> Forest Report 2015

Condition and Use of Swiss Forests

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> Forest Report 2015

Condition and Use of Swiss Forests

Editors: Andreas Rigling, Hans Peter Schaffer

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Project general management
Rolf Manser, FOEN
Dr. Christoph Hegg, WSL

Project managers
Hans Peter Schaffer and Roberto Bolgè, FOEN
Dr. Andreas Rigling, WSL

Editor
Dr. Manuela Di Giulio, WSL

Translation
Dr. Silvia Dingwall Stucki, assisted by Anne Wegner

Proofreading
Jacqueline Dougoud

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> Abstracts

The Forest Report 2015 provides information about the condition of the Swiss forests. It is based on the internationally recognised and standardised indicators of Forest Europe and is an international reference for sustainable forest management. The data basis is derived from comprehensive monitoring of the forest, which has been established during recent decades, and which enables the condition of the forest to be analysed in more depth. The Report takes a look back at the development since the publication of the last Forest Report in 2005, and can thus answer questions about complex forest ecosystems and how to manage them. The Report allows insights into the Swiss forest in all its facets, and serves as a reference book for both experts and laypeople.

Keywords:
Forest Europe, wood, indicator, monitoring, resources, forest services, forest use, forest condition

Der Waldbericht 2015 informiert über den Zustand des Schweizer Waldes. Er basiert auf den international anerkannten und standardisierten Indikatoren von Forest Europe und ist eine internationale Referenz für nachhaltige Waldbewirtschaftung. Die Datengrundlagen stammen aus einem umfassenden Waldmonitoring, das in den vergangenen Jahrzehnten aufgebaut wurde und eine vertiefte Zustandsanalyse erlaubt. Der Bericht schaut zurück auf die Entwicklung seit dem Erscheinen des letzten Waldberichts im Jahr 2005. Damit beantwortet er Fragen rund um das komplexe Ökosystem Wald und seine Bewirtschaftung. Der Bericht vermittelt Einblicke in den Schweizer Wald in all seinen Facetten und dient als Nachschlagewerk für Fachleute und Laien.

Stichwörter:
Forest Europe, Holz, Indikatoren, Monitoring, Ressourcen, Waldleistungen, Waldnutzung, Waldzustand

Le Rapport forestier 2015 entend renseigner sur l'état de la forêt suisse. Il s'appuie sur les indicateurs standardisés paneuropéens de Forest Europe et constitue une référence internationale pour la gestion forestière durable. Les bases de données sont issues d'un monitoring complet des forêts, mis en place au cours des dernières décennies. Il permet une analyse approfondie de l'état des forêts. Le rapport dresse une rétrospective de l'évolution depuis la parution du rapport précédent, en 2005. Il répond ainsi aux questions sur cet écosystème complexe et sur sa gestion. Il donne un aperçu de toutes les facettes de la forêt suisse et sert d'ouvrage de référence pour les spécialistes et les non-spécialistes.

Mots-clés:
Forest Europe, bois, indicateurs, monitoring, ressources, prestations forestières, utilisation de la forêt, état de la forêt

Il Rapporto forestale 2015 fornisce informazioni sullo stato del bosco svizzero. Si fonda su indicatori standardizzati di Forest Europe, riconosciuti a livello internazionale, e rappresenta un riferimento internazionale per la gestione forestale sostenibile. I dati provengono da un esteso monitoraggio forestale che si è costituito negli scorsi decenni e che permette un'analisi approfondita della situazione attuale. Il presente rapporto ripercorre l'evoluzione dei boschi rispetto al precedente Rapporto forestale, pubblicato nel 2005, e risponde agli interrogativi in merito al complesso ecosistema bosco e alla sua gestione. Inoltre fornisce uno sguardo sul bosco svizzero, considerato in tutte le sue sfaccettature e rappresenta un'opera di consultazione sia per gli addetti ai lavori che per i non esperti.

Parole chiave:
Forest Europe, legno, indicatori, monitoraggio, risorse, prestazioni del bosco, utilizzazione del bosco, stato del bosco

> Preface

The forest is important for Switzerland. It covers around a third of the country's surface area, shaping the landscape and influencing our quality of life. It performs valuable public services, such as providing protection against avalanches or rockfall, and reducing water discharge. It provides wood, a renewable resource that can be sustainably produced. In addition, it is an indispensable near-natural habitat for many species and a key recreation area for people. Roughly 94 per cent of the population go to the forest regularly. Most people feel refreshed and more relaxed afterwards.

But how is the forest doing? What functions does it perform? And how sustainable is it? The Forest Report 2015, written by scientific and professional experts, explores these issues. It provides information about the forest in all its facets and describes its development since the last Forest Report in 2005. Answers differ according to the focus of the question, including whether it is about the condition of the protection forest, the development of biodiversity or how successful forestry has been.

On the basis of this report, two general conclusions can be drawn. First, the condition of the forest is never static, as it is continually adapting to changing environmental conditions. Such change is not always easily visible to the human eye, but the Report shows impressively what change is happening, thanks to long-term forest observations. Second, the authors consider the condition of Swiss forests, taken as a whole, to be relatively good at the moment. Nevertheless, the changes in the past and the great challenges that are becoming apparent for the future raise the question: will it remain like this for the next 10 years, or are we currently experiencing the quiet before the storm? Some of the challenges we face are already making themselves felt. These include not only climate change, but also harmful and dangerous organisms unknown here up to now. The past also shows that new threats, which we cannot foresee today, may time and again arise.

Forest monitoring and reporting about the forest therefore continue to be needed in order to identify new developments early enough in future to be able to provide the public, the actors in forest policy and the decision-makers with reliable facts about the condition of the forest and how it is changing. Only in this way will it be possible for us to continue to make the best possible decisions about the forests of our children.

We wish you an enjoyable and informative read, and hope that this valuable fund of findings will give you the information and support you are looking for.

Josef Hess
Vice Director
Federal Office for
the Environment (FOEN)

Christoph Hegg
Deputy Director
Swiss Federal Institute for Forest,
Snow and Landscape Research (WSL)

> The Forest in the Process of Change

Andreas Rigling, Daniel Landolt, Rolf Manser

Introduction

The Forest Report 2005 asks the simple question "How is the Swiss forest doing?" This question could not then – and today can still not – be answered with a straightforward "well" or "badly" because the forest is a whole complex of many different elements. The answer must therefore consider different factors. The present Forest Report 2015 describes the current condition of the Swiss forest on the basis of a whole range of facts and figures. It provides a situational analysis from the perspective of today, but takes a retrospective look back to consider the development since the publication of the last Forest Report in the year 2005. It thus provides answers to questions about the complex ecosystem forest and how it is managed. It also looks to the future to draw conclusions for policy and research.

The Forest Report is based on the standardised and internationally recognised indicators of Forest Europe (Forest Europe et al. 2011). This provides a structure for considering the multifaceted topic and allows international comparisons to be made. In addition, it establishes a link with the basic indicators developed in collaboration with the cantons from the project "Monitoring forest sustainability" ('Nachhaltigkeitskontrolle Wald'). This chapter, "The Forest in the Process of Change", gives a synthesis based mainly on the results from the second part of the Report, which describes the Forest Europe indicators. Additional sources are cited.

The data basis for evaluating the condition of the Swiss forest has become more solid in recent decades because it can rely on comprehensive forest monitoring, among other things. An important trigger for this was the debate in the 1980s about forests dying (Waldsterben). It showed that, to be able to make reliable statements about the condition of the forest and how it has changed, the initial condition must be known and deviations from it measured and recorded. The National Forest Inventory NFI has been carried out since the mid 1980s, meanwhile for the fourth time. The Sanasilva Forest Inventory, the monitoring of harmful organisms and permanent forest observation have celebrated their 30-year anniversaries. The Long-term Forest Ecosystem Research programme can today use time series that are over 20 years old, containing measurement data from dozens of intensively studied plots. In addition, Switzerland has had, as one of the first countries worldwide, a systematic biodiversity monitoring programme for about 10 years. This was an outcome of the United Nations Conference on the Environment and Development in Rio de Janeiro in 1992. The Forest Report 2015 can also draw on further data from different ecological and socio-economic investigations, as shown in Graphics II and III[1]. Thanks to this widely backed-up data basis, our understanding of processes related to the Swiss forest has improved, and we are today in a better position to understand the complex interrelationships in the forest ecosystem than during the time of the debate about forests dying.

The forest is a system where the development and planning time periods are long. Thus there are correspondingly large uncertainties about planning since the social and economic context may change greatly during the course of a tree's life. Probably hardly a single forest stand in Switzerland is used today in exactly the way originally intended. The Galm forest near Murten (FR) is a good example of this. It was owned jointly by Bern and Freiburg until 1798, and from the 15th century on both cities used its wood for maintaining, among other things, the parapets and canon carriages in Murten. To ensure long-term future supplies of oak timber, the mayor of Murten had two large areas clearcut in 1713 and sown with acorns. The huge oaks found today in Obereichelried are the products of this seed. Their stems are today used to make wine barrels and provide the finest veneers for making furniture. Moreover, Obereichelried has, in the meantime, come to be considered to be an important gene reserve (Küchli and Chevalier 1992).

Estimating the future need for wood and other forest services in the 22nd and 23rd centuries is difficult as social change is taking place at an ever-faster pace. Swiss society is undergoing rapid urbanisation. Around 70 per cent of the population today live in urban areas (FSO 2014). Mobility and the pressure of urban development are increasing continuously and are leading to a decrease in the agricultural area of around a square metre per second as well as to increasing fragmentation of the landscape. The forest area has been protected under the Swiss Forest Act for over 100 years, but is being encroached on by residential areas. The forest as a large, near-natural habitat is thus increasingly threatened. Changes in the local population and their attitudes to forest and nature influence the framework conditions for the forest and its management. We are increasingly becoming a leisure society with new needs and requirements in connection with the forest (Pröbstl et al. 2010).

Furthermore, technical and economic developments that directly influence the forest have increased. Thus the marked expansion of the global goods trade, for example, has led to more harmful species being introduced (Roques 2010). The new focus of Switzerland's energy policy will, in future, also influence forest management. It is likely that more wood, a renewable raw material, will be used as energy wood than previously. This will affect other forest functions. For example, synergies with the goals of forest biodiversity may be possible, as 'open' forests will be promoted. On the other hand, the availability of less deadwood could negatively affect wood-dwelling species.

Climate change is creating new framework conditions for forest management and the provision of forest services (cf. Graphic I). The first signs of the effects of climate change on forests are becoming apparent in Switzerland and worldwide. Scientists agree that the changes observed so far are just the beginning of continuing processes and that they will become intensified as climate change persists. How severe the changes will really turn out to be is difficult to predict. This constitutes a difficult situation for the forest manager as, depending on the scenario, it is questionable how well today's tree species will be adapted to the environmental conditions expected in 50 to 100 years.

The forest is changing

Forest covers 32 per cent of Switzerland's surface area today. In mountainous regions, the forest area is increasing because many agricultural areas are only being managed extensively and some areas are no longer used at all. In such regions, the forest can expand and reconquer its original natural terrain. Moreover various studies in the Alps and worldwide show that climate change is continuously improving the growth conditions in mountain forests, whose growth is mostly restricted by cold. Trees at high altitudes are increasingly growing better, they can regenerate more easily, their stands are closing and the altitude of the upper timberline is slowly rising (Gehrig-Fasel 2007). The increase in the forest area may lead, on the one hand, to the loss of ecologically valuable habitats (e.g. dry meadows). On the other hand, some forest functions will be improved, for example, providing protection against natural hazards or storing CO_2 in additional trees (Rigling et al. 2012).

In the intensively used regions on the Swiss Plateau and in the Alpine centres, however, the forest area is increasingly under pressure due to the construction of housing and infrastructure facilities. The forest area has remained the same in these regions for decades, and the forest is protected by the Forest Act, but human demands are increasingly having an impact on the forest. Examples of this are recent discussions about extending housing into the forest (project idea for the forest town 'Waldstadt Bremer' in Bern). Buildings and facilities in the forest have also increased, with wind energy facilities in the forest as the most recent example. No development has, however, yet been observed in Switzerland that is comparable with that in Germany, where for several years now wind turbines have increasingly been constructed in forests.

It is not only the forest area that is expanding, but the growing stock has also increased further since the Forest Report 2005 (+3 %), although considerably less than in previous years. While the growing stock has mainly increased in the Alps (+14 %) and on the Southern slopes of the Alps (+30 %), it has diminished on the Swiss Plateau (–11 %). A reduction on the Swiss Plateau to this extent is not problematic as stocks are generally high and therefore can, to a certain extent, be reduced. What is striking here is the marked decrease in spruce of 31 per cent. This is due partly to storms, dry periods and bark beetles, and partly to more intensive use of spruce. Only 6 per cent of broadleaf forest areas on the Swiss Plateau today are still stocked with pure spruce stands, and the trend is towards a further decline (Brändli et al. 2015).

The increase in growing stock and forest area means that the Swiss forest still acts as a so-called carbon sink, which means it stores more carbon than it releases. The question is whether this will remain the case in future. Climate change could lead to an increase in extreme events like forest fires, storms or droughts, which would restrict the Swiss forest's performance as a sink, at least temporarily. The Swiss government had the Swiss forest's performance as a sink registered as a credit during the first commitment period 2008–2012 of the Kyoto Protocol. During this period the forest acted as a sink for around 1.6 million tonnes of CO_2 a year, which corresponds to about a third of Switzerland's reduction commitment.

The forest is an important near-natural habitat in Switzerland, which is increasingly being used by the public as a place for recreation. On average, people visit the forest once or twice a month in winter, and as much as once or twice a week in summer. This is where they can pursue and enjoy experiences and movement in a natural environment. The availability of infrastructure (e.g. fire-places, benches or shelters) surprisingly plays a rather minor role. The forest's natural characteristics tend to be positively valued. One of the few exceptions is the presence of more deadwood in many places, which is often perceived negatively. This runs counter to the important ecological function of deadwood as a habitat for many rare species.

Visitors to the forest appear to feel much more disturbed during recreation than 15 years ago (27 % vs. 18 %). The reason is that many more people are pursuing recreation in the forest. The most important sources of disturbance are cycling/biking, dogs and noise. Restrictions due to logging and the use of wood are seldom sources of complaint today – unlike in the first survey in 1997. Nevertheless, those looking for recreation tend to be very satisfied with their experiences in the forest regardless of the disturbances, and afterwards feel revitalized.

Current and future threats

In coming years, the vulnerability of our forests will change. Whereas today high nitrogen deposition and ozone concentrations continue to stress many forests, in future the direct and indirect effects of climate change will negatively affect the forest, as will the introduction of more harmful organisms.

No severe disturbance events have occurred since 1999. The traces of the windstorms 'Vivian' (1990) and 'Lothar' (1999), of the summer heatwave in 2003 and of the subsequent bark beetle epidemics are, however, still clearly visible in the Swiss forest even though they occurred several years ago. According to the latest climate models, extreme disturbance events are likely to become more frequent with climate change and to have more impact on the appearance and performance of our forests in future. One important indicator of the condition of the forest is the extent of defoliation. The Sanasilva Inventory, which has been carried out since 1985, shows that the increase in defoliation recorded up until 1995 has not continued, but has stabilised with large annual fluctuations. The fluctuations are mostly caused by extreme climatic events such as droughts or storms.

It has been possible to reduce nitrogen emissions considerably during the past few decades. Nevertheless, the deposition is today still above the critical value on 90 per cent of the forest area. Depending on the site, the additional nitrogen has different effects. It may stimulate tree growth or accelerate soil acidification and lead to the leaching out of important nutrients such as magnesium and potassium. Such leaching is relevant mainly on acidic sites, for example, in Ticino or in the Central Alps. This increases the risk of a nutrient imbalance, which may, in the long term, negatively affect the nutrient cycle of the forest soil and the trees. Nitrogen deposition from the air, which mostly stems from motorised traffic and agriculture, must therefore be further reduced.

Swiss forests are diverse and very varied in structure for the following main reasons. The structure of the relief varies greatly within a small area, as does the soil, which is geologically relatively young, as well as the climate, where conditions may differ considerably and change within a short distance. At the same time, this diversity has been promoted by the near-natural form of forest management practised in many places for decades, which favours natural regeneration and is characterised by different small-scale silvicultural interventions. This is especially noticeable in forests that would otherwise be naturally relatively homogeneous (e.g. in the beech forests on the Swiss Plateau). The Swiss forest is therefore, in all, considered to be adaptable and robust. These are important prerequisites for the forest still to be able to perform its services (cf. Graphic I) under changed climatic conditions. The research programme "Forests and Climate Change" of the Federal Office for the Environment (FOEN) and the Swiss Federal Institute for Forest, Snow and Landscape Research (WSL) will continue until 2016 to investigate what the greatest climatic risks are and which silvicultural measures are suitable for maintaining and improving the adaptability of the forest.

When cases of disturbance or damage occur, these should be used to check the composition of tree species with respect to the expected effects of climate change, and if necessary, to modify it. Thus targeted planting may supplement natural regeneration and increase the future diversity and stability of stands.

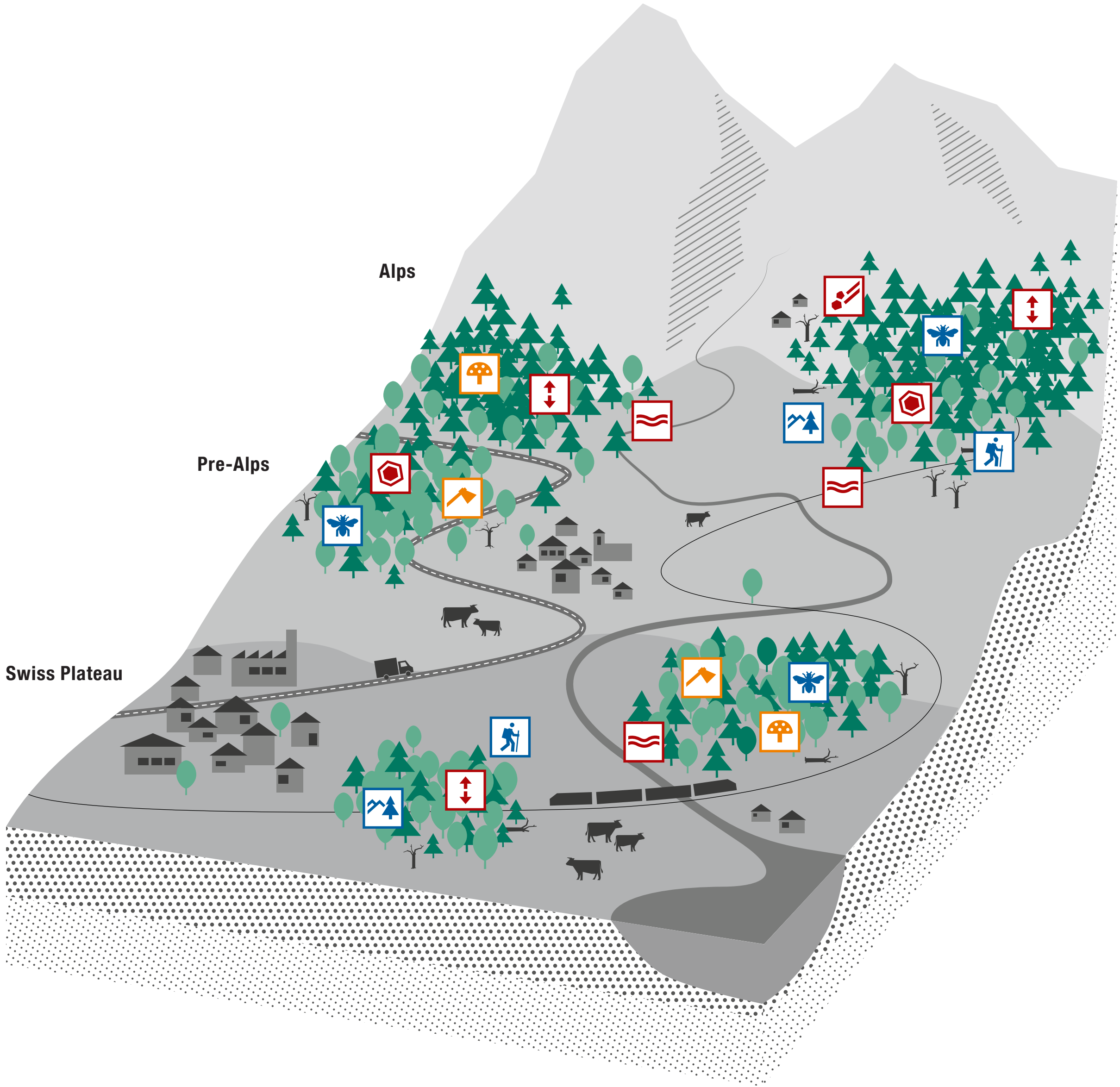
The threat to the forest from introduced organisms is already mounting today. These organisms may change our forest ecosystems quickly in unpredictable ways. Examples are chestnut blight, elm and ash dieback, as well as the tree-of-heaven, which behave invasively. The main transport routes for the global trade in goods have proved to be entry portals and distribution corridors for introduced pests. Once they have reached residential areas, they disperse further from there. Inspections, monitoring and control measures must therefore be coordinated more at the interfaces between the forest, transport routes, residential areas, green urban areas and agriculture. The aim is to prevent the introduction of new organisms by stringently checking goods and providing the relevant actors (especially importers and traders) with better information. Should cases arise, these must be tackled quickly and contained. To be able to do this, a form of crisis management is needed to select the most effective and efficient measures specifically for the particular harmful organism concerned.

