beech forest on carbonatic bedrock.

Site-related targets: The most stable states of a forest are assumed to be represented by the range in varia-tion of development of a natural forest. If the state does not comply with the range in natural forest dynamics (e.g. if there is a Norway spruce stand in a Melico-Fagetum forest, site association no. 8 according to Keller et al. 1998), the forest will be less resistant to disturbances (wind, insects, etc.). This does not imply that all the conditions which can be encountered in a natural forest are advantageous in a protection forest. In particular, extensive pioneer phases mostly offer poor protection.

The *site-related targets* should include all important tree species of the climax stand. The stand structure should be diverse, with single trees or clusters able to resist disturbance, and regeneration should be continuous. The self-regulating processes of the natural forest should be utilised to an optimum so that disturbances to the ecosystem can be avoided or kept to a minimum and the silvicultural interventions in the long term can also be as small as possible. The targets for the individual site types are listed in Appendix 2 (unavailable in English).

Hazard-related targets: The targets for the stand and the single tree to avoid or reduce the effects of dangerous natural hazards are specified. These requirements mainly concern the stem number, the size of the openings in the stand and the canopy density. The targets for avalanche, rockfall and flood prevention forests and for forests in active landslide and debris flow areas are listed in Appendix 1.

The minimum profile: The minimum profile is made up of the *minimum* targets of the relevant natural hazard (see Appendix 1) and the *minimum* targets of the applicable site type (see Appendix 2B, unavailable in English). A forest fulfilling the requirements of the minimum profile is expected to provide sufficient protection in the long term. The minimum profile serves as a benchmark to decide whether or not there is a need for action. Applying the same *standard* to all protection forests enables us first to identify where interventions in protection forests are necessary, and second to set priorities for public funding. The decision-making process thus becomes transparent.

The ideal profile: The ideal profile is made up of the *ideal* targets of the relevant natural hazard (see Appendix 1) and the *ideal* targets of the applicable site type (see Appendix 2B, unavailable in English). The ideal profile describes a forest condition which is expected to have the greatest protective effect in the long term.

Long-term silvicultural target: The long-term silvicultural target normally corresponds to the ideal profile (greatest protective effect in the long-term). Should there be other important interests (e.g. providing a habitat for capercaillie), the long-term silvicultural targets can lie between the ideal profile and the minimum profile (sufficient protective effect in the long-term). The leeway between the ideal profile and the minimum profile can also be used to minimise the long-term silvicultural intervention costs.

The target profiles were drawn up by researchers and practitioners in cooperation. They reflect the current state of knowledge. In view of their importance for decision-making, the profiles must be reviewed periodically as part of a target review (Chapter 5.5). The characteristics and categories were chosen so as to correspond wherever possible with those of the Swiss National Forest Inventory.

The profiles should be modified when applied only if local site features make it absolutely necessary. In this case the site-related targets should be adapted to the local features.

Source: Keller W., Wohlgemuth T., Kuhn N., Schütz M., Wildi O. 1998. Waldgesellschaften der Schweiz auf floristischer Grundlage. Statistisch überarbeitete Fassung der "Waldgesellschaften und Waldstandorte der Schweiz" von Heinz Ellenberg und Frank Klötzli (1972). Mitteilungen der Eidgenössischen Forschungsanstalt für Wald, Schnee und Landschaft 73, 2: 91–357.

3.3 **Target and treatment types**

The target profiles established on the basis of natural hazards and site types not only apply to individual stands but also to larger areas with similar conditions. All areas to which the same target profile applies are considered to belong to the same *target type*.

Within one target type, stands in very different states needing rather different interventions can occur. Areas within a target type which require the same type of intervention to a similar extent are called *treatment types*.

Target type
Compilation of stands with the same target profile. Stands belonging to the same target type do not necessarily lie in a contiguous area.

Treatment type
All stands within a target type in similar condition and requiring the same intervention. Stands belonging to the same treatment type do not necessarily lie in a contiguous area.

Determining target types on a map (Figure 4) gives an overview of the long-term targets for the protection forest interventions in the whole area. The treatment types provide the bases for planning and implementation measures.

For the assessment of the need for action, a so-called indicator plot, which is as representative as possible of every target type or treatment type, is selected.

Indicator plot
Area representative of a treatment type. Its size depends on the homogeneity of the stand (0.5 to 1 ha).

Indicator plots allow exploration of silvicultural questions. Later on, they can be used for success monitoring. Test results from indicator plots can be transferred to the whole forest area within the same treatment type.