Maintaining protection forests is a key task

Switzerland is a mountainous country: the Alps, Pre-Alps and the Southern slopes of the Alps cover nearly two-thirds of its surface area, and about a quarter of the Swiss population live in the mountainous region. This is not only a recreation area for the locals who live there and for visiting tourists, but also a habitat for many animal and plant species and a biodiversity

Graphic I > Forest services

Forest services considered in the Forest Report 2015. The forest functions: protective effect, use and wellbeing specified in the Federal Act on Forest (Forest Act 1991) are matched with the internationally agreed forest services defined in the Millennium Ecosystem Assessment (MEA 2005). Model-like classification of Swiss landscapes the Alps, Pre-Alps and Swiss Plateau, which can be correspondingly applied to the Jura and the Southern slopes of the Alps.



Protective effect

- Protection against natural hazards, e.g. against avalanches, rockfall, floods
- Groundwater protection, Drinking-water protection
- Climate regulation, CO_2 storage, Nutrient cycle
- Soil protection, including protection against erosion

Use

- Use of the resource wood
- Non-wood products, e.g. venison, mushrooms, honey

Wellbeing

- Landscape aesthetics
- Habitat, Biodiversity
- Recreation and leisure

Sources: Illustration based on the Forest Act and the Millennium Ecosystem Assessment hotspot in Europe. Moreover, important (from national and European perspectives) North-South transport corridors go through the Alps.

Living in a mountainous area means dealing with natural hazards on a daily basis. Life in the mountains is only possible thanks to the protection forest, even though most people in our technology-driven world are hardly aware of its importance. Nearly half of the Swiss forests act as protection forests. They provide protection against natural hazards such as avalanches, rockfall, debris flow and floods – and often against several of these hazards at the same time. This protection service can only be effectively performed if the condition and structure of the forest are suitable. Concretely, this means that the forest must cover at least a minimum area with a minimum stand density. A prerequisite for this is a form of forest management that meets the minimum standards developed by the federal government and the cantons, and is enshrined in the Forest Act (Frehner et al. 2005).

Protection forests are not managed according to purely economic criteria, but rather with the aim to make the forests more stable so that they can be maintained in the long term. This requires silvicultural interventions, which are usually more expensive in the mountains than harvesting timber in the lowlands. During such treatment, around 1.9 million cubic metres of timber are harvested, corresponding to around a quarter of the total harvested quantity. The costs of this cannot, however, be covered by the proceeds of the timber harvest alone. The forest owners responsible for maintaining the protection forest therefore rely on financial compensation from public funds for the services they perform. Thanks to the financial support of the federal government, cantons and municipalities, it has been possible to actively manage around half of Switzerland's protection forests since 1993. This has had an effect because, according to the National Forest Inventory, the protection forests have, since then, been more stable. The proportion of protection forest areas with critical or reduced stability decreased by 4 per cent, but today is still 53 per cent.

The long-term provision of protection functions requires sufficient forest regeneration. On more than a third of the total area, the protection forest has insufficient regeneration. This proportion has increased since 1995[2]. The composition of tree species on the regeneration sites is important because only if the tree regeneration is diverse and suitable for the site can the long-term protection function of the forest be ensured. This aspect is becoming more important in the light of the ongoing climate change. In this connection, the excessive pressure of wild ungulates in some areas is ground for concern as the game prefer to browse tree species that are important for stand stability, such as silver fir, maple and rowan. With silver fir, which is particularly sensitive, the browsing intensity has increased from 14 to 20 per cent since 1995. The offspring of this important tree species in protection forests is therefore endangered in some areas.

The protection of drinking water is another important function of the forest (cf. Graphic I). In Switzerland 80 per cent of drinking water is obtained from groundwater. The groundwater in forest areas is especially valuable because the concentrations of nitrate and pollutants in it are much lower than in the groundwater in agricultural or residential areas. In Switzerland, 12 per cent of the forest area is in the catchment area of a drinking-water intake facility and 10 per cent in a groundwater protection zone. In the Jura the corresponding values are 22 and 24 per cent. The near-natural silviculture and the promotion of a natural mixture of tree species contribute to safeguarding the good quality of the drinking water in the long term, as does the management on a small scale without the use of fertilisers or pesticides. The overly high deposition of nitrogen from the air can, however, lead in some forest areas to more nitrate leaching and may thus threaten the quality of the drinking water. A further reduction of nitrogen emissions is therefore also necessary from the point of view of drinking-water protection.

Biodiversity as chance

The biodiversity in the Swiss forest has – unlike in other habitats – developed positively. Already more than half the special and natural forest reserves planned have been established and today make up around 5 per cent of the forest area. In addition, the near-natural silviculture has resulted in a marked reduction in unnatural spruce stands. The windstorms 'Vivian' and 'Lothar' and the subsequent bark beetle epidemics have also contributed to this reduction. Nearly all forest regeneration (90 %) is natural. Planting is only done locally to reinforce protection forests, to promote species diversity or to produce valuable timber.

Despite these positive developments, some problem areas and challenges remain. In Switzerland, around 40 per cent of all species depend on the forest for their habitat, and of these, 9 per cent (about 2,500 species) are endangered. In the lowlands, old phases of forest development with large old trees and plenty of deadwood are still seldom, as are open forests and alluvial forests. Species groups that depend on long and continuous forest developments and biologically old stands include an above average proportion of endangered species (e.g. lichens and mosses). Furthermore, the increasing populations of game in many areas are also problematic from the point of view of nature conservation in forests if they threaten the natural regeneration of rare and ecologically valuable tree species. These deficits can be mitigated with existing instruments by consistently implementing near-natural silviculture across the whole area, and with additional measures like forest reserves, old-growth patches or the targeted promotion of habitats and species in combination.

A high genetic diversity does not only contribute to maintaining biodiversity but also supports the natural adaptability of the forest ecosystem. This is becoming more important in the light of the climate being warmer and drier in future. The genetic resources in the forest should therefore be preserved and provenances that are particularly well adapted to aridity and warmth should be promoted. If planting is necessary to regenerate a forest stand, the ecological suitability and not only the regional origin should be considered.

Promoting biodiversity can make an important contribution to the adaptability of our forests to disturbances and climate change. This also makes them valuable in the long term from an economic point of view. Moreover, the forest manager can "sell" this service. The public sector compensates for a large part of the ensuing costs, for example, of promoting rare species in the forest, because forest biodiversity is in the public interest.

Currently, a national and international debate is taking place about whether and how the palette of indigenous tree species should be expanded to include non-native species with the aim to ensure that forest stands are also stable in a drier climate and can adapt to it. This is why the potentials and the limits of indigenous and non-indigenous tree species under climate change are being investigated in the FOEN and WSL research programme "Forest and Climate Change".

With the planned step-by-step phasing out of nuclear energy as part of Switzerland's Energy Strategy, renewable energy sources and resource-efficient economies will play a central role. This may lead to a more intensified use of wood and an increase in timber harvesting since the full use of wood, a renewable raw material that can be produced in Switzerland locally and sustainably, has many advantages (cf. *Conflicting interests in the forestry*). For biodiversity in the forest, this means retaining sufficient deadwood and old trees and promoting them accordingly. More use of the wood could also create synergies with biodiversity promotion. Increased silvicultural interventions will allow more light to reach the forest floor, which is favourable for specialised animal and plant species. Traditional forms of management, like coppice with standards or coppice forests, could also become more attractive.

Conflicting interests in forestry

The forest belongs to around 250,000 forest owners, 97 per cent of whom are private individuals who own, on average, 1.4 hectares of forest. The around 3,300 public forest owners manage a good two thirds of the forest area, and the areas they own are thus considerably larger than those of the private forest owners. Half of the public forest owners do not have tax autonomy (local citizens' communities (Bürgergemeinden) and corporations).

Nearly 7,000 people work for forest enterprises and forestry service entrepreneurs, particular in rural and economically underdeveloped areas. The small-scale structure of forest ownership and management makes it often difficult to use Swiss forests efficiently. Some restructuring of the forest enterprises has taken place. Since 2005 the number of forest enterprises has fallen by 20 per cent according to the Swiss Forest statistics, which corresponds to a reduction of around 590 forest enterprises, of which about half were less than 50 hectares in size. This development is likely to continue, which is why the cooperation of the forest owners, among other things, must be further improved to ensure that the forest can be actively managed and that the forest can continue to fulfil its multifaceted functions in future.

Swiss forest enterprises earned almost 400 million Swiss francs in 2011, which corresponds to 0.06 per cent of the gross value added (GVA) of Switzerland's overall economy. If the wood, pulp and paper industries with their 15,000 enterprises and 90,000 employers are also included, the proportion of the GVA goes up to 0.85 per cent. This added value represents, however, only a fraction of the economic importance of the forest as, in addition to timber, the forest enterprises perform a variety of forest services of public interest, such as protection against natural hazards, climate and soil protection, and biodiversity services (cf. Graphic I). The forest provides, in addition, important recreation opportunities for locals and tourists. Since the modification of the National Fiscal Equalization (NFE) and the new division of tasks between the federal government and cantons were introduced in 2008, the federal government has paid around 130 million Swiss francs per year in contributions for the forest. These contributions are primarily for performing forest services of public interest. If the payments of the cantons are also included, then state contributions to forestry are about 100 million Swiss francs more, namely 230 million Swiss francs per year.

Forest services for the public are becoming increasingly important, but they are at the moment not converted sufficiently into financial value. The main income of the forest enterprises therefore still stems from selling timber. This discrepancy between the actual performance of services and incomplete compensation is one of the reasons why, with most forest enterprises, their costs are higher than their income – as has been the case since the 1990s.

According to the National Forest Inventory, the net increment since 1995 has been on average 8.1 million cubic metres of timber. Of this, only 7.3 million cubic metres, according to the same source, are used, and the trend has been downwards since 2006. In comparison, the total production of wood-based raw materials in Switzerland in 2009 was around 9.9 million cubic metres, which means that a significant part involved using imported timber/wood. A total of 9.6 million cubic metres are actually used in Switzerland. Theoretically then, the use of wood-based raw materials could almost be covered by the timber production within Switzerland, which would be desirable from the point of view of resource and environmental policies. In terms of quantity, the trade equilibrium for wood in 2009 was nearly in balance, but in terms of value, it was negative as the value of imports far exceeded that of exports. The reasons for this are that large quantities of unprocessed or only slightly processed wood leave Switzerland. These are processed abroad and then re-imported as finished products into Switzerland. This means that Switzerland loses a substantial proportion of the added value.

The forest can play an important role in Switzerland's Energy Strategy 2050 as it provides wood – a sustainably produced and renewable resource. Wood can be used in various ways to produce energy – in the form of heat, electricity or transportation fuels. Today it is estimated that 2.0 to 2.5 million cubic metres of energy wood a year are harvested in the forest in the form of woodchips or logs. Forest wood is thus the most important source of energy from wood. All sources of wood used for energy, i.e. from the forest, landscape maintenance, industry and waste, together cover around 4 per cent of Swiss energy needs. Nearly all of this wood is currently used for heat production. The amount of energy wood produced in the forest could be increased to at least 3.1 million cubic metres. This could be done sustainably, i.e. it would not negatively affect the forest and its functions. Moreover, increased use corresponds to the current policies of the federal government, in particular the Wood Resource Policy, the Forest Policy 2020 and the Biodiversity Strategy Switzerland. From the perspective of the national economy, intensified use makes sense. Where possible, this should be in the form of cascade use. This means using the wood as a material several times, for example, first as construction timber, then as particleboard, and only at the end for energy purposes. The contribution of the forest and wood to reducing CO_2 in the atmosphere can be maximised by realising the full potential for using the wood sustainably and consistently applying the principle of cascade use. The forest and its wood can thus make an essential contribution to climate protection.

The Swiss forest provides not only wood, but also a variety of other products with an estimated total value of around 90 million Swiss francs per year. Examples are forest honey, venison, mushrooms and Christmas trees. These so-called non-wood forest products play a minor role economically, but they are important regionally and for certain forest services. Thus for many people, collecting mushrooms is part of recreation in the forest. In addition, more and more people, both young and old, are discovering the forest as a schoolroom. A variety of forest-related courses for teachers are now available. In forest playgroups, forest kindergartens, forest schools, nature conservation centres and wildlife parks, people of all ages can use the forest as a special place of learning. This positive development helps people understand the forest, forestry and the multiple forest services performed.

Conclusion: Is the forest in Switzerland thriving?

How is the Swiss forest doing today? This Forest Report discusses a range of factors that are afflicting the forest and that raise questions about its sustainable development in some areas. The Report makes clear that the condition of the forest is never static, but rather continually changing and adapting to the environmental conditions. If we consider the development of the forest since 2005, then we judge the situation to be calm and relatively stable. The last winter storm to damage a large extent of forest was back in 1999. Defoliation fluctuates every year, but on the whole has not increased. Nitrogen emissions are still above the critical value, but are continually falling. While peak concentrations of ozone have fallen, average concentrations have tended to increase. Bark beetle populations have, after the infestation of the century in 2003, in the meantime shrunk to an uncritical level, and the dry winter and spring in 2011 left no marked traces in the forest. Biodiversity in the forest has developed positively. Introduced organisms, however, are cause for concern. In several regions, they have already done visible damage to some tree species, for example, elm and ash dieback, and chestnut blight, and caused losses.

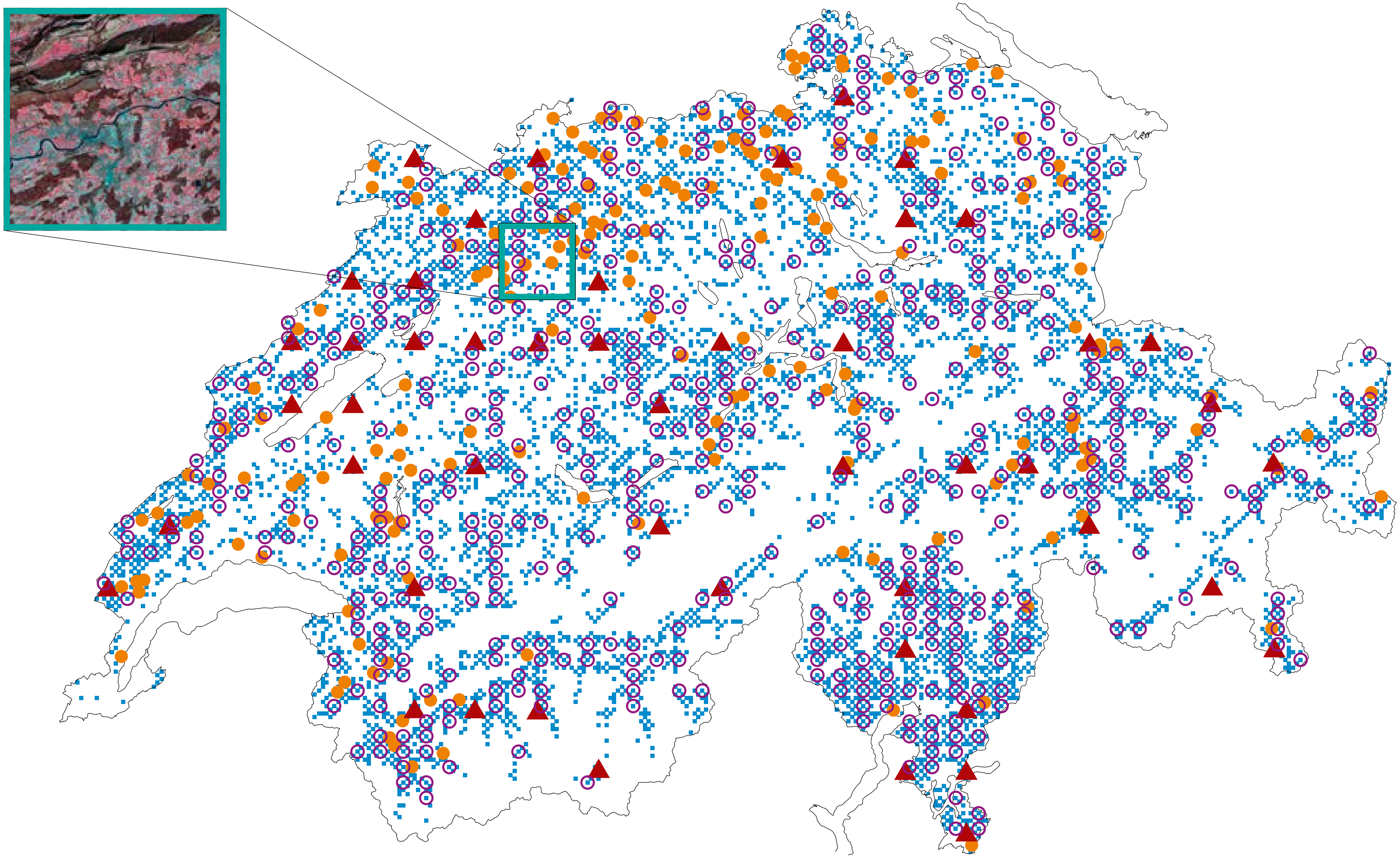
We therefore at present consider the condition of the Swiss forest as a whole to be relatively good. Will it remain good for the next 10 years, or are we currently experiencing the calm before the storm? We do not know, but we have learnt from experience during the past decades that far-reaching changes may occur suddenly and affect large areas. Our environment is changing fast, and forecasts for the future are subject to uncertainties, for example, in connection with the ongoing climate change and with the anticipated larger numbers of invasive organisms, which could change our forests rapidly.

Consequences for forest and environmental policy

The Federal Council formulated targets and strategies in 2011 for a national forest policy in its Forest Policy 2020. It

Graphic II > Data basis for the Forest Report 2015: Surveys of the whole of Switzerland

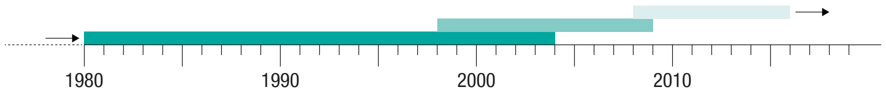
The data basis for the 2015 Forest Report is, thanks to the monitoring of the forest over many years, unique. These monitoring studies pursue varying goals and thus use different measurement methods. The map shows surveys that, through regular sampling, cover the whole of Switzerland and thus allow conclusions to be drawn about the forest in the whole country. The surveys are not very intensive, but include a large number of sampling points.



Remote sensing

The Federal Office swisstopo regularly records aerial images for the whole area. These photographs of landscapes taken from an aeroplane are then interpreted and assessed at WSL to find out about the development of the forest and landscape in Switzerland.

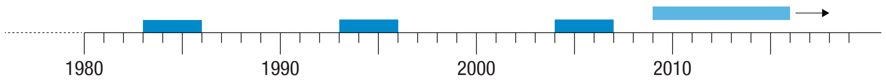
- 1927–2003: black-and-white photos
- 1998–2008: colour photos
- Since 2008: digital and colour infrared photos



National Forest Inventory NFI

On about 6500 sample plots throughout Switzerland, the condition and changes in the forest are regularly recorded in the NFI, based on evaluations of aerial photos, measurements and observation in the forest and surveys of the forest services.