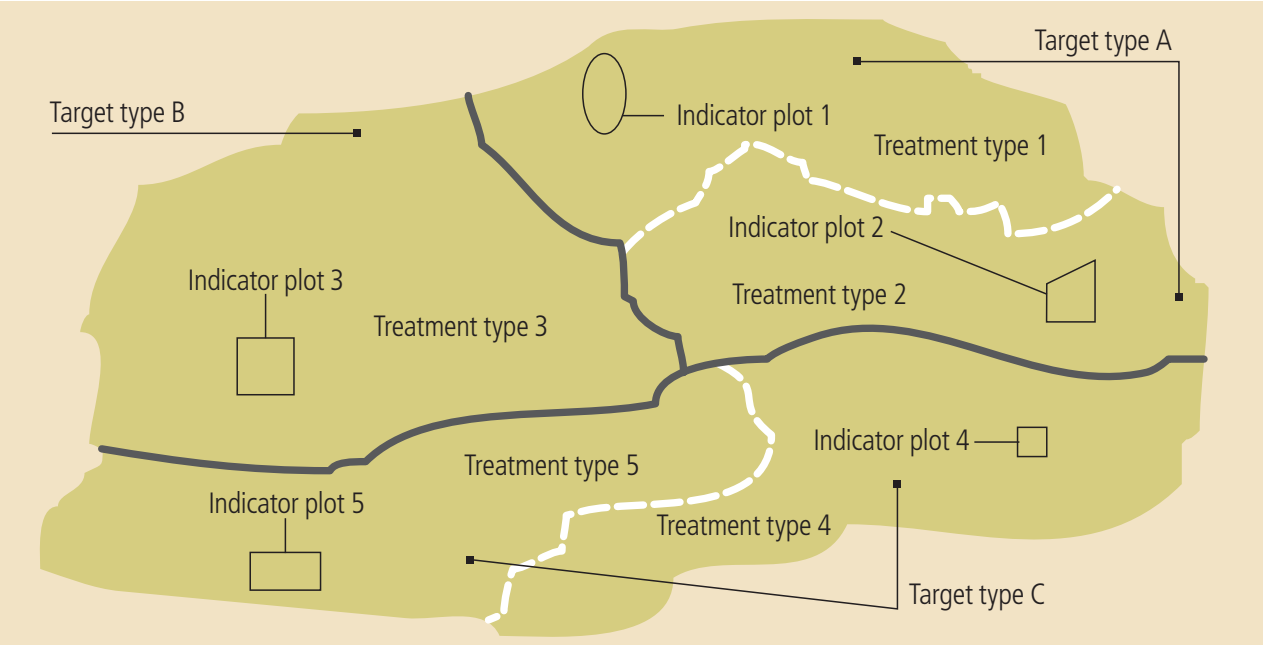


Figure 4: A planning area is subdivided in target and treatment types. An indicator plot is representative for a particular treatment type.

In areas with very diverse site conditions, the number of target and treatment types can become very large. For the sake of clarity, it may then be necessary to group the site types before specifying the target types. In this case, only similar site types with similar target profiles should be assign-ed to the same group.

If a stand map and a detailed stand description are available, target profiles can be directly assigned without delineating target and treatment types. A prerequisite for this is that the site conditions and the hazard potential are known.

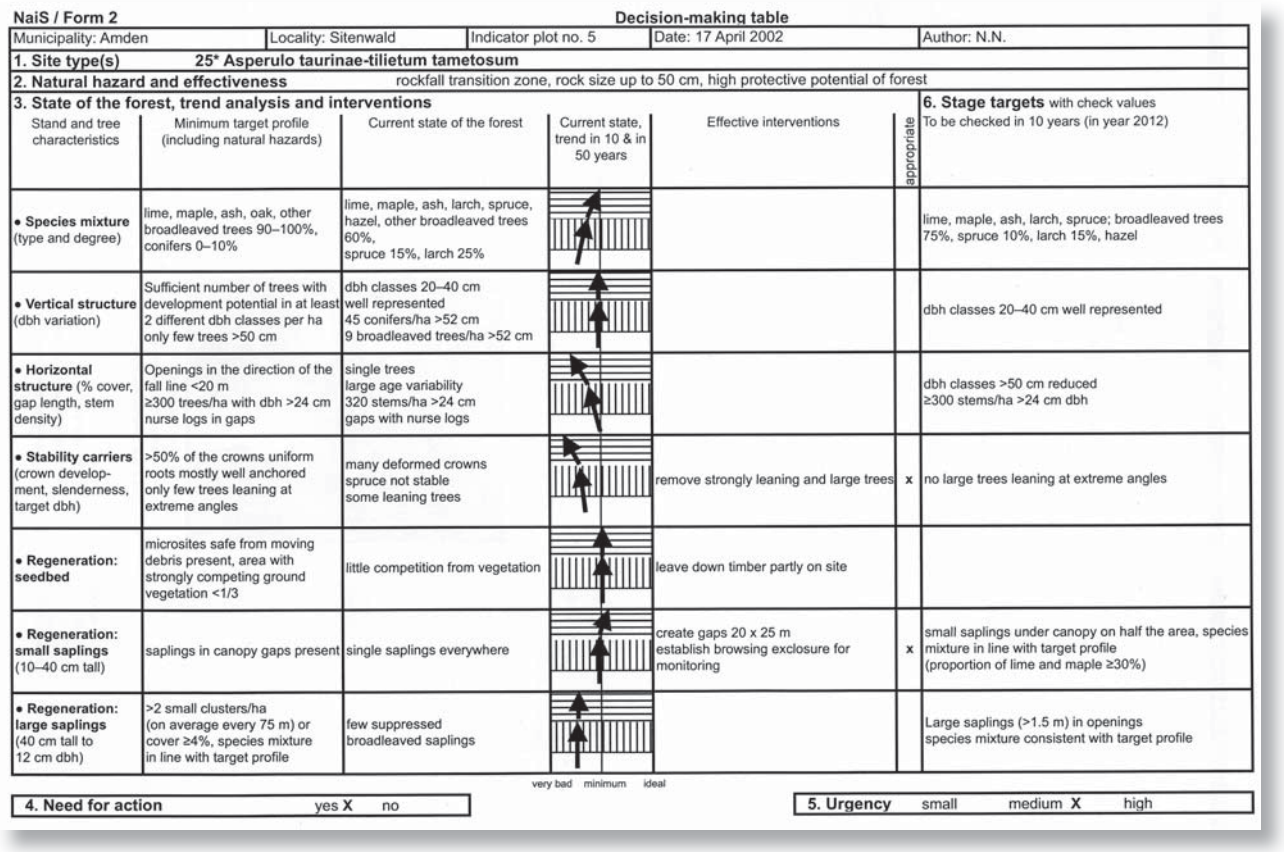
3.4 **Decision-making procedure on indicator plots**

Deciding what is the need for action on the indicator plots is the most important procedure in the planning of sustainable protection forest management. To this end a treatment concept for the most important treatment types must be elaborated. Both the planned measures and the intentional omissions should be transparent, traceable and controllable. To achieve this, the following conditions must be fulfilled:

- It must be easy to relocate the indicator plots. The targets, the objectives and the scope of the indicator plots must be defined.
- Decisions about the need for action and the corresponding information must be recorded in such a way that another professional can follow the decision-making process.
- The bases for estimating costs and deciding on the utilisation of the timber must be transparent.
- The documentation must be available for an effectivity analysis (Chapter 5.3).

To select indicator plots within a planning area, various factors as described in Chapter 4.1 need to be considered. It is advisable to establish each indicator plot and to collect the necessary information before doing the silvicultural analysis.

It is important to involve the local forest managers in the decision-making procedure on the indicator plots. They are familiar with the local conditions and also responsible for the implementation of the treatments. Form 2 (Figure 5) helps make the decision-making procedure transparent and traceable.



NaiS / Form 2 — Decision-making table

Municipality: Amden	Locality: Sitenwald	Indicator plot no. 5	Date: 17 April 2002	Author: N.N.

1. Site type(s) 25* Asperulo taurinae-tilietum tametosum

2. Natural hazard and effectiveness rockfall transition zone, rock size up to 50 cm, high protective potential of forest

3. State of the forest, trend analysis and interventions

Stand and tree characteristics	Minimum target profile (including natural hazards)	Current state of the forest	Current state, trend in 10 & in 50 years	Effective interventions	appropriate	**6. Stage targets** with check values To be checked in 10 years (in year 2012)
• **Species mixture** (type and degree)	lime, maple, ash, oak, other broadleaved trees 90–100%, conifers 0–10%	lime, maple, ash, larch, spruce, hazel, other broadleaved trees 60%, spruce 15%, larch 25%				lime, maple, ash, larch, spruce; broadleaved trees 75%, spruce 10%, larch 15%, hazel
• **Vertical structure** (dbh variation)	Sufficient number of trees with development potential in at least 2 different dbh classes per ha only few trees >50 cm	dbh classes 20–40 cm well represented 45 conifers/ha >52 cm 9 broadleaved trees/ha >52 cm				dbh classes 20–40 cm well represented
• **Horizontal structure** (% cover, gap length, stem density)	Openings in the direction of the fall line <20 m ≥300 trees/ha with dbh >24 cm nurse logs in gaps	single trees large age variability 320 stems/ha >24 cm gaps with nurse logs				dbh classes >50 cm reduced ≥300 stems/ha >24 cm dbh
• **Stability carriers** (crown development, slenderness, target dbh)	>50% of the crowns uniform roots mostly well anchored only few trees leaning at extreme angles	many deformed crowns spruce not stable some leaning trees		remove strongly leaning and large trees	x	no large trees leaning at extreme angles
• **Regeneration: seedbed**	microsites safe from moving debris present, area with strongly competing ground vegetation <1/3	little competition from vegetation		leave down timber partly on site		
• **Regeneration: small saplings** (10–40 cm tall)	saplings in canopy gaps present	single saplings everywhere		create gaps 20 x 25 m establish browsing exclosure for monitoring	x	small saplings under canopy on half the area, species mixture in line with target profile (proportion of lime and maple ≥30%)
• **Regeneration: large saplings** (40 cm tall to 12 cm dbh)	>2 small clusters/ha (on average every 75 m) or cover ≥4%, species mixture in line with target profile	few suppressed broadleaved saplings				Large saplings (>1.5 m) in openings species mixture consistent with target profile

very bad minimum ideal

4. Need for action yes X no

5. Urgency small medium X high

Figure 5: Form 2 serves to decide about the need for action. It lists the requirements of the minimum profile (tree mixture, stand structure, stability carriers, seedbed, seedlings and saplings). It documents the assessment and the decisions for the later success monitoring.