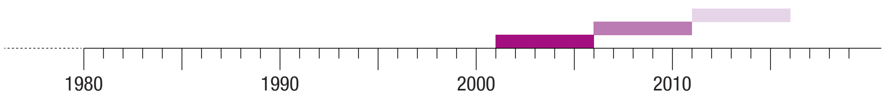
- NFI 1: 1983/85; NFI 2: 1993/95 and NFI 3: 2004/06
- Since 2009: NFI 4, continuous data collection



Biodiversity Monitoring Switzerland BDM

BDM monitors the long-term development of biodiversity in Switzerland with the aim to cover as broad a spectrum of biodiversity as possible. The data on the forest are assessed on an NFI sub-sample.

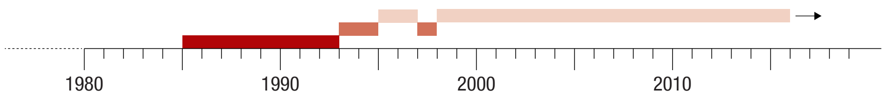
- 2001–2005: first survey
- 2006–2010: second survey
- 2011–2015: third survey



Sanasilva Inventory

The Sanasilva Inventory records the state of health of trees in the Swiss forest. It is part of the European Forest Condition Inventory. The most important characteristics, which are assessed annually, are defoliation and tree mortality rate.

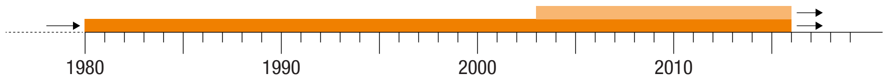
- 1985–1992: about 8,000 trees on 700 plots in a 4x4 km grid
- 1993, 1994 and 1997: about 4,000 trees on 170 plots in a 8x8 km grid
- 1995, 1996 and since 1998: about 1,100 trees on 49 plots in a 16x16 km grid



Forest Statistics and Test Network for Forest Enterprises TBN (Testbetriebsnetz)

The Forest Statistics is a comprehensive questionnaire survey of all forest owners carried out annually via the cantons. The main data collected concern the forest area, the use of the wood and planting. The TBN investigates a sample of 200 forest enterprises. The aim is to obtain a picture of the economic situation.

- Since 1923: annual forest statistics
- Since 2004: Test network TBN



Not shown on the map:

Info Species: Network of National Species Data Centres

The distribution and occurrence of animals, plants and fungi are systematically recorded. These records provide a basis for, among other things, the drafting of the Swiss Red Lists.

- 1950–1959: surveys for the historical breeding bird atlas
- 1967–1979: surveys for the Swiss distribution atlas of ferns and flowering plants
- Since 1980: systematic surveys of various groups of organisms

Socio-Cultural Forest Monitoring

The programme “Socio-Cultural Forest Monitoring” investigates the Swiss public’s attitudes, views and behavioural patterns in connection with the forest. This involves selecting a representative sample of households to interview.

- 1978: preliminary study Hertig
- 1997: WaMos 1
- 2010: WaMos 2

Land-Use Statistics

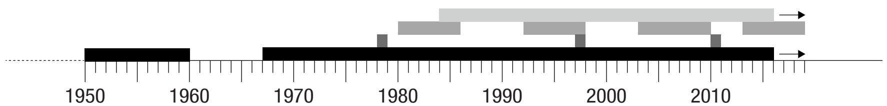
The Land-Use Statistics record information about the land use and land cover on 4.1 million points on a sample 100x100m grid on the basis of aerial photos from swisstopo. The Federal Statistical Office makes its geo-data available to all customers.

- AREA 1: 1979/85; AREA 2: 1992/97; AREA 3: 2004/09; AREA 4: 2013/18

Swiss Forest Protection PBMD

Swiss Forest Protection surveys, together with the cantonal forest services, damage to the forest. Abiotic factors, such as frost damage, as well as organisms (e.g. insects, fungi, wild ungulates) that could damage individual trees and the forest.

- Since 1984

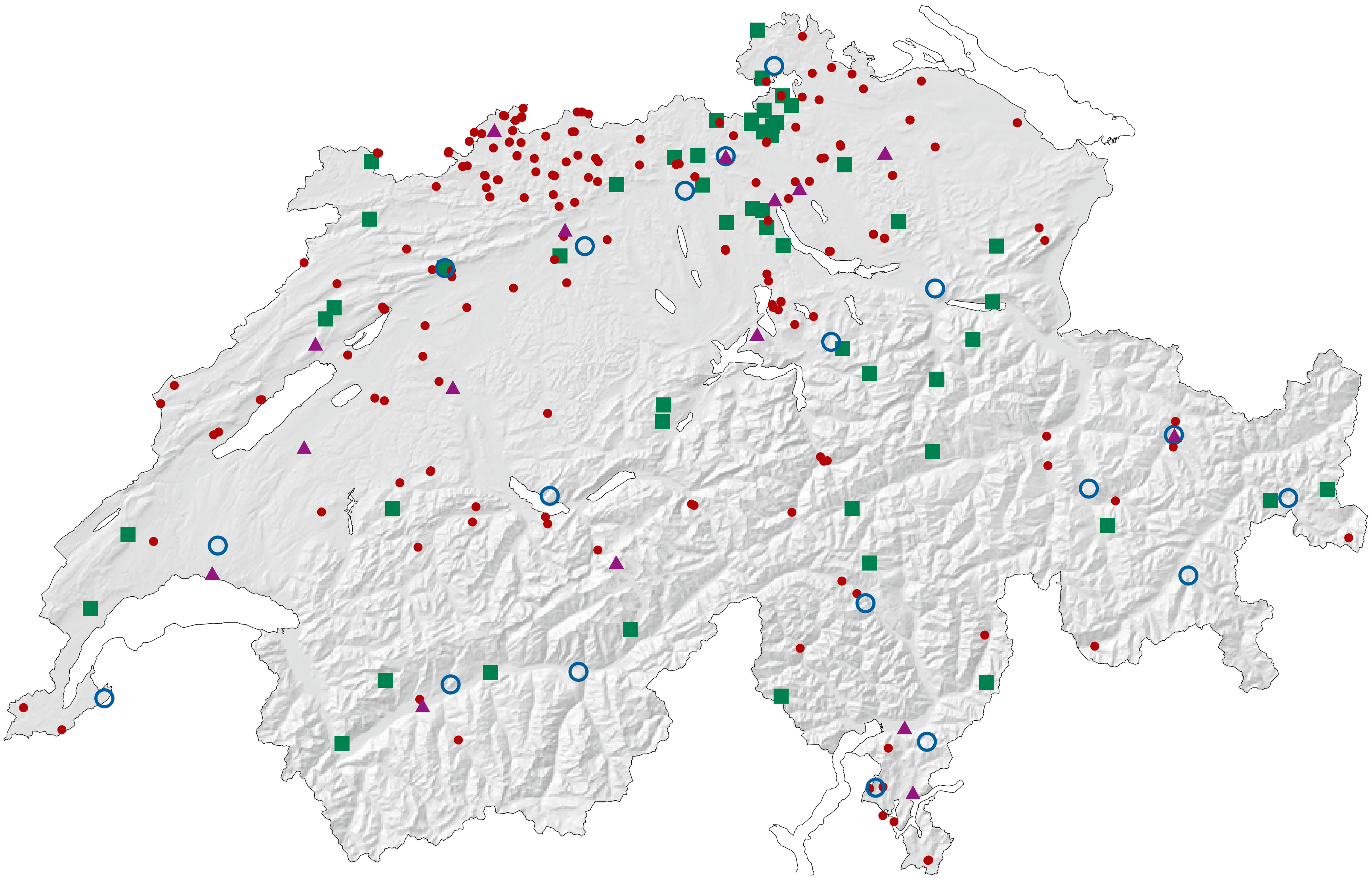


Observation or measurement in the field Survey

Source of maps: FSO GEOSTAT / Federal Office of Topography swisstopo; Data: Federal Statistical Office (FSO): Forest Statistics, TBN, Land-Use Statistic; WSL: Remote sensing, NFI, Sanasilva, Info Species, WaMos, Swiss Forest Protection PBMD; BDM

Graphic III > Data basis for the 2015 Forest Report: intensive surveys on selected sites

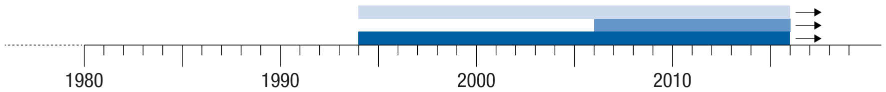
The extensive forest monitoring is supplemented with case studies involving complex measurements on different time scales ranging from annual surveys to measurements every second. These advance our understanding of the processes, interactions and material cycles in the forest, and thus of the whole forest ecosystem. In addition, numerous individual studies and observations help to increase our knowledge about the forest and its development.



Long-term Forest Ecosystem Research LWF

The LWF Programme investigates the effects of air pollution and changes in climate on the forest. Data are collected on 19 study sites, which form part of the ICP Forests Monitoring Network, to record the water, nutrient and carbon cycles. Two of the 19 sites are so-called super sites, on which the ETH investigates the CO_2 and water vapour exchange between the forest and atmosphere with the help of special measuring towers. In addition, experiments are performed on the LWF sites.

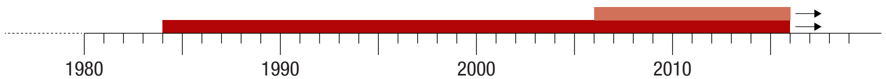
- Intensive monitoring sites: on 17 sites since 1994
- Super sites: on 2 sites since 2006
- Experimental investigation sites: on 2 sites since 1994



Permanent forest observation in several cantons

The condition of the forest in different cantons has been recorded and documented since 1984. The network of sites has grown from the original 51 to today's 179 sites. Initially, the focus was on the effects of acid rain, nitrogen and ozone, but today the impact of climate change on forests is also assessed.

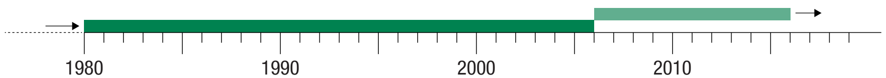
- Since 1984: in cantons AG, BE, BL, BS, SO, ZG and ZH
- Since 2006: additionally in cantons FR and TG



Monitoring the effectiveness of natural forest reserves

The aim of this monitoring is to find out how the forest in natural forest reserves develops in the long term and how it differs from managed forest. It helps in assessing the effectiveness of Switzerland's reserve policy. Inventories taken every 10 to 15 years record the structure of the forest: the trees, forest regeneration, deadwood and special habitat structures that provide habitat niches for birds, insects and fungi. It is a joint project of WSL, ETH and FOEN.

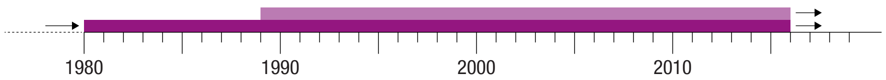
- Research on reserves at ETH 1948–2005 in 37 reserves
- Research on reserves at WSL, ETH and FOEN since 2006 in 49 reserves with modified methods



National Air Pollution Monitoring Network NABEL

NABEL measures the air pollution at 16 locations. Stations are distributed throughout Switzerland and measure the pollution at typical locations (e.g. streets in the city centre and residential areas). The Ordinance on Air Pollution Control (LRV) requires FOEN to collect data on air pollution. NABEL is intended to fulfil these statutory requirements: It measures indicator pollutants of national importance and distribution (e.g. nitrogen dioxide, ozone), for which emission limits are given in LRV.

- Since 1979: data collection at 8 locations
- Since 1989: data collection at 16 locations

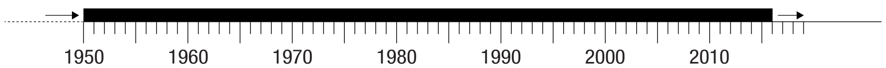


Not shown on the map:

Info Species: Network of National Species Data Centres

Info Species documents the distribution of animals, plants and fungi, and makes this data available for professionals, researchers and the interested public. The aim is to support the implementation of species protection and promotion. The data centres manage not only the systematically collected data, but also the reports of volunteers, which make up over half of the data.

- Since 1800: records collected in data centres in museum collections



Observation or measurement in the field

Source of maps: FSO GEOSTAT / Federal Office of Topography swisstopo; Data: WSL: LWF, Monitoring the effectiveness monitoring of natural forest reserves, Info Species; IAP: Permanent forest observation in several cantons; FOEN: NABEL would be reasonable to use the data of the Forest Report 2015 to check whether the federal government, cantons and forest owners are on the right path with this policy. The Forest Report is based, however, largely on data that involve a time span that goes back further than 2011. This is why an evaluation of the national forest policy and the effectiveness of its measures is not (yet) possible. The new findings do, however, allow conclusions to be drawn about the further orientation and implementation of the Forest Policy 2020 and about other basic political issues for the federal government.

The framework conditions for the forest and for sustainable forest management are changing greatly and quickly, and are difficult to predict. If we take a look at the future with its related uncertainties and risks that are difficult to estimate, the principle of distributing risks through diversity gains in importance. For forest management with its long production timeframes, this means ensuring that forest stands are stable and species-rich, that forest structures are varied and that valuable timber from different tree species is available. This will create a basis so that, should a certain tree species be lost, the rest of the stand will still be able to perform the forest services that future generations will need.

The forest area is developing in two opposite directions as it is increasing in the mountains but is under pressure from urban development on the intensively used Swiss Plateau. This development is leading to conflicts that require political solutions. The first important steps have already been taken. In 2012 the Forest Act was modified to tackle the problem of the growing forest area in mountain regions. The new regulations make it possible for areas where the forest has encroached on former agricultural land to be no longer classified as forest. This means they can then be cleared without a special permit. Moreover, Switzerland's Agricultural Policy 2014–2017 is more strongly oriented towards the cultivation of cultural landscapes in mountain regions, which should counteract the spreading of the forest.

On the intensively used Swiss Plateau, where the demand for building land remains high, the form of regional planning and land-use policies is a key issue. To ensure that, among other things, public areas for recreation can be maintained and that biodiversity can be promoted even in these densely populated areas, regional planning must aim to maintain the forest area and its spatial distribution in future. This is in accordance with the strict conservation of forest areas stipulated in the Forest Act.

The growing stock has increased since 1995 in most areas apart from the Swiss Plateau. The use potential is therefore not yet exhausted. Exploiting this potential is, however, one of the key aims of the Forest Policy 2020 in order to benefit from the advantages of wood as a resource and to improve the added value of Switzerland's forestry and wood industries. This means tackling several different aspects: the performance of the Swiss forestry and wood industries must be optimised further, which entails also optimising the structure of their enterprises. The federal government must continue to be active in the fields of research and innovation to do with wood and wood products. This will involve, most importantly, improving the turnover of broadleaf timber by finding new ways of processing and marketing it. The demand for Swiss timber must also be raised, partly through informing the public, the construction industry and institutions like the federal government, the cantons and pension funds. Pension funds are interesting here because they manage large sums of money, considerable amounts of which are invested in real estate. In the ideal case, these properties are partly or wholly built of wood. Thus the procurement criteria and funding conditions for public buildings and facilities need to be checked more to ensure that more Swiss wood is used.

While an intensified use of wood is desirable, it can lead to conflicts with other forest services in particular forest areas, for example, with measures promoting biodiversity or use for recreation. On the other hand, there could be mutual benefits. For example, open forests with high species diversity may result. Integrated and participative approaches to forest planning have instruments for solving conflicts, using synergies and weighing up different interests. It is up to the local actors involved to engage constructively in these processes.

In recent decades, human activities have continued to have considerable impact on the forest. Nitrogen deposition from the air may have markedly decreased, but in many places it is still above the critical values. Climate change is also beginning to affect the forest. Some tree species are already under pressure in Canton Valais because of drought. Reducing nitrogen deposition requires action primarily with respect to agricultural and transport policies. Moreover, a supplement to the Forest Act submitted to the Swiss Parliament in 2014 includes preventative measures to foster adaptation to climate change.

It is the aim of the Forest Policy 2020 to ensure the biodiversity in the forest continues to develop positively. The species living in the forest and the forest as a near-natural ecosystem should therefore be conserved. At the same time, problem areas must be tackled by, for example, promoting endangered species or old trees and deadwood. This involves continuing forest management according to the legal requirements of near-natural silviculture throughout the whole managed forest area. Furthermore, it is essential to press ahead with establishing forest reserves, the conservation of rare types of forest together with fostering species-rich forests and other priority habitats such as forest edges, alluvial forests and wooded pastures. To help with this, the federal government has published guidelines on biodiversity in the forest: “Biodiversität im Wald: Ziele und Massnahmen" (FOEN 2015). In this way, the measures can be adapted to the region and efficiently implemented.

In protection forests, it remains a challenge to safeguard the forest service of protecting people and their infrastructure facilities. Financial resources must be made available to improve the regeneration in protection forests. Problems with game animals browsing, for example, silver fir should be remedied by enforcing forest and hunting legislation more strictly. The presence of more large carnivores could, in coming years, help to achieve a natural balance.

Managing forests is, taken as a whole, currently a loss-making business. It is primarily up to the forest owners themselves to seek improvements in, for instance, ownership and management structures and the official recognition and valorisation of services performed. It is, however, also a challenge for national politics, which must formulate the basic framework conditions in Swiss legislation in such a way that the services performed by forest owners for the good of all can be turned into real value. What would be desirable is to integrate the direct beneficiaries on all political levels. This should reduce dependence on single sources of funding and the associated risks. One recent example is the contribution of the forest and timber to climate protection by reducing CO_2 emissions. Combined efforts are needed to ensure that forest owners receive compensation for this climate protection service in future.

Finally, it can be concluded that current findings about the condition of the forest support the federal government's strategies and instruments. These include: the Forest Policy 2020 (with the supplement to the Forest Act), the Wood Resource Policy, and Switzerland's Biodiversity, Climate and Sustainability Strategies. There is, therefore, no need to fundamentally modify them. The insights in this Report should, however, be used to prioritise, specify and implement the corresponding measures.

Consequences for research

The situational analysis in the Forest Report 2015 shows that forest monitoring in a quickly changing environment is important. Long-term observation time series are, namely, essential for the early detection of environmental changes, the analysis of the underlying ecosystem processes and checking the effectiveness of management measures. To establish the future course for forest and forest management, reliable forecasts based on modelling are needed. Here too long-term monitoring data play an important role since they can be used to calibrate existing models and fine-tune forecasts, as well as 'upscale' them by extrapolating from points to areas. The existing monitoring networks must therefore be safeguarded. Environmental change is a global phenomenon. Many regional problems have, accordingly, a global background. Process analyses cannot, therefore, stop at the Swiss border, but must be embedded in the international context. International networks play a decisive role here because they facilitate and encourage the exchange of data, know-how, results and approaches to solving problems. Switzerland can play a part in this and at the same time benefit from other foreign countries. The resulting insights must be adapted to Switzerland and made usable (so-called downscaling), while taking into account special national and regional features.

In coming years, forest research will also be confronted with themes like environmental and climate change, as well as the energy transition. In the following, selected research themes are presented and discussed. In the case of environmental change, it will be necessary to investigate, among other things, the effects of the expansion of the forest in the mountains and the increasing pressure of urban development on the Swiss Plateau on forest services. This will involve understanding above all not only the processes but also conflicts o ver use.

The direct and indirect consequences of climate change are among the most significant future threats to the Swiss forest. The influence of the changing climate on the forest is currently the focus of FOEN and WSL's research programme "Forest and Climate Change". The programme should answer many pressing questions and provide corresponding guidelines for practical use. It is expected to be completed by the end of 2016. The synthesis will show where research gaps still exist. Already today it is becoming apparent that the effect of drought on sites with a good supply of water is also relevant, but difficult to gauge. One important research area is exploring the interactions between different influence factors, such as between drought and nitrogen or ozone, or between drought and insect pests or diseases. In addition, thorough studies are needed of the potential and limits of management measures to improve the adaptability of our forests to climate change and insect pests.

For the protection forest, it is crucial to determine how climate change, the extensification of mountain agriculture and the excessively large populations of wild ungulates in some locations affect the protection services of the mountain forests. Here the positive effects of maintaining the protection forest on various forest services should be identified and management interventions further optimised.

While research on biodiversity has, in the past, concentrated on the general condition in the forest, in future more focus on functional aspects, rare species and checking effectiveness will be called for. This involves focussing both on biodiversity in itself and on the effects of biodiversity and rare species on the different forest services, as well as on the productivity (e.g. timber), stability (e.g. natural hazards) and attractiveness (e.g. recreation) of different types of forest.