Explanation of the decision-making procedure in Form No. 2

The **minimum profile** is derived from the identified natural hazard (Appendix 1) and the site type (Appendix 2B, unavailable in English). Appendix 2A (unavailable in English) also includes some tips for identifying the site type.

The next step is to record the same characteristics as those used in the minimum profile (tree mixture, stand structure, condition of the stability carriers, seedbed, small and large saplings) on the indicator plot. In many cases it is useful and necessary to record additional information regarding the **stand's condition** (Appendix 4, Form 3, unavailable in English).

Since the forest continually changes even without interventions, forecasts are made for all the characteristics for the next 10 and 50 years assuming a **natural forest development**. The expected development is marked with arrows. With this procedure the natural dynamics of the forest can be taken into account when deciding whether or not an intervention is necessary.

In making this decision, the expected condition of all the characteristics in 50 years is compared with the minimum profile. If the conditions are forecast to be worse than the minimum profile, **effective interventions** should be considered to improve the development. Provided the recommended interventions can be assessed as **reasonable**, there is a **need for action**. Should there be a need for action, the necessary interventions are normally fine-tuned to the ideal profile as a long-term silvicultural target. For later success monitoring, it is important that any intentional omission is also documented, i.e. it must be noted when interventions are not carried out and why.

To assess the **urgency of an intervention**, the current state of the forest is considered as well as the speed and the direction in which the stand could develop without

interventions. According to Principle 3 (Chapter 2.2), silvicultural interventions should be made at the point in time when the required impact can be achieved with a minimum input.

Stage targets are intermediate targets as steps towards realising the long-term silvicultural targets. They are to be reached within a time span of 5 to 10 years. The stage targets serve later as important references for a later effectivity analysis (Appendix 3, unavailable in English).

There is some leeway when defining the stage targets. In principle a stage target should not be below the minimum profile. Usually, it is a step in the direction of the ideal profile. If the initial condition is bad, this requirement cannot always be complied with. Some leeway can also be given to consider other interests (e.g. nature conservation, timber production) in the forest besides effective protection (cf. Appendix 4, Form 2, unavailable in English).

Following this decision-making procedure can also help in **estimating costs** (Appendix 4, Form 4, unavailable in English). In this connection the decision about **how to use the obtained timber** is important. First it must be clarified whether the timber is to be left in the stand for ecological or protective reasons (cf. Appendix 7, unavailable in English).

Normally the procedure described above serves both planning and success monitoring. Experience shows that cost estimations often require information about other treatment types. In such cases it is advisable, with the help of Forms 2 and 4, to process other areas. These are not normally subject to long-term monitoring.

A stand description can be used to quantify the interventions and expenditures more precisely.

3.5 Deciding on interventions for a planning area

The information gained from studying the indicator plots provides a good overview of the interventions in a particular planning area and their costs. The accuracy of these estimates, however, depends on the variety of the treatment types, the information contained in the stand maps and the selected net of indicator plots (Chapter 4.1).

For the implementation of the interventions within a planning area, the targets and the interventions must be clearly identifiable on the basis of a recent analysis for all intervention units, i.e. contiguous areas which receive the same silvicultural treatment.

As a rule the decisions made on the indicator plots serve as a reference for all intervention units within a specific treatment type. The corresponding information, especially the type and the scope of the interventions (Form 2), can be taken over directly. Naturally the practitioner will nonetheless have to tailor the intervention to the specific local situation.

If an intervention unit is not represented by an indicator plot (i.e. if there is no indicator plot with the same target profile and similar condition), the decisions can be made immediately before the intervention, analogous to that on the indicator plots (Form 2). Unlike the indicator plots, no long-term monitoring is done in this case. Therefore, the standards regarding the level of detail and precision of the survey are lower. This method has the big advantage that the silvicultural planning is always up-to-date because the planning and execution of the interventions are temporally close together.

This procedure results in the collection of the most important information required for an annual work program and the budget, which permits an easy analysis of the interventions in the field (Chapt. 5.2 and Appendix 3, analysis of interventions, unavailable in English).

4 Requirements for a planning scheme

4.1 The network of indicator plots

Establishing and managing indicator plots is relatively costly. It is therefore advisable to select them carefully so that their long-term utility can be assured.

The indicator plots are representative of many other stands, so they can be used to determine the appropriate tar-get profile, to analyse the need for action and to assess the effect of certain interventions. The findings and experiences gained from the indicator plots serve as guidelines for all stands within the treatment type.

The significance of the indicator plots:

- The need for action (Chapter 3) is determined on the basis of just a few areas, but with an in-depth examination of the relevant silvicultural questions.
- Important information is obtained that provides a basis for planning (targets, priorities for interventions, cost estimation, effectivity analysis).
- Detailed assessments, observations and documentation of the forest development on the indicator plots are preconditions for the effectivity analysis, which is part of success monitoring (Chapter 5).
- The management of the indicator plots promotes manager skills (on the job training) and ensures that the knowledge gained is rapidly implemented. The indicator plots form the basis for success monitoring in protection forest management (controlling).
- Indicator plots can be used as a basis for teaching and further education, and are also useful for performing convincing public relations campaigns.

Selection: Indicator plots are selected by dividing a planning area into target and treatment types. In practice, it is rarely possible to select an indicator plot for every treatment type. In selecting the areas, it is advantageous to prepare a table with the most important target types in an area, and with the most silviculturaly delicate treatment types. If the stands within a target type have a similar structure, just one single indicator plot can, in some circumstances, be sufficient. If there are clear differences between the stands, it may be necessary to delineate several treatment types within the same target type, and to select the corresponding number of indicator plots. A stand map with a detailed stand description facilitates the well-targeted selection of the relevant areas.

The selection can also be used to inform the public about the concrete silvicultural targets for an area (e.g. in a region used for establishing a Forest Development Plan) and, accordingly, about what actions are to be taken in protection forests.

Number of plots: Basically the diversity of the natural conditions determines the number of target and treatment types and thus the number of indicator plots. However, determining the number of indicator plots is a process of optimisation. On the one hand, the areas of protection forest represented by the indicator plots should be as large as possible and, on the other hand, the management efforts required must be reasonable. The following considerations can help make the appropriate selection:

- The number of target types can be reduced if stand types with similar target profiles are grouped together.
- Treatment types covering a proportionally large area have more weight.
- Treatment types where the effect of the silvicultural intervention is uncertain are important for the effectivity analysis.
- Preference should be given to selecting indicator plots in areas where it is suspected that alternative interventions or even no intervention can also lead to the target.
- Additional areas can be used to determine the need for action in silvicultural planning (Form 2, Figure 5), without these subsequently being used as indicator plots.
- A network of indicator plots across several management units can be shared if managers cooperate across borders in establishing indicator plots.

Experience shows that a forester with a traditional range of about 1000 ha size can manage, on average, three to seven indicator plots. Moreover, for every 50 to 100 ha forest area, one indicator plot is necessary. This framework

should make it possible to focus on the most important problems in the protection forests with well-selected indicator plots. The managers should have enough opportunity to monitor the effects of their interventions without excessive extra work.

Indicator plot size: The size of an indicator plot is governed mainly by the stand structure. As a rule smaller plots are chosen in homogenous stands and larger plots in heterogeneous stands. Experience has shown that the ideal size lies between 0.5 ha and 1.0 ha. Areas of approximately 1 ha are suitable in e.g. mountain selection forests, whereas areas of approx. 0.5 ha are adequate for young stands up to pole size. As the indicator plots will be monitored over a long period with in general a heterogeneous structure as the goal, the indicator plots should not be too small in homogenous treatment types.

Quality and input: The indicator plots are important for managing protection forests, which means the surveys and observations must be reliable, and it should generally be clear where and when they were made. This requires accurate surveys and documentation. This is only possible if sufficient time is available. Experience has shown that a two-person team takes one to two days to establish an indicator plot (incl. documentation). The time required for the follow-up surveys varies according to the characteristics to be recorded and the observation cycle. On average, half a day per plot and year (incl. documentation) is required.

Continuity: The explanatory power of the effectivity analysis increases the longer the period of observation. Many questions can only be answered after a number of years or even after decades. It is therefore important to ensure that observations on the indicator plots can take place in the long term, for example, by linking them with forest planning.

Maintenance: The forest services of the cantons are responsible for ensuring that capable personnel carefully and competently establish, maintain and analyse the indicator plots. Decisive here is involving the local forest manager in this process. The supervisors of the indicator plots must be well trained.

4.2 Bases and preconditions for planning

The cantons are responsible for forest planning. For this reason this manual specifies only the minimal preconditions which must be met in order to practise sustainable protection forest management. The definition and the delineation of protection forests are decided on a higher level and cannot be dealt with here.

Planning area: The planning of the protection forest intervention should involve large units. The planning areas should be chosen in such a way that the operators (forest owners, forest service) and the beneficiaries (local communities) of the area can identify with the targets of the planning and also feel responsible for it. The planning of protection forest management should be combined with general forest planning. Experience has shown that there is a tendency in small project areas to carry out a relatively large number of severe interventions within a short time. If planning areas are larger and more extensive, there is a better chance that interventions will be carried out at the right time and place. Moreover, selecting target and treatment types is best done with larger planning areas, where the corresponding network of indicator plots can be laid out and maintained for the long term.

Prerequisites for planning: The selection of the target and treatment types requires information about the protection forest, site conditions and forest conditions.