In forestry, the necessary basis must be developed to improve the efficiency of management and to expedite the quantification of the services performed and make them more visible. The energy transition and new technological developments in the use of wood could present great opportunities for the forest enterprises. Here it will be necessary to ensure that the increasing demand for the renewable resource wood is in harmony with the other forest services. Demands on the forest continue to increase, and so too does the need for coordination. For the future, scientifically sound bases, scenarios and approaches are therefore needed to optimize the performance of different forest services in the framework of integrated planning and to use synergies so that the public's future needs in the forest can be met.

1 Comparisons with the Forest Report 2005 refer to different timeframes depending on the data source, which are specified in the text.

2 Development since the publication of the 2005 Forest Report, which referred to data from the NFI 1993/95.

> Introduction to the European indicators of Forest Europe

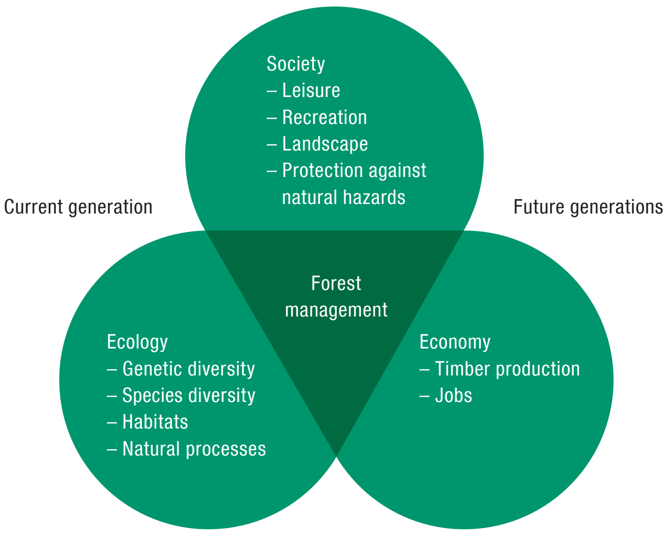
Hans Peter Schaffer

The present Forest Report 2015 investigates how the condition of the Swiss forest has developed since the publication of the Forest Report 2005. Both forest reports are based on the indicators used in Forest Europe (Forest Europe et al. 2011). Their results are therefore directly comparable and can be compared with those of international reporting. The results of the indicator measurements enable an assessment of whether the Swiss forest is being used sustainably. Prerequisites for such an assessment are long-term data series about the condition of the forest ecosystem, based on data from comprehensive forest monitoring conducted since the 1980s (cf. Graphics II and III). Long-term targets must also be defined, and the federal government has accordingly specified such targets in the Forest Policy 2020 (FOEN 2013c).

Sustainably used forest

Providing people with enough food and other vital goods from the forest is an issue that can be traced back a long time (Sedlacek 2012). In his "Sylvicultura oeconomica" (Sächsische Carlowitz-Gesellschaft 2013), Hans Carl von Carlowitz 300 years ago described a method of sustainably managing the forests and conserving the resource wood in the long term. Even then, he was concerned about the shortage of the raw material wood. During this time, the insight developed that the regeneration of a resource should be set as the measure of how much it could be used. For forest management, this means that, in the long term, the amount of timber used may not exceed the increment. In Hans Carl von Carlowitz's time, the forest had been over-used for some time and he therefore proposed the cultivation of reserves. In order to be able to use the timber later and for the sake of succeeding generations, felling was, where necessary, stopped.

Such reflections on sustainable forest management led to the development of the concept of sustainability. The UN Brundtland Commission defined, in its 1987 report, sustainability as a development that "meets the needs of the present without compromising the ability of future generations to meet their own needs". This type of development presumes an interaction between society, the economy and ecology, and the resulting concept consists of these three dimensions. The concept of sustainability was first presented at the world summit in Rio de Janeiro in 1992, and was then adopted by the Swiss Federal Council. Graphic IV shows how the concept of sustainability in the federal Forest Policy (FOEN 2013c) is applied to forest management.



Graphic IV *The concept of sustainability in terms of the three dimensions Society, Economy, and Ecology. Source: FOEN 2013c*

Monitoring sustainability in the forest

A sustainable form of forest management aims to maintain indigenous forest ecosystems and fulfil the public's current and future needs in the forest. The Swiss Forest Act (WaG 1991) acknowledges – as a basic condition – that it is not only people's needs and resulting demands that set the standards, but also the long-term provision of the following services society requires of the forest:

> The forest should be preserved in area and spatial distribution.
> It should be protected as a near-natural community.
> It should be able to fulfil its main functions, namely those of providing protection, wellbeing and utility.

Table I

Description of the 13 basic indicators (Bernasconi et al. 2014) and how they relate to the indicators in Forest Europe (Forest Europe et al. 2011). The corresponding chapters in the Forest Report 2015 are also given.

	Basic indicators of the federal government and the cantons	Indicators in Forest Europe and related chapters in the Forest Report 2015
1	**Forest area:** Sum total of all areas that, at a federal level and in the cantons, are recorded as forest as a result of the cantons' own assessments.	1.1 Forest area
2	**Growing stock:** Volume of stemwood in bark of all living trees and shrubs in the forest area.	1.2 Growing stock
3	**Forest structure:** Distribution of the forest area according to developmental state and/or diameter classes.	1.3 Age and stand structure
4	**Forest damage:** Extent of damage to the forest categorised according to the most important types of damage or damage groups, as well as according to the year or the period when the damage occurred.	2. Health and vitality (2.1 to 2.4)
5	**Relationship use of fellings/net increment:** Relationship between the use of the wood and the net increment (volume of stemwood in bark) over a certain period of time in relation to the entire forest area.	3.1 Timber use and increment
6	**Composition of the types of trees:** The area of all main types of trees as a proportion of the living trees.	4.1 Species diversity
7	**Natural tree species composition:** Evaluation of the naturalness of tree species composition depending on the proportion of conifer wood.	4.3 Closeness to nature
8	**Deadwood:** Volume of standing and lying deadwood in the forest area.	4.5 Deadwood
9	**Treated area of protection forest:** Proportion of the removed and treated protection forest area according to year of the last intervention and the type of natural hazard.	5.2 Protection against natural hazards
10	**Protective effect of the protection forest:** Proportion of the area of the protection forests that fulfils the minimum requirements for Sustainability in Protection Forests (NaiS – Frehner et al. 2005).	5.2 Protection against natural hazards
11	**Results of forest management:** Total revenue from forest management minus the total costs, where possible classified according to the primary functions.	6.3 Economic situation of forest enterprises
12	**Result of the timber harvest:** Total revenue from the forest harvest minus the total costs of the forest harvest in relation to the 'productive forest area'.	3.2 Roundwood
13	**Recreation in the forest:** The frequency of visits to the forest is one of several ways of describing recreation in the forest, in addition to the satisfaction of those seeking recreation or visitor frequency.	6.10 Recreation in the forest

Monitoring sustainability requires targets, as well as indicators for measuring the extent to which they have been reached. The federal government has specified the targets at a national level in its Forest Policy 2020. An evaluation of effectiveness is therefore necessary to assess the implementation and attainment of these targets. This requires measurement variables, so-called indicators. The related data should be as easy to measure and as reproducible as possible. Using indicators enables the conditions and changes in ecosystems to be recorded in a quickly changing environment over a long period (Schaffer 2010). Indicators, however, only describe part of the reality and therefore record only a few aspects of forest ecosystems. These systems are characterised by complex interrelationship structures. Choosing meaningful indicators is therefore generally difficult. A whole set of indicators are needed to survey the forest as, preferably, a whole ecosystem, and to identify any changes.

Criteria and indicators used

The Forest Report 2015 uses the indicators in Forest Europe (Forest Europe et al. 2011). The set consists of 6 so-called criteria and a total of 35 indicators. The 6 criteria are presented and described in the following chapters:

1. Resources
2. Health and Vitality
3. Use
4. Biodiversity
5. Protection Forest
6. Social Economy

Each criterion and the related indicators are dealt with in a separate chapter, with a summary followed by descriptions of the individual indicators. The data compiled for each indicator record various variables from different perspectives (Graphics II and III). This means that the results are not always covering the same area and may be fuzzy – depending on the dataset used. For example, the Forestry Statistics are based on a survey of all forest enterprises in Switzerland. They provide information on the economic state of the forest enterprises and the economic cycle of timber. In the National Forest Inventory NFI, in contrast, aerial photographs are evaluated and data collected in the forest, which involves, for example, specialists measuring trees and recording their volume. These data are supplemented with surveys of the cantonal forest services. Both surveys provide information on the use of timber (chapter 3), but from different perspectives. They are therefore not directly comparable. This is why the data sources used are always cited in this report.

Basic indicators of the federal government and the cantons

Based on the international Forest Europe indicator set used here, the federal government and the cantons have developed a set of 13 indicators to ensure comparable sustainability reporting at a national level (Rosset et al. 2012). This set is a minimum set of indicators that can be supplemented by the cantons according to their requirements. These 13 indicators are called the basic indicators. Table 1 shows the relationship between these basic indicators and the indicators used in Forest Europe.

1 Resources

Urs-Beat Brändli, Bruno Röösli

The forest in Switzerland covers a third of the country's surface. The forest area in the Alpine regions has increased continuously for 150 years, and by as much as 7 per cent since the 2005 Forest Report alone. In many places stands have become denser. The overall growing stock has increased by a further 3 per cent, although not as much as in the previous period. The growing stock on the Swiss Plateau has, however, decreased, especially that of spruce, which has diminished by almost a third. Since the overall growing stock is greater, the forest serves as a sink for increasing amounts of CO_2.

Summary

The forest area on the Swiss Plateau has remained constant, but has increased in Alpine regions. The situation 200 years ago was very different: deforestation was decimating the forest, and severe flooding occurred. In 1876 the first national law to protect the forest from clearance and overexploitation was passed. Since then the forest has spread, at first through afforestation, but in recent decades almost entirely naturally as it has expanded into abandoned Alpine meadows. An expansion of the forest is not, however, always desirable, which is why the law was changed in July 2013. Since then, the Swiss cantons have been able to specify so-called 'static forest boundaries' between the forest and open land beyond which newly formed stands can be removed without special clearing permission.

A distinctive feature of the Swiss forest is its diversity: conifer forest covers 43 per cent of the forest area, broadleaf forest 25 per cent, and mixed forests 32 per cent. Since 1995[1] the proportion of conifer and mixed forest has fallen by 3 per cent in favour of broadleaf forest.

The forest has many functions. Today nearly half of Switzerland's forest area acts as protection forest, while on about a third of the forest area wood production has priority. Other important primary functions are nature and landscape conservation as well as recreation, which have priority on about one sixth of the forest area.

The growing stock is increasing, especially in the Alps and on the Southern slopes of the Alps. There are, however, large differences between the regions and forest types. On the Swiss Plateau the stock of conifers has decreased, whereas that of broadleaves has grown in all regions. In comparison with other European countries, the Swiss forest contains substantial quantities of wood, amounting to 350 cubic metres per hectare of forest area. A considerable proportion of the wood stock grows on steep and rather inaccessible terrain where harvesting trees is not worthwhile. In addition, many stands are too old for harvesting and consist mostly of trees with large diameters for which there is little demand on the market at the moment. From an ecological point of view, however, the Swiss forest is relatively young as very few trees complete their natural life spans. From this perspective, more old trees would actually be desirable.

The continuous growth of the forest means it is binding increasing amounts of carbon, although it can only absorb a small part of the CO_2 emissions from industry, traffic and private households. Nevertheless this accounts for about 40 per cent of the CO_2 reduction to which Switzerland has committed itself. The economic value of this forest service amounts to several million Swiss francs a year. It is therefore understandable that forest owners are claiming compensation for the carbon fixing their forest provides.

1 The development since the publication of the 2005 Forest Report, which referred to the data from the 1993/95 National Forest Inventory (NFI).

1.1 Forest area

Bruno Röösli, Fabrizio Cioldi, Paolo Camin

> *The Swiss forest performs many tasks. Among the most important, depending on the particular area, are: providing protection against natural hazards, timber production, and biodiversity and landscape conservation.*

> *About a third of Switzerland's land surface is covered with forest. The regional differences between the Swiss Plateau and the Southern slopes of the Alps are great.*

> *The total forest area has grown by 7 per cent to 1.31 million hectares since 1995. The forest is expanding, particularly in Alpine regions where agricultural land use is diminishing.*

> *The cantons can now specify so-called 'static forest boundaries' to prevent the forest expanding to areas where it is not wanted.*

> *Pure conifer forests account for 43 per cent of the forest area, making up the largest proportion. Since the 2005 Forest Report pure broadleaf forests have increased and today cover 25 per cent of the forest area.*

Forest functions

The Swiss forest is expected to fulfil all kinds of requirements: it should provide wood, store as much carbon dioxide (CO_2) as possible, provide protection against avalanches and rockfall, supply clean drinking water, provide a habitat for plants and animals, as well as be (freely) available for people to relax and recuperate. To meet these demands, most cantons map, as part of their forest planning, the local forests functions, and specify which should have priority in the mostly multifunctional forests. In the whole of Switzerland between 42 and 49 per cent of the forest area[1], depending on the definition of forest area used and how data is collected, serves to provide protection against natural hazards (section 5.2). Wood production has priority on 32 per cent of the forest area, nature and landscape protection on 12 per cent and recreation on 1 per cent (Brändli et al. 2015). Recreation is in principle possible anywhere in the forest area, but it only has priority over other functions on a few areas. Wood can also be used in many areas apart from forest reserves where the wood is no longer used (section 4.9).

Forest cover and use

According to NFI 2009/13, the forest today covers almost a third of Switzerland's land surface, with considerable differences between the regions. On the Swiss Plateau only a quarter of the land is covered with forest, whereas on the Southern slopes of the Alps it covers half the land area.

All of Switzerland's forests are freely accessible to a locally acceptable extent, with the exception of a few protected areas and military facilities. In general, forest owners have no legal restrictions on how they manage their forests, and there are no corresponding prohibitions. Stricter provisions, however, apply in, for example, groundwater protection areas. Where forest owners stop harvesting wood in, for example, forest reserves, they do so voluntarily. Normally in such cases, they reach an agreement with the canton, which, together with the federal government, gives them compensation (section 4.9).

Fig. 1.1.1 *The area of forest is under pressure not only on the Swiss Plateau but also in Alpine tourist centres like Davos (GR). Photo: Ulrich Wasem*

Development of the forest area

Most of the Swiss population live on the Swiss Plateau, where unbuilt areas, particularly green spots, are becoming scarce because residential areas and infrastructure have been expanding (Fig. 1.1.1). The forest area on the Swiss Plateau and in much of the Jura region has remained the same for decades (Fig. 1.1.2). It has, however, not always been like this. Up until the 19th century, a great deal of forest in Switzerland was cleared, which created serious environmental problems. Erosion increased, and the risk of floods, rockfall and avalanches became more acute. The federal government reacted in 1876 to this development by passing the so-called Federal Act on Forest Police, of which a central part was a ban on clearing the forest. Since then the forest area has grown and stabilised. The total forest area today amounts to 1.31 million hectares. It has increased since 1995 by 82,300 hectares, i.e. by 7 per cent. In Alpine regions the forest has been expanding naturally for a long time (Fig. 1.1.2), especially in areas where agricultural land has been abandoned.

In some places a larger forest area is not desirable because the forest may spread into the habitats of rare animal and plant species. The Federal Act on Forest was therefore changed in July 2013. Since then the cantons have been able, in areas where they wish to prevent the forest expanding, to establish static forest boundaries with open land. Beyond these boundaries, any newly formed stands are no longer legally considered forest, and can be removed without clearing permission so long as no other regulations apply.

Forest types

In Switzerland today, 62 per cent of the forest area is covered with conifer forests. Specialists distinguish between pure conifer forests where more than 90 per cent of the trees are conifers and mixed conifer forests with between 51 and 90 per cent conifers. Since 1985 pure conifer forests have decreased by 8 per cent. Broadleaf forests are also classified as pure or mixed. Together they comprise 38 per cent of the total forest area (Fig. 1.1.3). The proportion of pure broadleaf forests has increased by 5 per cent since 1985, and that of mixed forests by 2 per cent. The proportion of broadleaf forests has mainly increased at lower altitudes, where broadleaf forests grow naturally (section 4.3). Having forest stands that have adapted to the site reduces the risk of loss due to windthrow or pests, and they are also likely to be more resilient in the light of climate change.

[1] The detailed figures are: 42 per cent according to Brändli et al. 2015, 45 per cent according to Abegg et al. 2014 and 49 per cent according to Losey and Wehrli 2009.

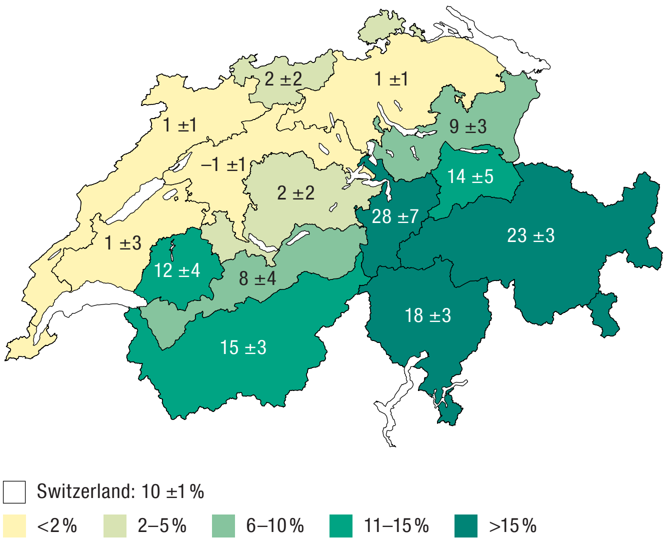


Fig. 1.1.2 *Regionally, the forest area has developed differently. It remained the same size on the Swiss Plateau and the Jura between 1985 and 2013, but increased in Alpine regions. Source: NFI*

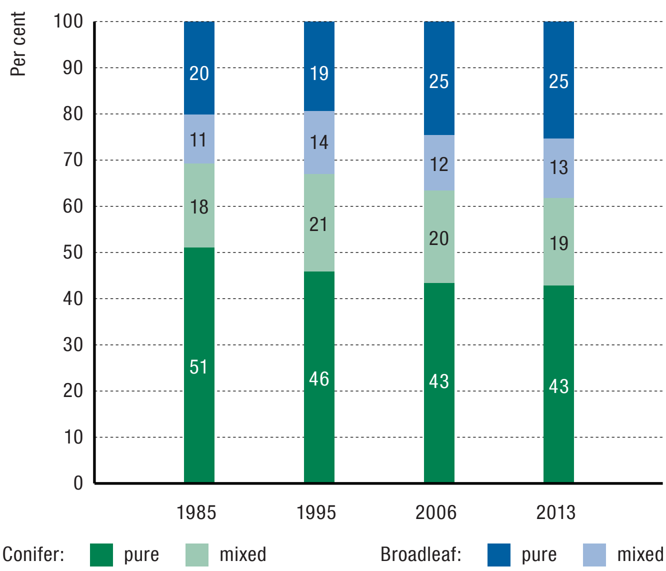


Fig. 1.1.3 *Distribution of forest types between 1985 and 2013. Pure conifer forests are most frequent, although they have decreased. Source: NFI*

1.2 Growing stock

Paolo Camin, Fabrizio Cioldi, Bruno Röösli

> *The Swiss forest contains 419 million cubic metres of growing stock, amounting to 350 cubic metres per hectare of forest. This average value is one of the highest in all Europe.*
> *Conifers make up 68 per cent of the growing stock. Spruce accounts for 44 per cent, which is the highest proportion of the growing stock, followed by beech with 18 per cent and silver fir 15 per cent.*
> *The growing stock increased by 3 per cent between 1995 and 2013, but with marked regional differences. On the Southern slopes of the Alps it went up by 30 per cent, whereas it decreased by 11 per cent on the Swiss Plateau.*
> *The stock of beech and silver fir increased particularly strongly between 1995 and 2013, whereas the stock of spruce decreased overall, and on the Swiss Plateau by as much as 31 per cent.*
> *The reduction in the spruce stock has been so dramatic that the timber industry fears it will not in future have enough Swiss spruce to process.*

Wood stock

The wood stock corresponds to the volume of stemwood from a particular forest area and is often the forest owner's most important capital. It also accounts for the largest proportion of carbon stored in the forest (section 1.4). The volume of wood in Swiss forests is regularly measured. These measurements distinguish between the volume of living trees (growing stock) and that of dead trees (volume of deadwood). The sum of these two quantities results in the total volume of wood. How is the total wood volume in the Swiss forest determined? On each NFI sample site, all trees with diameters measured at breast height greater than 12 centimetres are recorded. According to the NFI 2009/13, the total wood volume in the Swiss forest was 447 million cubic metres. Of this, around 6 per cent consisted of dead trees (section 4.5). The total volume of wood in inaccessible forest areas and shrub forest is not, however, included in this figure.