Protection forest area: When planning protection forest management, a map of the protection forests with information about hazard potential is necessary. The assessment of the hazard processes, the selection of the catchments areas and the evaluation of the damage potential is done during higher-level planning. This manual is intended to help in assessing the potential effectivity of the forest. In Appendix 1, the relationships between hazard processes and forest influences are summarised.

Site: The selection of the target types and the goal-oriented implementation of the planned interventions are based on an overview of the site associations in the whole

area. Ideally this should be a site map. At least all the site types in each stand should be known. The advantage of the site map is that it contains all the information needed for planning and implementation. If this is missing, the local manager should be in a position to assess the site conditions every time an intervention is necessary and to select the correct target profiles.

State of the forest: The selection of treatment types within a target type requires an overview of the state of the forest in the whole area, for instance, in stand maps. Structure-type maps that include the tree species mixture, basal area, top-height and stand layers give a good overview of the state of the forest. The recording of the forest state must be coordinated with management planning. The more accurate the available data, the easier and more exact the planning can be. When implementing the planning, it must be adapted to the current state of the stand to be treated.

Target: With the selection of the target type, the long-term targets for the protection forest are set, based on the target profiles. In view of the relevance for the public, it is advisable to include the target types in the higher-level planning, e.g. in the Forest Development Plan.

Priorities: Priorities can be set at various levels. The point is to decide which area has precedence over others. At the higher level the delineation of the protection forests is already an assessment, but such high-level decisions are not included in this manual.

Within the planning area, the priorities can be determined according to the following possibilities:

- Target types of varying importance: Indications of the potential contributions of the forest in providing protection against natural hazards (large, medium, poor, see Appendix 1), and information concerning silviculture in the various site types (Appendix 2, unavailable in English) allow a differentiated assessment of the importance of the silvicultural interventions for the target types.
- Treatment types with varying urgency: The selection of the treatment types in combination with the derivation of the urgency on the indicator plots gives an indication of the current state of the forest and allows the identification of areas with an above-average need for action. This information, together with that on current variables such as timber prices, available means or operational factors, makes it possible to stagger the interventions expediently.

Continuity: Long-term continuity is essential. Protection forest management cannot be seen as a once-off improvement of neglected stands. Managers must be able to reconsider their decisions and set priorities anew. Traditionally, funding was provided for a period of 5 to 10 years to implement interventions. It was unknown if the protection forest interventions would be further subsidised at the end of a project, so many managers tended to maximise the interventions. If continuity, however, is ensured, it is easier to await the natural development and to shelve interventions. This manual is oriented towards long-term and continuous protection forest management.

Planning periods: Management experience in protection forests, and in mountain forests in general, show that the influence of the managers actually is less than is often thought. Analyses in the experimental plots of the Swiss Mountain Forest Management Group showed that many of the changes are the result of natural influences (storms, avalanches, bark beetles, ungulates, etc.). Effective protection forest management must therefore be tuned to what can be expected in a natural development. The situation must be re-assessed for every intervention before it is carried out.

Experience also shows that detailed planning is often overtaken by natural development after a few years. It is ap-propriate to determine the long-term targets as recommended with the selection of target types. It is possible to estimate the need for action and the costs in the medium term (5–10 years) with the help of the indicator plots. The

cost estimates should be considered as credit rates for a long-term protection forest management. The implementation, i.e. operational planning and carrying out the interventions, is done at short notice, within the framework of the annual programme and the budget.

Success monitoring: Success monitoring involves monitoring the effects of protection forest interventions (Chapter 5). A suitable method must be integrated in a planning concept.

Integral risk management of natural hazards: Forests provide an important, but not the only form of protection against natural hazards. Protection forest management is therefore to be seen as part of an integral management of natural hazards, which includes organizational measures, development planning and technical measures.

5 Success monitoring

5.1 Goal and overview

The goal of success monitoring in protection forests is to achieve a high protective effect as efficiently as possible.

According to the seven principles described above, carrying out interventions must be monitored and their effectiveness verifiable in subsidised protection forest management. Appropriate monitoring should ensure that new find-ings and experiences are fed into practical implementation as fast as possible.

Success monitoring includes the following four stages:

1. Implementation assessment:
   Were the planned interventions completed at the correct location and were they executed professionally?
2. Effectivity analysis:
   What effect do the completed interventions or the selected omissions have on the forest's state?
3. Silvicultural monitoring:
   To what extent does the forest's state correspond to the target profiles?
4. Target review:
   Are the target profiles adequate and appropriate?

Monitoring is part of a closed loop of planning, implementing, monitoring and steering. It is mainly done on two levels of monitoring: the analysis of the interventions and the analysis of effectivity. Silvicultural monitoring provides information for the higher level of forest planning and the target review assesses how appropriate the targets, and especially the target profiles, are.

Success monitoring is challenging and requires contributions to problem solving from professionals from various fields on the different control levels. As it may not be immediately clear why four different levels of monitoring are necessary, what must be *monitored* and who is responsible for what, each level will be described separately. The four levels have not evolved from a preconceived theory but have resulted from a close examination of the relevant issues. To illustrate this, and to emphasise the importance of the four monitoring levels, these issues, phrased as questions, are given before the relevant description.