Living trees provide the increment and make up the growing stock, which is one of the most important international indicators of sustainable forest management. In the Swiss forest it amounts to 419 million cubic metres of wood in total. Per hectare this means, on average, 350 cubic metres of wood, which is one of the highest levels in the whole of Europe. In comparison, German and Austrian forests contain 300 cubic metres of wood per hectare, and in Italy and France the level is as low as roughly 150 cubic metres (Brändli et al. 2010b).

The site influences how much a tree grows and thus the growing stock, which is why it is not the same in all forests in Switzerland. It is highest (448 cubic metres per hectare) in the Pre-Alps because there the forests grow on fertile sites and are not intensively used (Fig. 1.2.1), and lowest, only 236 cubic metres per hectare, on the Southern slopes of the Alps. The main reasons for these differences are the site conditions and previous forest use, such as coppice forest or orchard management. Forests in the Jura and on the Swiss Plateau contain 364 and 393 cubic metres of wood per hectare, respectively, and are thus close to the Swiss average.

Forest owners also influence the wood stock: privately owned forests contain on average 413 cubic metres per hectare and thus have more stock than public forests, where stocks are, on average, 318 cubic metres per hectare (Brändli et al. 2015). Private forests are frequently on more fertile sites and are used less than public forests.

Availability

More than a third of Switzerland's timber resources are located in the Alps and on the Southern slopes of the Alps. These regions are often difficult to access and the harvesting costs of the timber are correspondingly high. The low prices for timber in recent years mean that marketing the wood often does not cover the costs of harvesting it, as the following figures indicate. The average gross revenue from wood was 83 Swiss francs in 2010 (WVS 2011). For about a quarter of Switzerland's wood stock, the potential cost of harvesting the wood is, however, more than 100 Swiss francs per cubic metre wood (Duc et al. 2010). The wood stock with the highest harvesting costs is mainly in the Alps, the Southern slopes of the Alps and the Pre-Alps. The Forest Policy 2020 aims better to exploit the potential for sustainable use of timber and to develop measures so that the reserves that have not yet been used can be mobilised throughout Switzerland (section 3.1).

Tree species

The altitude at which a forest stand grows influences the composition of tree species in the stand. More than half the forested areas in Switzerland are above 1,000 m a.s.l. Conifers make up the largest proportion, 68 per cent, of Switzerland's wood stock, accounting for 75 per cent in the Pre-Alps and as much as 84 per cent in the Alps. Spruce made up 44 per cent of the wood stock in 2013, which is the largest proportion, followed by beech with 18 per cent and silver fir 15 per cent (Fig. 1.2.2). The volumes of other species like pine, larch, maple, ash and oak are considerably smaller, amounting to between 2 and 6 per cent.

Previous development

Since the NFI 1983/85, the wood stock has steadily increased for various reasons. The most important is that, for decades, less wood than grows has been used. The expansion of the forest onto formerly cultivated land in Alpine regions has boosted the increase in stock. During the 18 years between NFI 1993/95 and NFI 2009/13, the wood stock rose by 3 per cent. This and the estimate below do not include the forest expansion because only the sample plots surveyed in both Forest Inventories were compared.

Again there are large regional differences. The wood stock increased particularly strongly (14 %) in the Alps, and by as much as 30 per cent on the Southern slopes of the Alps. In contrast, on the Swiss Plateau it fell by 11 per cent because the forest there was used more and was more affected by storm damage and bark beetle infestations. The differences are not only great between the regions but also between the tree species. The stock of spruce, an economically interesting tree species, sank by 5 per cent in Switzerland and on the Swiss Plateau by as much as 31 per cent, whereas that of the silver fir rose by 9 per cent. Overall the stock of conifers diminished slightly, while that of broadleaf trees grew in all regions. Beech alone increased by 6 per cent and, on the Southern slopes of the Alps, by as much as 42 per cent. These trends are basically positive from an ecological point of view and in the light of climate change, but they do not correspond with the current needs of the timber industry.

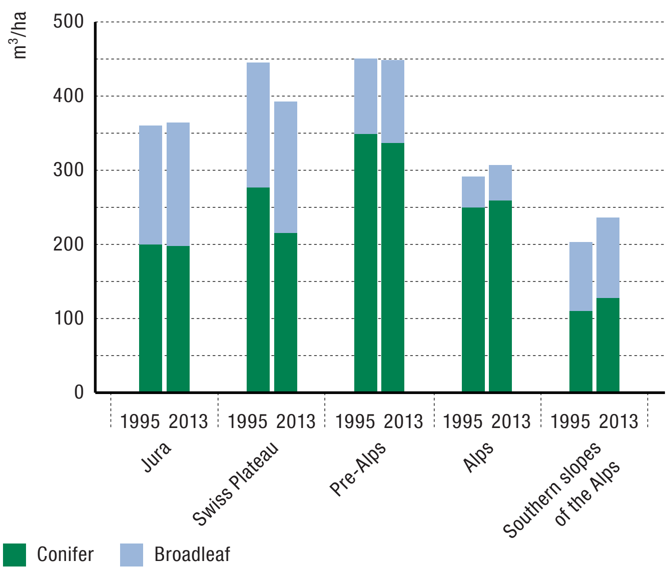


Fig. 1.2.1 *Stock of conifer and broadleaf trees in the 5 production regions: Comparison of NFI 1993/95 and 2009/13 (including the increase in forest area). Source: NFI*

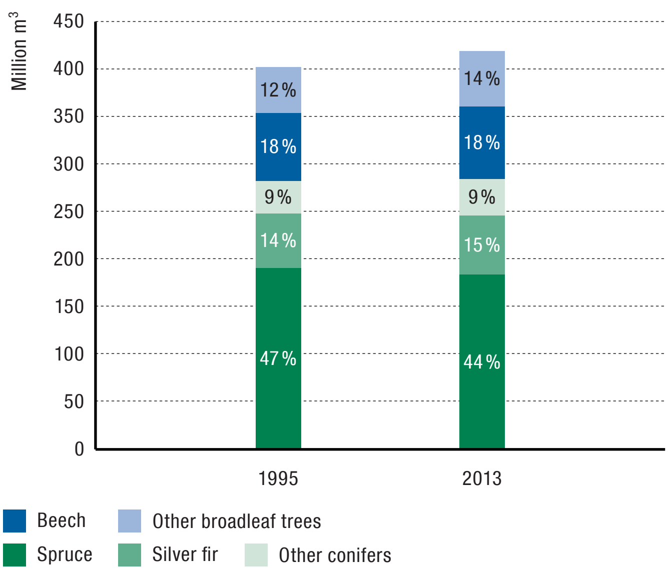


Fig. 1.2.2 *Proportions of stock of the economically most important tree species: Comparison of NFI 1993/95 and 2009/13 (including the forest area increase). Source: NFI*

1.3 Age and stand structure

Urs-Beat Brändli, Fabrizio Cioldi

> *From an economic point of view, the age structure in the Swiss forest is not sustainable. Many stands are too old and consist of trees with large diameters, which are less in demand on the timber market at the moment. The forest lacks younger stands aged up to 30 years old, but its age structure has improved overall since 1995.*
> *From an ecological point of view, the Swiss forest is rather young. Very few stands reach their natural life expectancy, and only 0.4 per cent of Swiss forests are older than 250 years. Since 1995 the number of large old trees has markedly increased, but today they still make up only a small proportion of the whole forest stand.*
> *Stands that are variably structured, multi-layered and not too dense are ecologically preferable, and also better able to withstand wind and snow pressure.*
> *Stands on more than a quarter of the forest area are very dense, and have increased slightly since 1995 in all regions apart from the Swiss Plateau. This is probably a consequence of the forests in the Alps and on the Southern slopes of the Alps being used less intensively.*

Age structure

The age of a forest stand is important both ecologically and economically. Opinions about the composition of an 'optimal forest', however, differ. From an economic point of view, a forest with a well-balanced age structure is preferable because the tending requirements of the young forest are then less subject to fluctuation, as are the timber yields from thinning and final cutting. The sale of timber is still the most important source of income for forest owners. A sustainable age composition enables forest enterprises and forestry service entrepreneurs to generate regular yields, to make efficient use of their workforce, and sustainably supply the timber market. From an ecological point of view, however, old growth patches with many dead and mighty trees, so-called habitat trees, are desirable as they are habitats for many wood-dwelling animal and plant species (section 4.5). People who go to the forest for recreation also prefer a natural diversity, old stands and large trees with thick stems (Bernasconi and Schroff 2008). In protection forests, on the other hand, uneven-aged stands with sufficient regeneration should ensure the protective effect is sustainable.

Classifying the composition of a stand as even- or uneven-aged is a matter for the experts from the National Forest Inventory NFI, who decide on the basis of the different tree diameters in the stand. In NFI 2009/13 26 per cent of the stands were classified as uneven-aged. In even-aged stands, which make up 74 per cent of Switzerland's forest area, the age of a stand is determined as precisely as possible without taking core samples. Instead of core sampling young stands, the branch whorls on conifers are counted, while in other stands the tree-rings on the stumps of felled trees are counted. In most cases, however, experts estimate a stand's age on the basis of the dominant tree diameter and tree height.

Optimal age structure

The composition of a forest is considered to be sustainable from an economic point of view if the same volume of wood can be harvested each year. To achieve this, two possible management designs are in principle possible: high forest with group selection with area felling and permanent or plenter forest (single tree selection forest), where only single trees are removed. In an ideally structured high forest with group selection, the areas covered by each age class – ranging from young forest to mature forest ready for final felling – are the same size. This means that all the timber is cut on the same-sized area each year (professionals call this 'final cutting'), and forest regeneration takes place on the whole cleared area. The time span between two final cuttings is called the 'rotation period'. For the NFI, the economically optimal rotation period for the main tree species varies between 120 and 180 years, depending on the growth rate on the site (Cioldi et al. 2010). This then allows an ideal age distribution to be estimated for the whole of the Swiss forest. If these target values are compared with the actual age distribution in the forest, there appears to be a lack of young stands up to 30 years old and of stands aged between 60 and 90 years (Fig. 1.3.1). Since NFI 1993/95, the forest's age structure has, on the whole, improved. Nevertheless, the optimal rotation period is still exceeded in 6 per cent of the forests, and on as many as 13 per cent of very good sites (Brändli et al. 2015). If the rotation period were set at 90 years, which is what would be optimal with the current demand for spruce assortments, then on very good sites as many as 38 per cent of all stands and 39 per cent of all spruce stands would be too old. The Swiss forest is thus, from an economic perspective, overaged and not sustainably structured.

Ecologically, however, the Swiss forest is too young. In comparison with virgin forests, they lack stands in the 'second half of life'. The main reason for this is harvesting. The natural life expectancy of the trees is at least twice as high as the economically optimal rotation period of the particular tree species. Old and dying trees foster species diversity, especially as there are many rare species that rely on the dead branches, holes and cracks in large old trees. On the Swiss Plateau, where beech stands can naturally grow to be 350 years old, only 11 per cent of all stands are older than 120 years according to NFI 2009/13, and only 0.5 per cent older than 180 years (Fig. 1.3.2). Trees at higher altitudes tend to have a longer life expectancy. Thus spruce stands in the Alps can grow to be 400 years old or even older. But even there, only 7 per cent of the stands are older than 180 years, and hardly any stand reaches its potential maximum age. This means that mountain forests are not in danger of becoming physiologically overaged in coming decades. Many older protection forest stands, however, do not contain enough regeneration (section 5.2). Only 0.4 per cent of Swiss forests are older than 250 years (Brändli et al. 2015). In managed forests today, the federal and cantonal authorities are, together with forest owners, creating 'islands' of old and dead wood to promote older trees and longer development phases, and thus species diversity in the forest (section 4.9).

Tree diameter

The stem diameter of a tree is not only relevant as an indicator of its economic value and use for timber production, but also gives an idea of the tree's relative age. To see whether an uneven-aged plenter or permanent forest has a sustainable structure, the distribution of the number of stems per diameter class is considered. The stem diameter is measured according to the international norm 1.3 metres above the ground (so-called diameter at breast height).

According to NFI 2009/13, thin trees are much more frequent in the Swiss forest than thick ones (Fig. 1.3.3). This is not surprising since most trees die before they become very old and large. Huge broadleaf trees are particularly rare for several reasons. Many broadleaf trees, such as birch, rowan, hornbeam and alder species, do not grow naturally to be very large. Moreover broadleaf forests mainly occur at lower altitudes where the forests have been intensively used for years and have regenerated naturally.

Large trees with a diameter of more than 80 centimetres are classified as giants in the NFI. Their wood is usually not very interesting for the timber industry because it often contains rot. Moreover, there is little demand for thick stems in the industry. Giants provide, however, ecologically important habitats for species that take time to spread (e.g. lichens), and for many animal and fungi species because they often

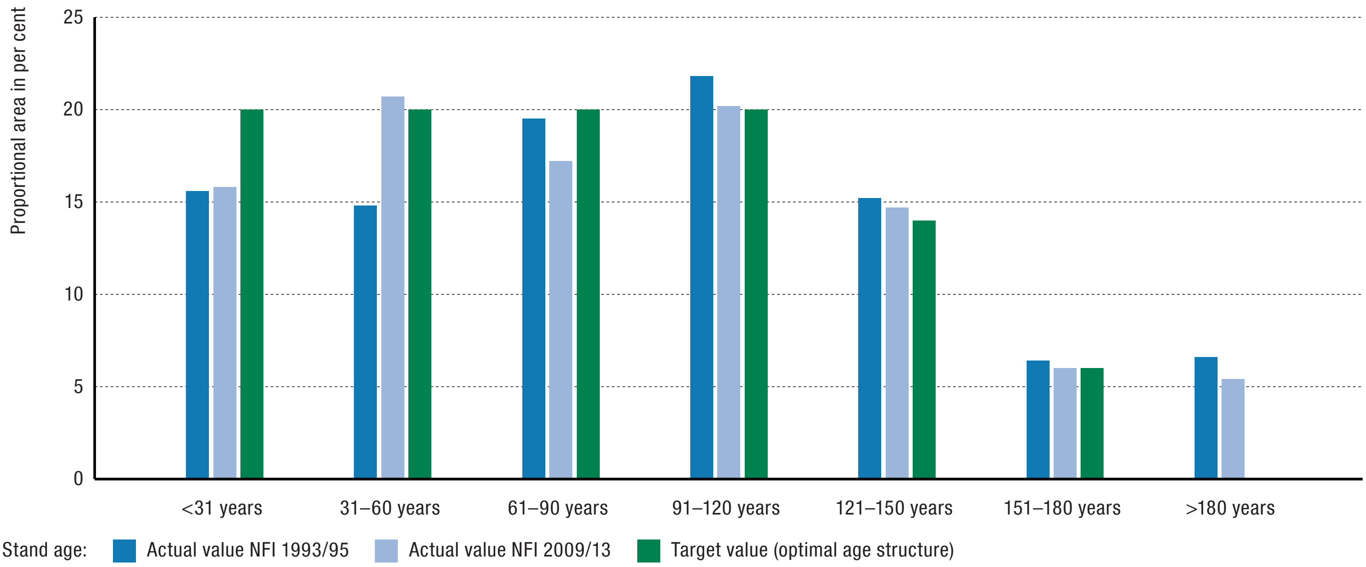


Fig. 1.3.1 *Distribution of age classes in even-aged forests. For sustainable wood production, the actual and the target values should correspond well. Source: NFI*

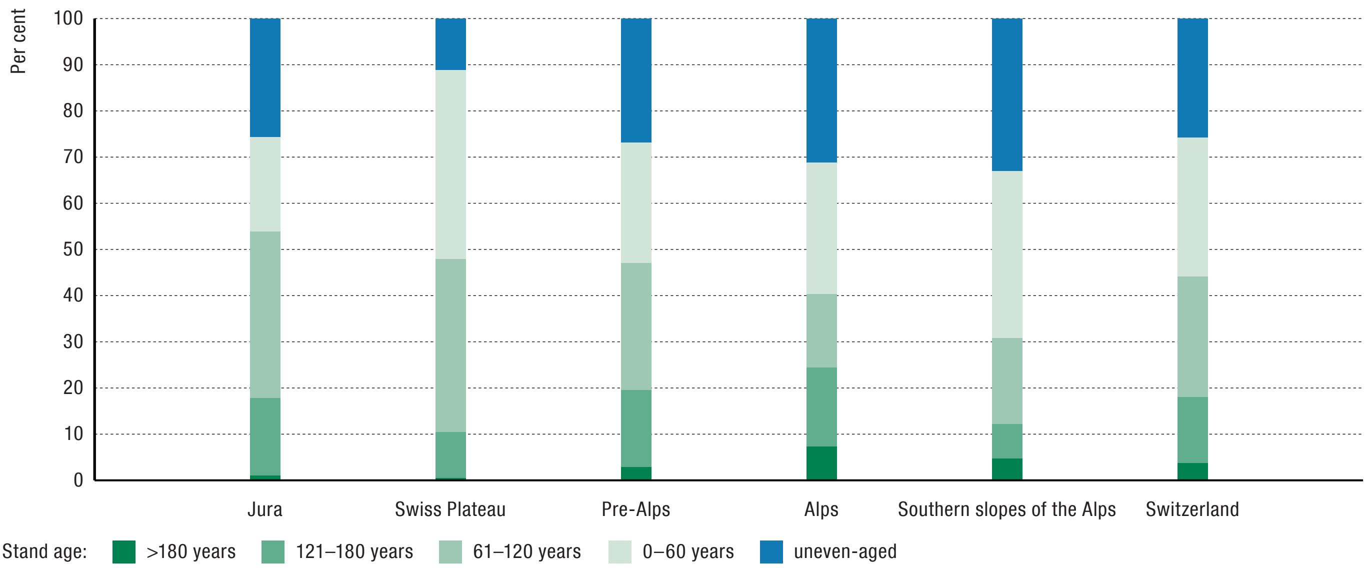


Fig. 1.3.2 *Distribution of stand age classes according to production in the 5 regions. Source: NFI 2009/13*

have dead branches and other microhabitats like cracks (section 4.5). Today there are on average 1.7 giants per hectare forest, of which about three-quarters (1.3) are conifers and the rest (0.4) broadleaves (Brändli et al. 2015). In NFI 1993/95 the average was only 1.1 giants per hectare, i.e. the giants in the Swiss forest have significantly increased. It is still, however, very different from natural unmanaged forest. In beech forests in Switzerland, for example, giants are 30 times less common than in Europe's largest beech virgin forest in the Ukrainian Carpathians (Brändli and Abegg 2013).

Stand structure

Stand structure describes both the vertical and the horizontal composition of the forest. From an ecological point of view, multi-layered or stepped stands provide more diverse habitats than single-layered stands, but they are more difficult to manage. The most ideal management systems are layered permanent and plenter forests, as well as group-selection forests and shelterwood forests with two-layered old timber stands (Fig. 1.3.4). And what about the vertical structure in the Swiss forest? According to NFI 2009/13, only 36 per cent of stands are single-layered, 49 per cent are two- or three-

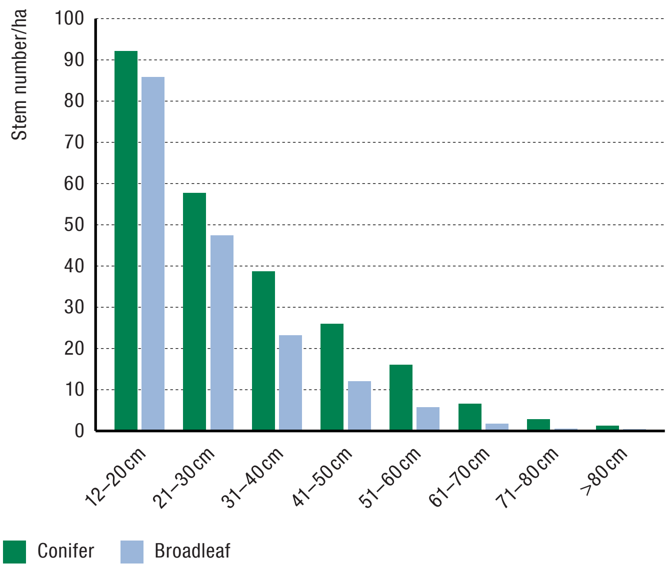


Fig. 1.3.3 *Distribution of the number of living broadleaf and conifer trees according to diameter class. Source: NFI 2009/13*

Fig. 1.3.4 *Two-layered beech forest in Reppischtal (ZH). The upper layer consists of old timber, and the lower layer of natural regeneration. Photo: Urs-Beat Brändli*

layered, 14 per cent are stepped and 1 per cent have a so-called 'cluster structure'. Clusters are layered groups of trees, which form ideal protection forests.