5.2 Implementation assessment

The implementation assessment checks whether the planned interventions have been carried out at the correct location and with due professional care.

Question: How can we ensure that the implementation of effective and target-oriented silviculture is performed at the correct location?

Solution: Ensure that the implementation of protection forest management can be checked in the field using a simple sampling method.

The goal of the success monitoring is to ensure that the forest management is as effective as possible. The knowledge gained from the assessment of the indicator plots and the later effectivity analysis must therefore be implemented throughout the area as fast as possible.

The implementation assessment is needed to enable the cantonal and federal forest authorities to inform third parties reliably about whether the forest management has been implemented at the correct location, according to the planned framework and professionally. It should be possible to do on the spot checks that require little documentation. An implementation plan, and a basic intervention description for every intervention unit, will, however, be needed.

5.3 Effectivity analysis

Checks made with the effectivity analysis will show whether the interventions realised or deliberately omitted have the wished for effect on the state of the forest.

Question: How can the manager decide which interventions can be applied under which circumstances?

Solution: The manager monitors and documents the effects of the interventions or the deliberate omissions on the indicator plots. The experiences gained from these operations allow the manager to manage the protection forest increasingly more effectively.

The currently valid target profiles, based on the nature of the natural hazards and the sites, can be defined by the federal authorities. In contrast, the interventions must be tuned to the state and potential development of each stand

and to the local conditions (e.g. hazard potential, topography and operational conditions). This means that the interventions are not predetermined but must be defined by trained individuals on the spot. As it is often uncertain which interventions or deliberate omissions are correct or which level of intervention intensity is the most effective, practitioners need an instrument to analyse the effectivity of their silvicultural interventions.

The effectivity analysis is first of all the task of the local managers. The cantonal forest services provide support by ensuring the conditions are suitable. They provide, in particular, for the long-term continuity of the monitoring and documentation and support the managers in carrying out the effectivity analysis (analysis and interpretation).

When applying expert knowledge to the whole protection forest area, the local managers must be the key people for the effectivity analysis. They can observe which interventions or which omissions are successful and thus make sure there is no untimely delay between analysis and implementation and no losses due to lack of local acceptance.

The effectivity analysis on indicator plots is the core element in the silvicultural monitoring in a protection forest. It promotes the professional competence of the manager and therefore enables protection forest management to be highly effective and tuned to local conditions based on up-to-date knowledge. The effectivity analysis is very important, which means the managers must be well-trained and backed by the cantons and the federal government.

5.4 Silvicultural monitoring

Silvicultural monitoring involves checking to what extent the status of the forest corresponds to the target profiles. It serves as an important link to higher planning and monitoring levels.

Question: How can an overview of the condition and development of the protective function of the forests be obtained for a large region (cantons, the whole of Switzerland)?

Solution: The level of protection provided can be monitored by comparing the actual state of the forest with the target profiles. The target profiles are broadly based and take recent findings into account, which makes them therefore suitable measures for silvicultural monitoring.

The maintenance and promotion of the forests' protective functions are anchored in Swiss forest law. The federal government and the cantons use taxpayers' money to manage protection forests. It is therefore just a matter of time until reliable data on protective levels will be needed on the cantonal and federal levels. Performing silvicultural monitoring is, however, not the subject of this manual.

Doing an effectivity analysis on the indicator plots also involves a form of selective silvicultural monitoring and familiarises the managers of the protection forests with this monitoring instrument. This is an important precondition should, at a future date, compensation be based not on the interventions executed (managed area, m^3 of timber harvested, etc.), but on achieving a particular state of the forest.

The target profiles provide the criteria and the thresholds for silvicultural monitoring at a higher level.

5.5 **Target review**

The adequacy and the appropriateness of the target profiles established are checked in a target review.

Question: What influence does the state of the forest have on natural hazards and therefore on risks to people and material assets?

Solution: Protection forest management is based on the assumption that there is a direct link between risk reduction and the state of the forest. This link has been partially demonstrated by research, but should be subject to further study.

Normally it is not known where and when dangerous natural hazards will test the protective function of a managed forest. Moreover, it is hardly likely that both a managed and an unmanaged forest will be put to the test by the very same natural hazard. For this reason it is almost impossible for practitioners to prove the direct effect of the forest and silvicultural management on the safety of people and material assets.

Research can help here by investigating the effect of the forest on the hazard processes through specific monitoring and appropriate experimental designs.

The closer the forest comes to the ideal state, the better is its protective effect and the smaller the risk to people and material assets. This assumption is not really contested. Should, however, the question arise about e.g. the ideal number of stems in a rockfall protection forest or how much cover an avalanche protection forest must have, no definite answer can be given. What still needs to be investigated is whether the minimal and ideal standards aimed for, which are based on the natural hazards as defined in this manual (Appendix 1), can substantially lower the risks in practice. Here the target analysis is used, which is that part of silvicultural monitoring that presents above all a challenge for science.

Question: How can the cost and effort involved in protection forest management be kept to a minimum?

Solution: If protection forest management can optimally use natural forest dynamics, it will require minimum efforts in the long term and be the most effective.

Minimum does not mean as cheap as possible in the short term, but rather at least cost in the long term.

The effort required to maintain a protection forest is thus assumed to decrease the closer to nature the forest becomes. Those states of the forest that are as close to those of natural forests are defined in the manual. The assumption is not disputed in principle, but a periodic check is necessary because of the following three problematic areas:

1. We still have a great deal to learn about the natural dynamics of our forests.
2. How much scope there is for action within the natural dynamics is often unknown (e.g. what should the target diameter be to ensure in the long term there is the required number of stems with an effective minimum diameter?).
3. How strongly does climatic change influence forest dynamics?

Because of these uncertainties, the requirements based on site types (Appendix 2C, unavailable in English) must periodically be reviewed in the target analysis. Forest research and, in particular, practical experience provide the bases for the target analysis. The most important resources for the practitioner will, in future, be the effectivity analysis on the indicator plots.

6 Legal bases

Forest legislation (WaG[1] and WaV[2])

The forest legislation differentiates between

- Minimal management in forests with a protective function (silviculture type B), and
- Silvicultural management in forests with a direct protective function (silviculture type C).

Three conditions must be fulfilled to be able to receive compensation for such interventions in protection forests from the federal government and the cantons. The intervention must:

- conserve and promote the protective function of the forest.
- be directed by the authorities.
- be limited to the sustained conservation of stand stability.

Subsidy legislation (SuG[3])

The subsidy legislation stipulates that financial aid and compensation must be adequately justified and their targets must be achieved by economical and effective means (Art. 1 Paragraphs 1 a and b SuG).

Furthermore, there is an obligation to provide information (Art. 11) and the appropriate authorities must be able to audit the assignment (Art. 25).

To make this possible, the decisions must be transparent and traceable, and the effect of the interventions must be controllable.

Circulars[4]

In Circular 8 from the Swiss Federal Forest Agency, the specific requirements for sustainable protection forest management are subject to the following goals:

Forests with protective functions (silviculture B and C) reduce the risk to people and valuable material assets in their sphere of influence down to an acceptable level.

The necessary silvicultural interventions to achieve a goal differ in silviculture B and C as follows (next page):

Silviculture type B

Article 20, Paragraph 5 WaG

5 Where a protective function requires a minimal management, the cantons ensure it.

Article 19, Paragraph 4 WaV

4 Minimal intervention measures for the conservation of the protective functions are those interventions which are limited to the sustained conservation of the stability of the stand; the accrued timber is to be used in constructions on the spot or it is left in the stands if it poses no hazards.

Article 38, Paragraph 1 a WaG

1 The confederation pays up to 70 percent of the costs of the following interventions:

a. minimal silvicultural interventions of limited duration which are necessary for the conservation of the protective function and are ordered by the authorities;

Article 47, Paragraph 3 a WaV

3 Compensation is made according to Table 1 of the Appendix for:

a. minimal silvicultural interventions according to Article 19, Paragraph 4, which are necessary for conserving and promoting the stability in forests with a protective function.

Silviculture type C

Article 38, Paragraph 1 b WaG

1 The Confederation pays up to 70 percent of the costs of the following interventions:

b. silvicultural interventions in open, unstable and destroyed forests with direct protective function when the total costs are not covered and these interventions are ordered by the authorities.

Article 19, Paragraphs 1–3 WaV

1 All interventions which contribute to conserving or restoring the stability and quality of the stands are considered silvicultural interventions.

2 Interventions in young forest management are:

a. tending of young growth and thickets and thinning in pole stage stands in order to create a stable standing crop;

b. the specific interventions to tend regeneration in single-tree selection forests, in other multi-storied forest, in coppices with standards and coppices as well as in multi-storied forest edges,

c. protective measures against game damage;

d. the construction of trails through areas of difficult access.

3 Interventions involving thinning and regeneration are:

a. the removal of logging slash and the establishment of a new stand as well as all the necessary accompanying measures;

b. logging operations and hauling of the timber.

Article 47, Paragraph 3 b WaV

3 Compensation is made according to table 1 of the Appendix for:

b. silvicultural measures according to Article 17, Par. 1 a and Article 19, Par. 2 and 3, which are necessary to conserve forests with a direct protective function (Art. 42, Par. 2).

[1] Federal Law on Forests of 4 October 1991 (Waldgesetz, WaG), SR 921.0
[2] Ordinance on Forests of 30 November 1992 (Waldverordnung, WaV), SR 921.01
[3] Federal Law of 5 October 1990 on Financial Contributions and Indemnities (Subventionsgesetz, SuG), SR 616.1
[4] Circular 8 of the Federal Office of the Environment, Forests and Landscape of 30 October 2003