The horizontal structure affects the light availability in a stand. Dense forests are not very desirable for several reasons: They have little ground vegetation and are unsuitable for animal and plant species that require light and warmth. They contain little browsing material for game animals, which means the sparse regeneration is more likely to be damaged by game animals. Moreover, tree crowns are smaller in a dense stand, which is also less able to withstand wind and snow pressure. If a protection forest, commercial forest or special forest reserve (section 4.9) contains stands with dense crown closure, then this probably means that more silvicultural treatment is needed.

More than a quarter of the stands in Switzerland today are crowded and have overly dense closure. The differences between the economic regions are relatively small. Only in the south-eastern Alps region (the Grisons) is the proportion much less than in the rest of Switzerland (Fig. 1.3.5). Between 1995 and 2013 the proportion of dense stands in the whole of Switzerland did not significantly change (Brändli et al. 2015). On the Swiss Plateau it even decreased, mainly due to the effects of the storm 'Lothar'. In the Jura, parts of the Pre-Alps, and Valais, as well as on the Southern slopes of the Alps, dense stands, however, slightly increased. The stands in the sub-alpine level, in particular, have become denser. This indicates that the trend is for more silvicultural treatments to be needed in mountain forests as a consequence of the less intensive use of forests in the Alps and on the Southern slopes of the Alps (Cioldi et al. 2010).

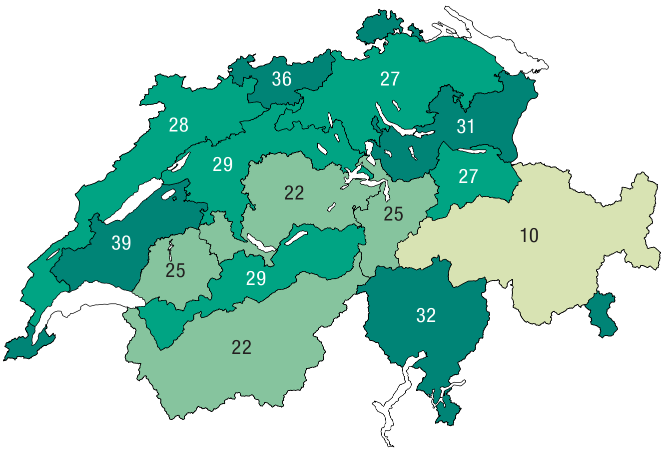


Fig. 1.3.5 *Proportion of dense stands in the 14 economic regions in Switzerland. Source: NFI 2009/13*

1.4 Carbon stock

Nele Rogiers, Frank Hagedorn, Esther Thürig

> *Forests play an important role in the global carbon cycle. The Swiss forest binds 5 times more carbon in its plants and soil than is contained in the atmosphere over Switzerland in the form of carbon dioxide (CO_2).*
> *The Swiss forest has the highest carbon stock per area in Europe, namely 270 tonnes of carbon per hectare (t C/ha). Around 121 t C/ha are stored in living trees, and a further 149 t C/ha in the organic layer and deadwood.*
> *In this Forest Report, the carbon balance of the forest has been included for the first time and estimated according to the Kyoto rules. As more wood is growing in the Swiss forest than is used, its carbon stock is also increasing. The forest is therefore making a substantial contribution to meeting the reduction targets for greenhouse gases to which Switzerland has agreed under the Kyoto Protocol.*

Carbon emissions

Greenhouse gases in the atmosphere, including CO_2, have increased by over a third since the 19th century and led to a change in climate (IPCC, 2007). To mitigate the impact of climate change, various measures must be taken to reduce the emission of these gases. Forest growth and afforestation help to remove CO_2 from the air since plants absorb it and deposit the resulting carbon (C) in the forest biomass. Forest management can, through systematic interventions, structure the forest in such a way that it absorbs as much CO_2 as possible. This is why carbon stocks in forests and their development have been a focus of attention in politics and research.

Carbon stocks in biomass in the forest

Calculations of the amount of carbon sequestered in the living biomass in the forest are based on the following data: wood stock (section 1.2), estimates of the distribution of biomass in stems, branches, leaves and roots, as well as figures for the density and carbon contents of wood. The greatest uncertainty in this calculation model lies in the underground biomass, which is difficult to assess, but which is important because roots store approximately a quarter of the deposited carbon.

The amount of carbon calculated to be stored in the living biomass in the Swiss forest amounts, in total, to about 144 million tons. The Swiss forest thus stores, on average, 121 tonnes of carbon per hectare (t C/ha). The carbon stocks in the Swiss forest are large partly because of the favourable growing conditions prevailing. The stocks in Austrian forests are similarly high because the management systems and site conditions are comparable. The high value in Switzerland is, however, also partly due to the ongoing underuse over the past decades of broadleaf stands, private forests, forests on steep slopes and remote mountain forests (section 1.2; Brändli 2010).

The distributions of the carbon stocks between dead and living biomass are very different in the 5 production regions. The forests with the largest carbon stocks in the living biomass are situated in the Pre-Alps (Fig. 1.4.1), where the growing conditions for the forest are particularly good. The lowest carbon stocks per hectare are found in the living biomass on the Southern slopes of the Alps. The forests there are relatively young and have the least increment.

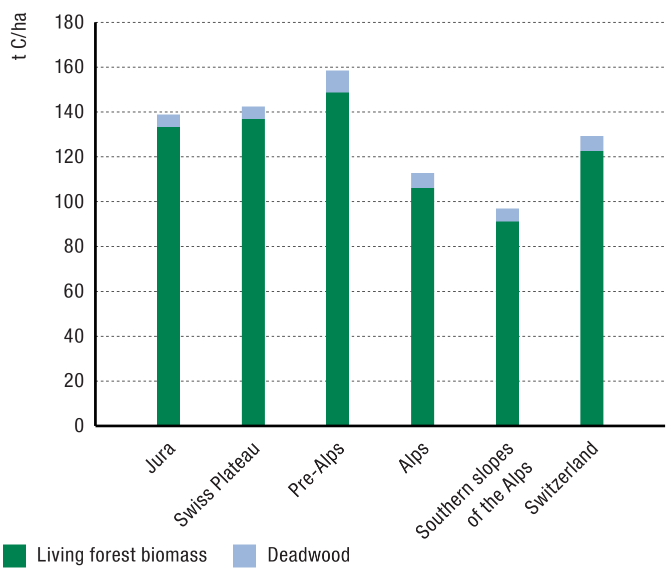


Fig. 1.4.1 *Distribution of carbon stocks in the living and dead biomass in the 5 production regions. Source: NFI 2009/13*

Carbon is not only stored in living biomass but also in deadwood, which contains, on average, nearly 7 t C/ha (section 4.5). It remains there until the deadwood has been fully decomposed or integrated in the soil humus. The most carbon stored in deadwood, amounting to an average of nearly 10 t C/ha, is found in the Pre-Alps.

Carbon stocks in the forest soil

The soil in Swiss forests stores, together with the organic layer, on average 143 t C/ha (Fig. 1.4.2), which is a bit more than that contained in living biomass. These figures are based on the analysis of around 1,000 soil profiles, representative of the heterogeneous site conditions found in Swiss forests. The carbon contents of forest soils increase with altitude and with the associated cooler and more humid conditions. This increase is one reason why Swiss forest soils contain roughly 50 per cent more carbon than other central European countries, which are at lower altitudes.

Forest soils in southern Switzerland have the largest stocks of carbon (Fig. 1.4.2). This seems to contrast with the small quantities of carbon stored in living biomass (Fig. 1.4.1). Experts attribute this to the frequent forest fires and the high contents of iron and aluminium oxides, which protect the humus from being decomposed by microorganisms (Fig. 1.4.3).

Swiss forests contain 5 times as much carbon in their living and dead biomass as is in the atmosphere over the country (Fig. 1.4.4). Of this, somewhat more than half is stored in the soil together with the organic layer, while the rest is in the living and dead trees (Fig. 1.4.5).

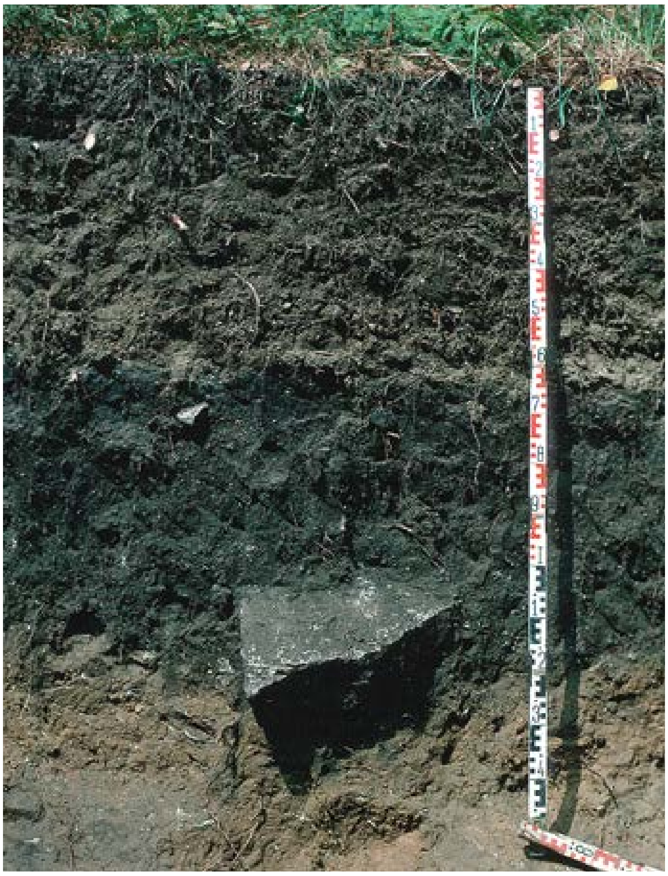


Fig. 1.4.3 *Forest soil in Ticino. The black colouring is due to the high levels of 'black carbon', i.e. traces of forest fires, indicating that such fires were frequent. Photo: Marco Walser*

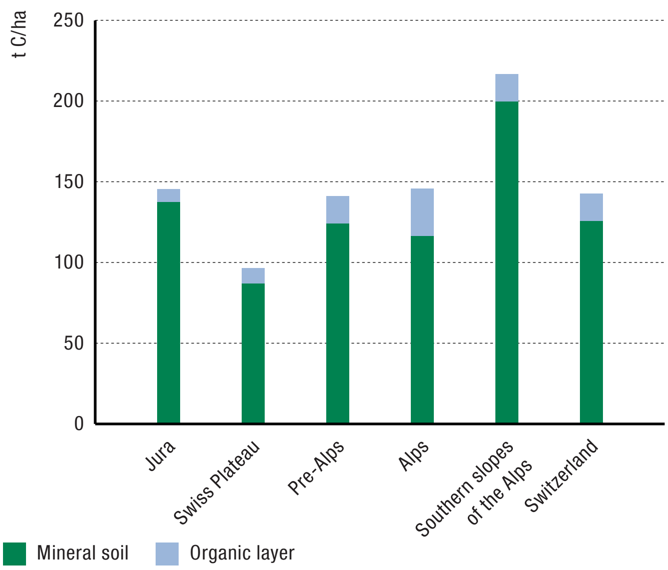


Fig. 1.4.2 *Carbon stocks in the forest soil and in the organic layer in the 5 production regions. Source: Nussbaum et al. 2012*

CO2 balance in the forest

As trees grow, they absorb CO_2 in the form of carbon into their biomass. When they are harvested, carbon is released again through combustion as CO_2 into the atmosphere. The effect is the same when trees in the forest die and rot. Forest soil and the organic layer on top of it gain or lose CO_2 depending on the climatic conditions and the chemical composition of the organic layer. The CO_2 balance in the forest consists of the CO_2 uptake as a tree grows, and of changes in the CO_2 stored in the organic layer, soil and deadwood, minus the CO_2 losses arising from forest exploitation and wood decomposition. If the uptake of CO_2 is higher than its loss, the result is a carbon sink, but in the reverse case, the result is a carbon source.

The CO_2 balance in forests is of special importance in the Kyoto Protocol. By signing it, Switzerland made an international commitment to reduce its greenhouse gas emissions between 2008 and 2012 by 8 per cent compared with the 1990 levels. This corresponds to an annual reduction of 4.2 million tonnes of CO_2. Switzerland also decided to include the CO_2

sinks and CO_2 sources for its forests in these calculations. The data collected in the four National Forest Inventories between 1985 and 2013 provide the basis for calculating the sink and source values in the Swiss forest.

Swiss forests have acted as sinks for CO_2 for some time now because more wood grows in them than is removed or decomposes (section 1.2). In addition, the forest area is expanding (section 1.1). Storms can turn these sinks locally into sources. For example, the windstorm 'Lothar' destroyed within just a few hours at the end of 1999 forest stands that had stored nearly 15 million tonnes of CO_2 in their living biomass. Most of this wood was subsequently used in construction, which meant the atmosphere was burdened only with the CO_2 from wood that was not used for construction or turned into wooden products. If the CO_2 is deposited in long-lasting products made of wood like houses, it will not be emitted into the atmosphere for a long time. Thus the house where Niklaus von Flüe, the hermit from Obwalden, was born in 1417 has stored CO_2 for centuries. Since 2013 it has been possible to include the wood used in construction under the Kyoto Protocol.

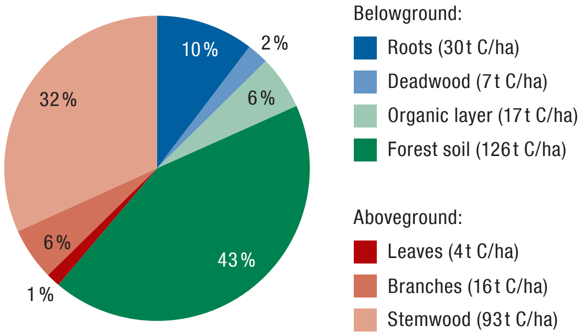


Fig. 1.4.5 *Distribution of carbon stocks in the forest. The forest soil and stemwood together store 75 % of stocks. Source: NFI 2009/2013; Nussbaum et al. 2012*

Significance of the forest as a carbon sink

The Swiss forest stored on average 1.6 million tonnes of CO_2 per year between 2008 and 2012. This corresponds to 3 per cent of the current Swiss greenhouse gas emissions. Thus the Swiss forest sequesters only a small proportion of these emissions (Fig. 1.4.6). Under the Kyoto Protocol, however, these 1.6 million tonnes of CO_2 can be counted as forest sinks, and thus as a significant contribution to the reduction commitment Switzerland made under the Protocol. If these forest sinks had not been included, Switzerland would have had to buy emission certificates to the value of several million Swiss francs to meet the reduction target.

Even though forest sinks are very important for the national economy, forest owners are not able to benefit from the services they provide because there are no appropriate regulations for compensation at a national level. This means that access to the so-called compliance market with internationally tradable certificates is blocked. The only option forest owners have is to sell their sink services on the voluntary market. The price of a tonne of CO_2, however, varies greatly.

From the point of view of forest policy, increasing forest sinks is only desirable so long as other forest functions can be

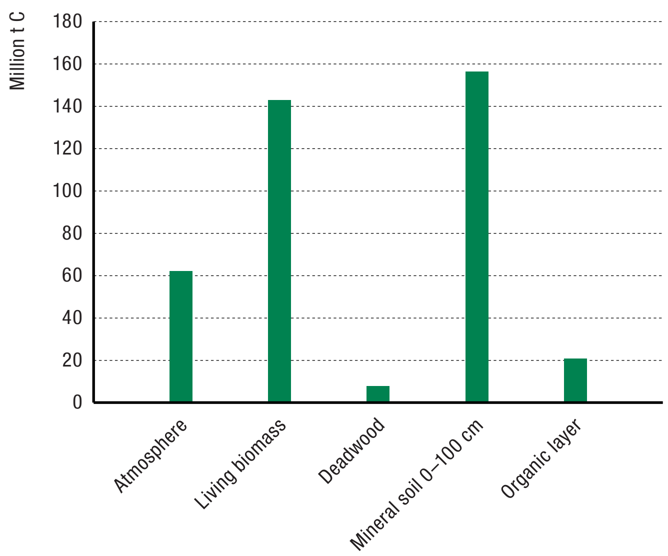


Fig. 1.4.4 *Distribution of carbon stocks in the forest and in the atmosphere. Source: NFI 2009/2013; Nussbaum et al. 2012; IPCC 2007*

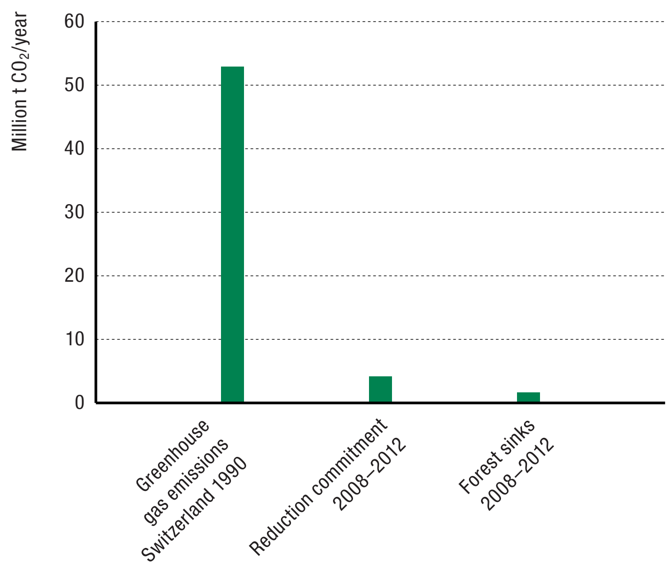


Fig. 1.4.6 *Total reductions in greenhouse emissions in Switzerland according to the Kyoto Protocol and assessable forest sinks (1 t C ≙ 3,67 t CO_2). Source: FOEN 2014b*

maintained and sustainable forest management safeguarded. According to the Forest Policy 2020, the forest and the use of wood should contribute to mitigating the effects of climate change. The potential for sustainable use of the wood should be tapped to the full. If this could be done, the carbon balance of the forest would be more-or-less in equilibrium for a long time. Wood from the forest can continue to perform a climate-friendly function as the greatest CO_2 saving effect can be reached if the potential for sustainable use of the wood is fully exploited and the wood used in cascade, i.e. if the wood is first used to build houses and make furniture, and then burnt at the end of its life cycle. In this way, the CO_2 can remain stored in the wood for a long period, just as it has been in the house where Niklaus von Flüe was born.

2 Health and Vitality

Marcus Schaub, Christian Küchli

Since 2005, Swiss forests have been spared disastrous storms. Sulphur deposition from the atmosphere has decreased further. In contrast, high nitrogen deposition and increasing soil acidification still disturb the nutrient balance of trees. Defoliation and tree mortality have remained, on average, stable for many years, but periodically they have increased strongly due to droughts and insect infestations. The rate of unwanted introduction of alien animal, plant and fungal species has continued to increase markedly since 2005. The ongoing climate change will, in future, be even more of a challenge for the forest and forestry.

Summary

Since the Swiss Federal Ordinance on Air Pollution Control came into force in 1986, the emissions of sulphur and nitrogen compounds have decreased, as have the peak concentrations of ozone. Nevertheless, nitrogen deposition exceeds the critical value on over 90 per cent of Switzerland's forest area. A fifth of 1,240 soil profiles evaluated contain low stocks of calcium, especially in Ticino and in the crystalline basement of the Central Alps. Overly high nitrogen deposition, particularly on these soils, leads to progressive acidification and the leaching of important nutrients like magnesium and potassium. This increases the risk of a nutrient imbalance, which in the long term negatively affects the nutrient supply of trees. Intensive management with the harvesting of full trees may considerably increase the removal of nutrients, in particular on acid sites, and upset the nutrient balance further.

Only a few exceptional natural events occurred between 2005 and 2012, and most caused just local damage to the forest. Fires destroyed about 100 hectares of forest annually, and the storms 'Kyrill', 'Emma' and 'Quinten' resulted in 350,000 cubic metres of windthrown timber (windthrow). Since 2005, the amount of wood infested with bark beetles has dropped from 1 million to 0.1 million cubic metres per year. Droughts led to higher pine mortality in Valais and the Rhine Valley near Chur in 2006 and 2007.

Pronounced droughts, storms or heavy hail weaken trees, and make them particularly susceptible to pests and diseases. Warm temperatures also favour the infestation and development conditions of pathogens and insects, especially of introduced harmful organisms that are thermophilic. The Asian longhorned beetle and the chestnut gall wasp, which were both introduced from China, are thus endangering urban green spaces and forest stands. Of the fungal diseases, ash dieback is increasingly threatening stands of ash, and the dangerous red-band needle blight has recently attacked pines in the forest. Climate change is likely to lead to more droughts and heavy hail, which means that forest pests may become more significant.

The Sanasilva Inventory investigates the condition of tree crowns in order to be able to make statements about the forest's state of health. Since 1985 it has recorded the condition of the crowns of around 1,000 trees a year on 50 sites. Extreme climatic events like 'Vivian' and 'Lothar', the hot summer in 2003 and the spring drought in 2011 led to a temporary deterioration of the crown conditions and to higher mortality. Generally, the increase in defoliation found between 1985 and 1995 has not continued, and the level of defoliation has stabilised with large annual fluctuations.

The ongoing climate change will present the forest and forestry with a growing challenge in the future, as several factors that are important for the health and vitality of the forest are likely to change.

2.1 Air pollutants

Anne Thimonier, Peter Waldner, Elisabeth Graf Pannatier, Sabine Braun, Beat Achermann, Beat Rihm, Sabine Augustin

> *The emissions from air pollutants have markedly decreased since the 1980s. As a result, atmospheric deposition has also dropped, especially that of sulphur.*

> *Nitrogen deposition continues to be too high. Model calculations have shown that the so-called critical loads for nitrogen are exceeded on more than 90 per cent of the Swiss forest area.*

> *High nitrogen deposition increases the risks of nitrate leaching into groundwater, an imbalance in the nutrient supply for trees and a change in the ground vegetation.*

> *Peak concentrations for ozone have been falling since the 1980s. The mean level has, however, risen. Ozone is a strong oxidant, which plants take up through their stomata and which can hinder their growth. According to models, the mean loss in growth due to ozone pollution in Swiss forests is estimated to be around 11 per cent per year.*

Sulphur and nitrogen pollution

Emissions from air pollutants have decreased over the past three decades (Fig. 2.1.1). This is largely thanks to the measures implemented at national and international levels under the Geneva Convention on 'Long-range Transboundary Air Pollution' (UNECE), concluded in 1979. This has led to emissions of, in particular, sulphur being significantly reduced, as the clear decrease in atmospheric sulphur deposition in the forest shows (Graf Pannatier et al. 2012).

Although emissions of nitrogenous air pollutants are decreasing, they are still higher than the targets set by the Federal Council. Nitrogen (N) is needed for plants to grow, but normally only occurs in natural ecosystems in small quantities. Overly high nitrogen deposition can, therefore, on the one hand, act like a fertiliser, but on the other, push the nutrient balance of trees out of equilibrium and lead to the acidification of forest soil (section 2.2). Moreover, excess nitrogen may be leached into the groundwater in the form of nitrates and thus impair its quality (section 5.1). Nitrate leaching is accompanied by the leaching of important nutrient elements such as calcium, magnesium or potassium, which contributes to nutrient depletion of the forest soil.

As part of the 1979 Geneva Convention, threshold values for nitrogen deposition, so-called critical loads, were set. These are 10 to 20 kilograms of nitrogen per hectare and year (kg N/ha/year) for broadleaf forests, and 5 to 15 kg N/ha/year for conifer forests. If these values are exceeded, the effects on the functions and structure of forest ecosystems are likely to be harmful. The nitrogen deposition in Swiss forests can be estimated with the help of models. They amount to between 5 and 65 kg N/ha/year (Fig. 2.1.2). These values exceed the critical loads on 90 per cent of sites. The Swiss Plateau is where the local emissions are highest and also where the critical loads are exceeded the most. The critical loads are also exceeded on the Northern slopes of the Alps and in Ticino. In a few regions, the emissions are below the threshold, including in the inner-Alpine side valleys, where precipitation is low.

Impact on forest ecosystems

Chronic deposition of air pollutants can bring about slow changes that take time to become visible. The Swiss and European networks of permanent forest observation plots allow any changes to be identified in good time. The quantification of annual nitrate leaching on such permanent observation plots shows that the risk of leaching increases with higher nitrogen deposition. Such nitrogen leaching indicates that forests are saturated with nitrogen (section 5.1). Moreover, chemical analyses of beech leaves and spruce needles show that, since 1984, phosphorous concentrations have decreased, especially in areas with high nitrogen deposition. This leads to trees' nutrient balance getting out of equilibrium, which makes, among other things, the trees less resistant to parasites, drought and frost (Flückiger and Braun 2011).

Biodiversity Monitoring Switzerland (BDM 2013) has demonstrated that the ground vegetation of forest ecosystems subjected to increasing nitrogen deposition contains more plants that indicate nitrogen-rich conditions.

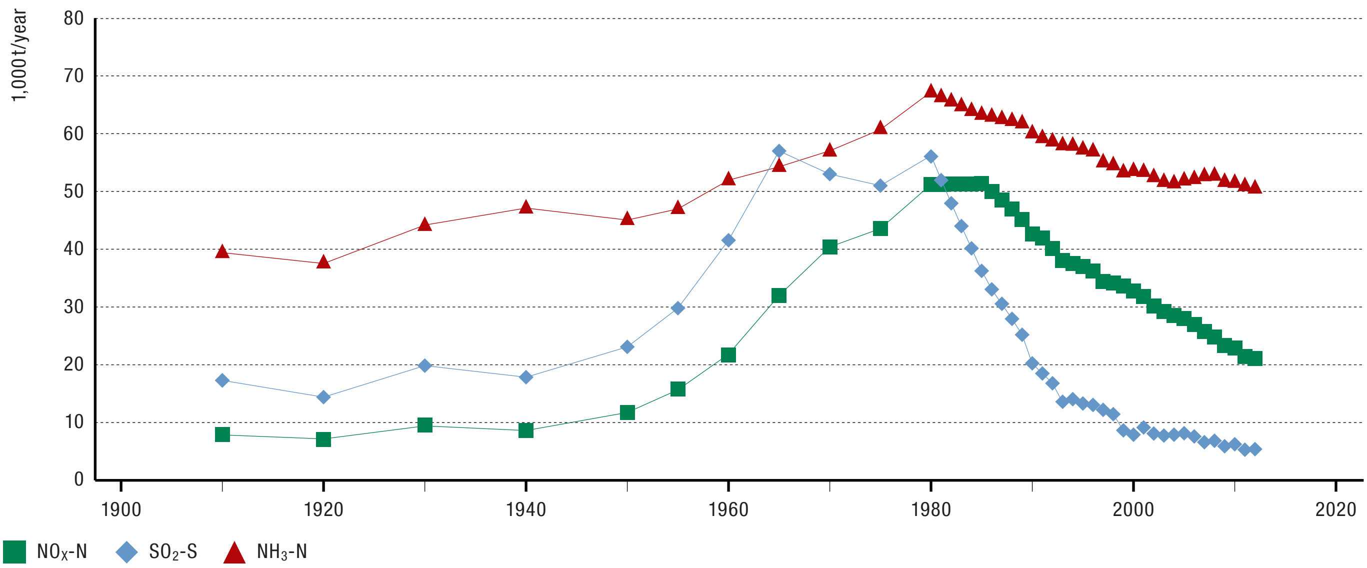


Fig. 2.1.1 *Emissions of nitrogen oxide (NO_X), sulphur dioxide (SO_2) and ammonia (NH_3) in Switzerland from 1910 to 2012, in kilotonnes S/year and kilotonnes N/year. Source: FOEN 2014a*

Ozone

Ozone (O_3) is an oxidising agent and can reduce photosynthesis in plants. Ozone is an air pollutant that is formed through chemical reactions between nitrogen oxides and hydrocarbons when summer temperatures and UV radiation are high. In Switzerland, peak concentrations have been falling since the 1980s, whereas average concentrations have increased. With climate change, this air pollutant may become more important in future. Ozone is taken up by plants through their stomata into their leaves. Both the uptake (ozone flux) and ozone sensitivity vary greatly from tree species to tree species. A UNECE expert group applied fumigation experiments to determine the critical value for ozone. For beech, the critical value is 4 millimoles per square metre and year (mmol/m²/year), which corresponds to a reduction in growth of 4 per cent. For spruce, the critical value is 8 mmol/m²/year, which corresponds to a reduction in growth of 2 per cent. Through a combination of measurement data and model calculations, it is estimated that the mean ozone flux in Switzerland is 17.7 mmol/m²/year for beech and 27.3 mmol/m²/year for spruce. From this, the mean reduction in growth can be estimated as 11 per cent per year (Braun et al. 2014).

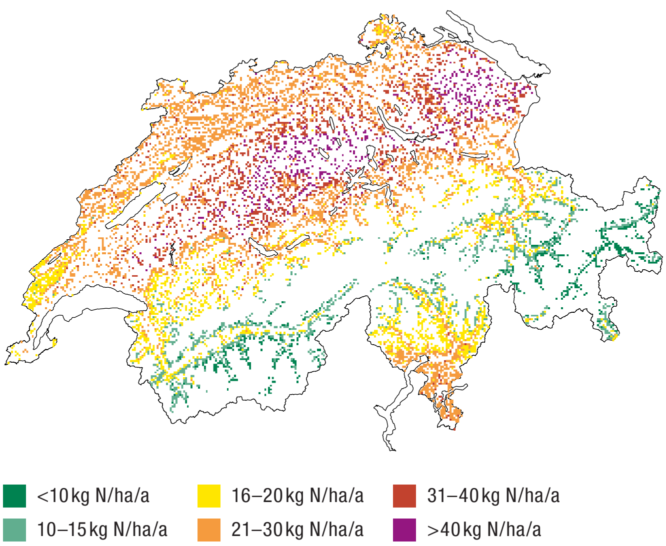


Fig. 2.1.2 *Nitrogen deposition in Swiss forests amounts to between 5 and 65 kg N/ha/year. The threshold values for forest ecosystems are 5–20 kg N/ha/year. Source: FOEN/Meteotest*

2.2 Soil

Elisabeth Graf Pannatier, Oliver Thees, Stephan Zimmermann, Sabine Braun, Sabine Augustin

> *The nutrient content of a soil depends on its age and history of use, as well as on the geology. It is an important factor in the nutrient supply of trees. Currently, nutrients also enter the soil through the air, in particular in the form of excessive amounts of nitrogen.*
> *The larger number of sites and soils investigated means that the data-base has greatly improved in comparison with that of the Forest Report 2005. As a result, it has been possible to assess the temporal development of the chemistry of soil water.*
> *Of the soils studied, 20 per cent have low stocks of calcium. A further loss of nutrients may be detrimental for sustainable soil fertility.*
> *As a consequence of the reduction in sulphur deposition from the air, the sulphate concentrations in soil water have also mostly diminished. Nitrogen deposition, on the other hand, is still high and may lead to heavy nitrate leaching and nutrient loss.*
> *Full tree harvesting may be detrimental for sustainable soil fertility in sensitive sites.*

Nutrient stocks in the soil

The nutrient content of the soil in Switzerland depends on the geology, the soil's age, use and water balance, as well on the atmospheric deposition, and is decisive for the nutrient supply of trees. Important nutritional elements for the cell growth of plant organs are calcium, potassium, magnesium, phosphorous and nitrogen. Here the focus will be on calcium only.

A lack of calcium negatively affects biochemical processes and can reduce the growth of shoots and roots, or cause leaves and needles to yellow or lead to other visible symptoms. Tree species differ in their needs for calcium in their nutrient supply. To assess the calcium stocks in the forest soil, the amounts in the top 40 centimetres of mineral soil and the organic layer are often considered. This is usually the most important part for supplying trees with nutrients.

According to the Working Group 'Local Mapping' (Arbeitskreis Standortskartierung, 1996), calcium stocks are classified into 7 classes ranging from 'very little' to 'high amount'. The 1,240 soil profiles investigated (Fig. 2.2.1) revealed that soils with very low to low calcium stocks (9 % and 11 %, respectively, of all soils) occur mainly in Ticino, in the crystalline basement of the Central Alps and on the Swiss Plateau (Fig. 2.2.2). There the parent rock is acid, and the soils thus have low pH values. On the Swiss Plateau, soils with low calcium stocks are particularly frequent in the Emmental (Canton Bern) and Langenthal (Canton Bern / Canton Aargau) regions, as well as in the Bernese Napf region, the area around Zugerberg (Canton Zug) and Höhronen to Schmerikon (Canton St. Gallen) on Obersee. One important reason for this is that these regions were not covered with glaciers during the last Ice Age and earlier moraine layers were eroded away down to the acid molasse. Soils with high to very high calcium stocks (15 % and 33 %, respectively, of all soils) occur particularly in the Jura and in the Calcareous Alps. Unlike the soils with the acid parent material, large amounts of calcium are continually released through the weathering of the carbonate rock. Soils with average calcium stocks (32 % of all soils) are distributed across Switzerland.

Sites with low calcium stocks are strongly acidic. They house fewer soil organisms that decompose fallen leaves and needles. As a result, the litter takes longer to decompose, and forms an organic layer, while less nutrients are available for plants. The lower the calcium stock, the greater is the proportion of calcium stored in the organic layer. The organic acids released from the litter also contribute to the acidification of the topsoil. The acid production can be reduced through forest management. In mixed stands, for example, the litter can be decomposed and mineralised more easily, so that nutrients become more quickly available.

Soil acidification

Acid-forming processes in the soil and atmospheric deposition may increase soil acidification. Depending on the mineral composition of the soil, weathering counteracts acidification. If the rate of weathering is lower than the acid deposition, the soil acidifies.

If the acidification is advanced, the pH value and the base saturation decrease, i.e. the supply of basic nutrient cations (calcium, magnesium, potassium) is depleted. Soil acidification leads not only to a loss of nutrients, but can also result in an increase in acid cations (e.g. aluminium). This may impede root growth or have a toxic effect on roots. Such processes can be identified through analysing the soil water. This involves installing collection devices that monitor the chemical composition of the soil water over a long period so that conclusions can be drawn about its development over time. The composition of the soil water is influenced by atmospheric deposition, by exchange processes between the soil solid phase and water, as well as by the decomposition of organic substances.

Acid deposition from the air influences the chemical composition of the soil solution, and leads to the loss of basic cations and thus to soil acidification.

The chemistry of the soil solution in Switzerland has been studied since 1997 in forest areas with different tree species, soil properties and atmospheric loads. There are 50 observation plots in Switzerland today, and approximately 350 in Europe. The soil water on these plots is continuously collected and analysed every 2 to 4 weeks. To draw conclusions about the development of the soil solution, 29 plots for which there are continuous measurement series of the topsoil from 2002 to 2012, are being studied in more depth. These long-term investigations have shown that acidification varies from site to site (Braun and Flückiger 2012; Graf Pannatier et al. 2012). In 23 of the 29 plots, the concentrations of sulphate have decreased (Fig. 2.2.3) as a consequence of the decreasing sulphur deposition. The leaching of basic cations or aluminium in acid soils remains, however, high, because nitrogen deposition continues to be heavy. In 25 of the 29 plots, the ratio of the basic nutrient cations and aluminium has diminished (Fig. 2.2.4). Experts call the ratio of the nutrients calcium, magnesium and potassium to aluminium the BC/AI ratio. It influences plant growth and is an important indicator of soil acidification. A decrease is evidence of acidification.

Nutrient export through timber harvesting

Forest soil is continuously receiving nutrients or having them removed (Fig. 2.2.5). Nutrient export takes place mostly through timber harvesting and leaching through the soil water. Nutrient deposition occurs either through the weathering of the parent rock and the mineralisation of organic substances (especially through the decomposition of autumn leaves), or through atmospheric deposition.

The promotion of renewable energy and the technical streamlining of timber harvesting are likely to result in an increase in the use of full trees. This enables more wood to be used for energy and also reduces harvesting costs. Using full trees means that not only are the stems and their bark

Fig. 2.2.1 *Soil profile of strongly acidified brown earth. Photo: S. Zimmermann*

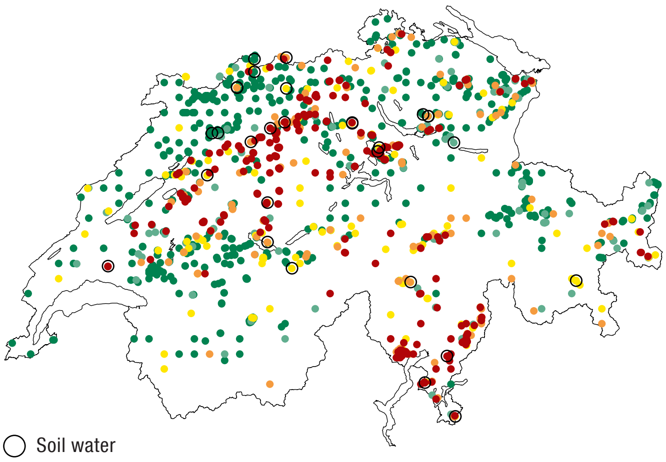


Fig. 2.2.2 *Calcium stock of the top 40 centimetres of mineral soil, including the organic layer. 1,240 soil profiles were investigated. The data are classified into 5 groups according to the 7 classes 'very low' to 'very high' (Arbeitskreis Standortskartierung 1996). 'Soil water' marks the position of the 29 study plots. Source: WSL, IAP*

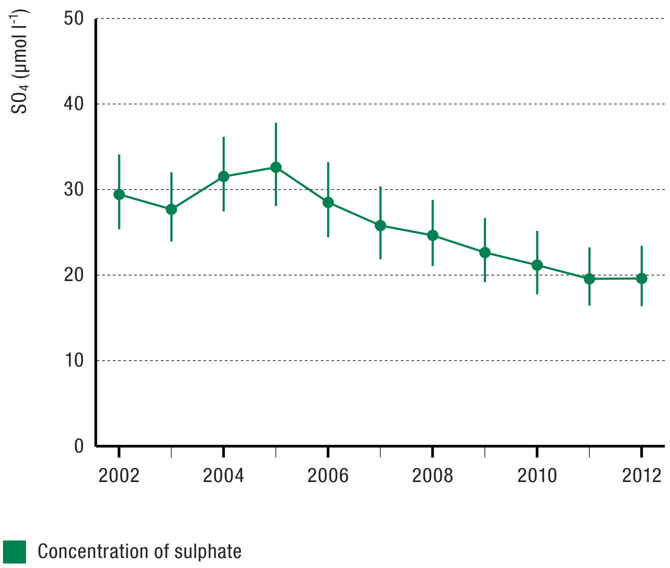


Fig. 2.2.3 *Development of mean concentrations of sulphate (SO_4) in the topsoil (0–40 cm) on 29 plots between 2002 and 2012. Source: WSL, IAP*

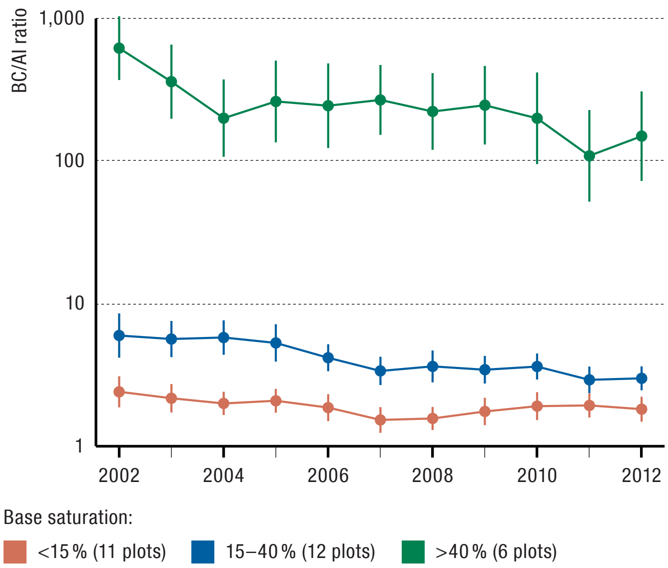


Fig. 2.2.4 *Mean BC/Al ratio in soil water on 29 plots with different base saturation levels in the topsoil (0–40 cm). Source: WSL, IAP*

taken out of the forest stand, but also the branches, twigs, needles and sometimes even leaves. This increases nutrient export considerably, and can – depending on the forest's location and the intensity of use – negatively affect the nutrient supply. As a result, soil fertility may be endangered, particularly in nutrient-poor forest sites. Such negative effects can be lessened by notably reducing the number of thinnings involving the use of full trees on sensitive sites and leaving large parts of tree crowns in the stand. In Switzerland today, full trees are used on 12 per cent of the forest area, and in the Alps and Pre-Alps on even more. This harvesting method is particularly efficient economically for the management of protection forests, and helps to ensure that the forests are actually managed. The certification PEFC and FSC (section 3.4) allow full trees to be used, but with restrictions: enough harvesting residues – branches, twigs, needles and leaves – must stay in the stand to ensure that the nutrient supply is not, in the long term, endangered.

At the moment, initial basic information is available on the ecological and economic effects of using branches, twigs and needles intensively, and on measures to lessen the resulting negative impacts. These must, however, first be researched in more depth and prepared for implementation. In Switzerland and neighbouring countries, researchers in forestry and foresters are therefore working on quantifying the nutrient export through timber harvesting and on assessing the long-term risks for the ecosystem and timber production (Lemm et al. 2010). The aim of implementing the findings will be to take the nutrient balance in the forest soil into account in forest planning and to evaluate this aspect with respect to its comprehensive sustainability (Fig. 2.2.6).

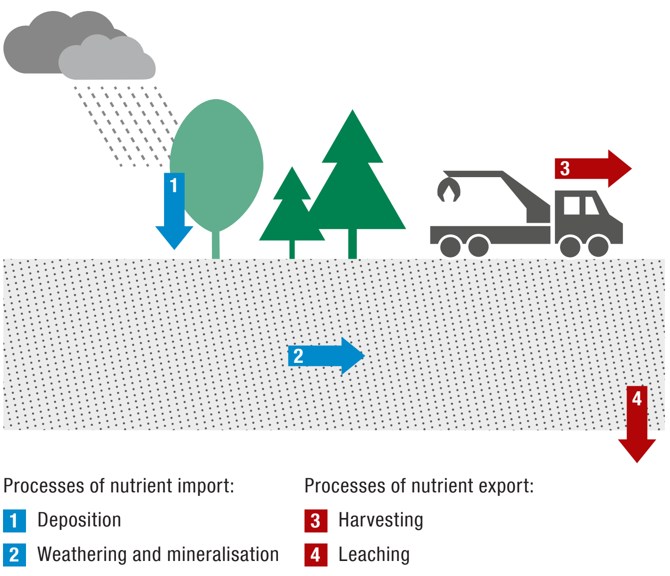


Fig. 2.2.5 *Nutrient fluxes in a forest ecosystem where the wood is used: Export through harvesting and leaching; import through deposition and weathering.*
Source: Illustration based on Lemm et al. 2010

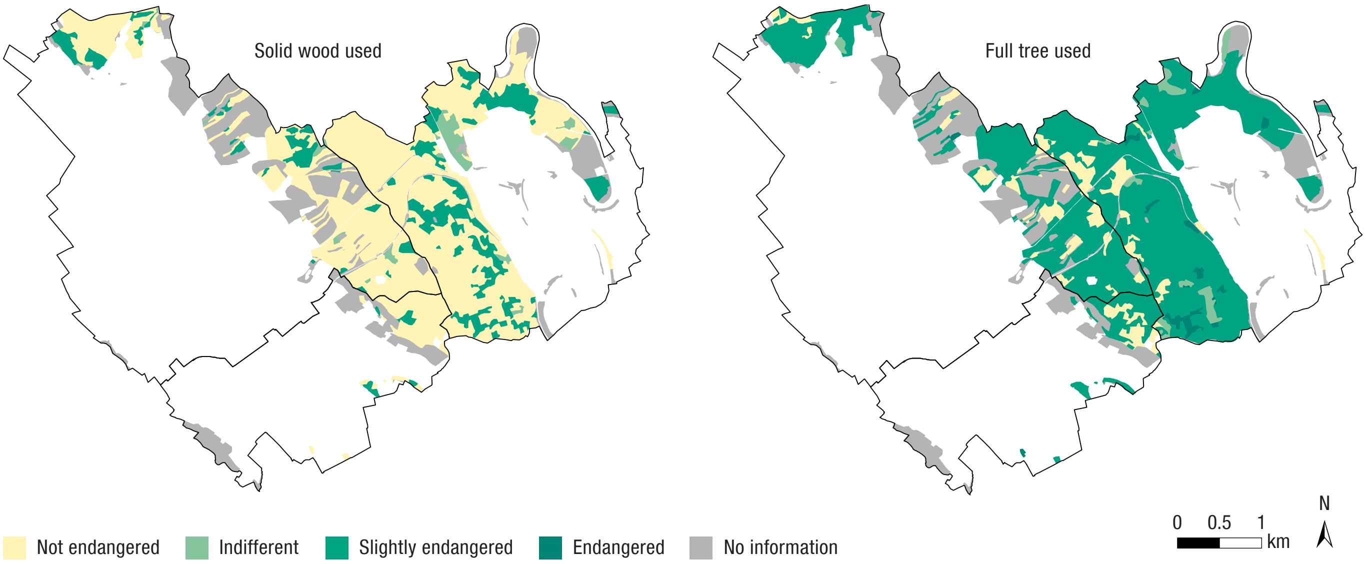


Fig. 2.2.6 *Soil endangered by nutrient export in 2 management forms in the forest enterprise Wagenrain, Canton Aargau, according to the nutrient-balancing model NBM. Solid wood: aboveground wood with a diameter of over 7 cm over bark. Full tree: tree including branches, twigs, needles and leaves, but without roots. Source: Lemm et al. 2010*

2.3 Condition of tree crowns

Andreas Schwyzer, Christian Hug, Peter Waldner

> *The Forest Report of 2005 stated that defoliation between 1985 and 1995 increased. Since then the condition of tree crowns has stabilised, but with large annual fluctuations.*
> *Climatically extreme events, such as the storms 'Vivian' and 'Lothar', the summer heat-wave in 2003, and the spring drought in 2011, resulted temporarily in a deterioration of the condition of tree crowns and in a higher tree mortality.*
> *Trees weakened by these extreme events were more susceptible to severe insect and fungal attacks, which lead temporarily to more defoliation and mortality.*
> *Crown conditions may also be influenced by site factors like soil wetness, low pH values and nutrient resources.*

Condition

The condition of Swiss forests has been recorded since 1985 in the Sanasilva Inventory. Each year about 1,000 trees on around 50 sample plots of the National Forest Inventory (NFI) are assessed (Graphic II, pp. 16–17). The same methods are used in the ICP Forests (International Co-operative Programme on Assessment and Monitoring of Air Pollution Effects on Forests) in almost all European countries to collect comparable data. One of the most important and meaningful indicators for describing the condition of the forest is defoliation (Needle-/Leaf Defoliation NLD), which is given in comparison with a tree with full foliage or needle cover. Reference pictures, showing varying degrees of defolation, are available for the most important tree species. They serve to ensure that the trees are always assessed according to the same criteria (Müller and Stierlin 1990). Trees with more than 25 per cent defoliation are considered damaged. Since just one assessment of defoliation is not sufficient to classify a tree as 'healthy' or 'sick', time series over many years are required. Only with long-term observations is it possible to reliably determine any changes in the state of health of a forest.

Development of crown conditions

The proportion of strongly defoliated trees (NLD >25–95 %) increased markedly between 1985 and 1995 (Fig. 2.3.1). Since then, no long-term trend is clearly evident, but large fluctuations in defoliation occur. This always increases rapidly at first and then return slowly to normal. Maximum values were reached in the years 1995, 2000, 2004 and 2012. Shortly before each maximum, the lowest values were recorded (1999, 2003 and 2009). This pattern suggests that the fluctuations were not triggered by a slow environmental change, but by short-term extreme events. The Sanasilva Inventory also records the causes of defoliation, such as weather conditions – mainly storms, frost and drought – as well as damage from insect feeding. This allows conclusions to be drawn about the most important reasons for the increase in defoliation. Figure 2.3.1 shows how climatic events lead directly or indirectly to an increase in defoliation. After the storm 'Lothar' (1999), the hot summer of 2003 and the spring drought of 2011, defoliation each time reached a maximum. Such climatic events make trees more susceptible to infestations with insects or fungi. The extent of the insect and fungi damage reflects the development of defoliation relatively precisely. Thus the fungus *Hymenoscyphus pseudoalbidus* (asexual stage: *Chalara*

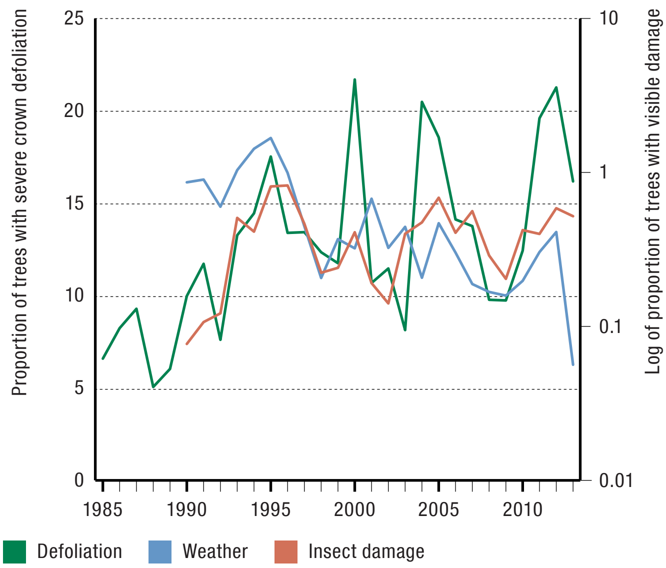


Fig. 2.3.1 *Development of the proportion of trees with severe defoliation (NLD >25–95 %), as well as damage from weathering and insects. Source: Sanasilva Inventory*

fraxinea), which originally came from Asia, caused dieback in the crowns of many ash trees (Zhao et al. 2013; ash dieback, section 2.4). In addition, the development of crown conditions is influenced locally – depending on the site and tree species – by other factors, for example, wet soil, low pH values and the limited availability of nitrogen or magnesium (Dobbertin et al. 2012; Thimonier et al. 2010).

The reactions of broadleaf trees to climatic events differ from those of conifers, but only slightly (Fig. 2.3.2). The defoliation of broadleaf trees increased more strongly than that of conifers after the hot summer of 2003, but also fell again faster. Conifers also react more sensitively to storm events.

Mortality

The mortality rate shows no sign of a long-term trend and has remained around 0.5 per cent since 1985 (Fig. 2.3.3). The mortality rate rose above the long-term average of 0.5 per cent in the early years after the Sanasilva surveys started in 1985, after the hot summer in 2003 to 0.7 per cent, and again after the spring drought in 2011 to 0.8 per cent. After the dry periods in 2003 and 2011, more broadleaf trees, which mostly grow at lower altitudes, died than conifers, which grow at higher altitudes, where drought is less frequent. This indicates that the availability of water is important and that it can influence both defoliation and the mortality rate.

A WSL experiment conducted in Canton Valais since 2002 confirms this observation: Scots pines on dry sites react to greater water availability with stronger needle growth, less defoliation and a sinking mortality rate (Dobbertin et al. 2010). Studies in other parts of Europe support these findings. Most sites in central and northern Europe have remained stable, whereas in the Mediterranean region, which has been plagued for years by droughts, needle and leaf loss, has dramatically increased for all the main tree species (Carnicer et al. 2011).

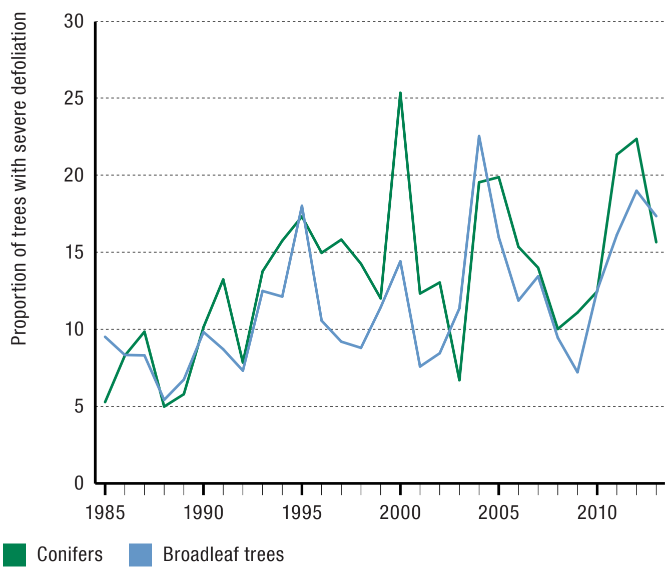


Fig. 2.3.2 *Proportion of conifers and broadleaf trees with severe defoliation (NLD >25–95 %). Source: Sanasilva Inventory*

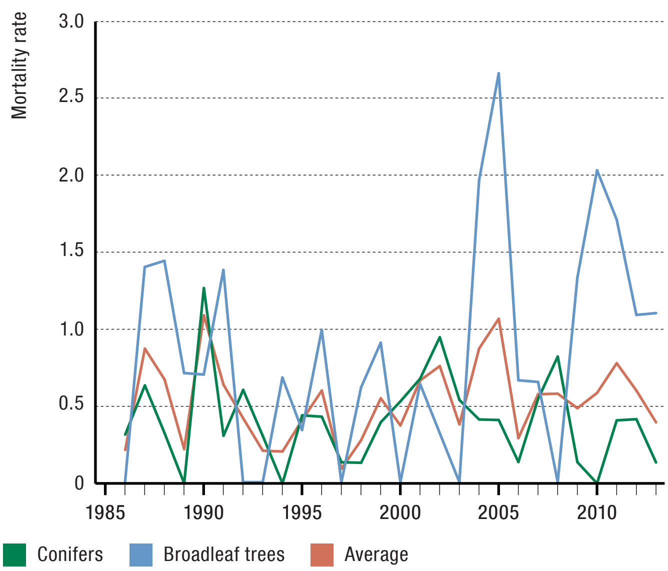


Fig. 2.3.3 *Development of the mortality rate of conifers and broadleaf trees. Source: Sanasilva Inventory*

2.4 Forest damage

Thomas Wohlgemuth, Marco Conedera, Roland Engesser, Beat Wermelinger, Michael Reinhard, Beat Forster, Franz Meier

> *The ongoing climate change is increasingly posing a challenge for the forest and forest management.*

> *Fewer unusual natural disturbances occurred between 2005 and 2012, apart from the floods in 2005. Most of them led to only moderate direct damage to the forest.*

> *Climate change increases the risk of forest fires, but with better prevention, the likelihood of severe damage can be reduced.*

> *Higher temperatures and drought amplify the risk of an infestation of forest insect pests, which can lead to the death of some stressed trees.*

> *Global trade has resulted in growing numbers of non-indigenous organisms being introduced. Usually they first appear in urban green spaces. This is why these areas should be monitored so as to have an early warning system for harmful organisms that may affect the forest.*

> *Ornamental plants and wood used as packing material, in particular, must be more strictly controlled, both internationally and nationally, to identify alien organisms.*

Climate change and abiotic natural disturbances

Temperatures worldwide will continue to rise further due to climate change – affecting Switzerland as well. As a consequence, extreme abiotic events are likely to become more frequent. The risk of forest disturbance can be reduced through various measures including: strengthening the resilience of existing forests, improving the adaptability of forest regeneration and introducing organisational measures like forest-fire prevention. The following estimates are based on linking the experiences from the extreme events during the period 2005 to 2012 with climate change scenarios for Switzerland.

Forest fires

In the period 2005 to 2012, 40 fires per year in Cantons Ticino (on the Southern slopes of the Alps), Valais and Grisons (Central Alps) were registered with an average burnt area size of 101 hectares per year (Fig. 2.4.1). Since 2008, 31 fires annually have occurred in the other cantons in Switzerland (North of the Alps) with, on average, an area of 6 hectares burnt. In recent years, fires North of the Alps have been reported more often, probably in connection with the introduction in 2008 of the forest-fire data-bank (WSL-FOEN) for the whole of Switzerland. The largest forest fires were those on 23 April 2007 in Ronco sopra Ascona (Canton Ticino), in which more than 200 hectares were burnt, and on 26 April 2011 in Visp (Canton Valais), when 130 hectares of forest were destroyed. In comparison with the period from 1980 to 2004, the number of forest fires annually in the Southern and Central Alps during the years 2005 to 2012 fell from 101 to less than half the number (40), and the average size of the area annually damaged from 477 hectares to 101 hectares.

One reason for this reduction is probably the increasing use of forest-fire protection strategies. These include regional and national evaluations of how dangerous the situation is on the basis of weather-data analyses, the internal organisation of fire brigades to improve fire-fighting and the building of infrastructure to ensure that there are water hydrants in priority areas. During the period from 2005 to 2012, the damage caused by forest fires was less than that caused by windthrow or beetle infestations.

In Switzerland the risk of forest fires will generally increase in the long term as more heat-waves and longer drought periods will occur due to climate change. To reduce this risk, the national and cantonal forest authorities are developing strategies for forest-fire protection involving silvicultural interventions, as well as an improved warning system for the public in case of danger. Since the Alarm Ordinance came into force on 1 January 2011, the federal government and the cantons have been obliged to inform the public about the danger of forest fires so that corresponding threat assessments can be systematically performed throughout the country.

Windthrow

Hurricane-force winds occur in Switzerland mostly during winter storms and cause large amounts of forest damage at irregular intervals – most often during the months of January and February. Switzerland was largely spared destructive storms from 2005 to 2012. The amounts of wind-damaged timber during this period were correspondingly small in comparison to the damage that the windstorm 'Kyrill' caused in neighbouring Germany, or the 13 million cubic metres of windtrow timber the windstorm 'Lothar' produced in 1999 in just Switzerland alone. In January 2007, the windstorm 'Kyrill' damaged timber on the Swiss Plateau amounting to around 100,000 cubic metres of timber, followed in March 2008 by 'Emma', which created 50,000 cubic metres on the Swiss Plateau and in the Pre-Alps, and 'Quinten' in February 2009 with around 200,000 cubic metres.

The winter storms that cause the most windthrow in forests in Central and Northern Europe are part of extratropical cyclone systems. According to the latest estimates of the Intergovernmental Panel on Climate Change IPCC, these are likely to move further towards the North Pole by 2050, so that the southern parts of Central Europe, and thus also Switzerland, should be less frequently affected by winter storms. This would mean that, in the long term, the risk of windthrow should fall, which goes against earlier assumptions and can be considered a new scenario. Nevertheless, in Zürich, which probably has the longest series of wind measurements worldwide, the total number of peak gusts per year has increased during recent decades (up to 2008; Usbeck et al. 2010).

It is not only the wind force that influences the extent of damage, but also the height of the stand. The taller the trees, the more damage is likely. Evaluations of the areas damaged by Lothar on the Swiss Plateau suggest that this interrelationship is more marked for conifers than for broadleaf trees (Dobbertin et al. 2002). Appropriate silvicultural measures can reduce the vulnerability of a stand to windthrow so that less damage occurs. They should aim to adapt the forest composition by, for example, reducing the growing stock or increasing the diversity of tree species, and structuring stands horizontally and vertically.

Heat, drought and interactions

The potential for damage to forests increases through interactions between various climatically extreme events. Two events during the past 15 years have shown this clearly. The first example is the enormous surge in populations of spruce bark beetles, which began on 'Lothar' windthrow areas. The following warm summers – especially the hot summer of 2003 – led to beetle-infested wood in quantities never encountered before. The second example is the effect of recurring droughts on tree growth: This has resulted in more infestations with harmful organisms and triggered the deaths of repeatedly stressed trees. This phenomenon has been detected in the lower regions of the Rhone valley in Valais, in the Rhine Valley near Chur and in Domleschg.

With further climate warming, larger numbers of trees, especially Scots pine, growing on dry subsoils in central alpine valleys can, in the medium term, be expected to die than after the dry period from 2003 to 2006. Climate scenarios suggest that the negative interactions between various climatically extreme events and harmful organisms on the Northern and Southern slopes of the Alps will become more significant (cf. *Invasive pests and pathogens* below).

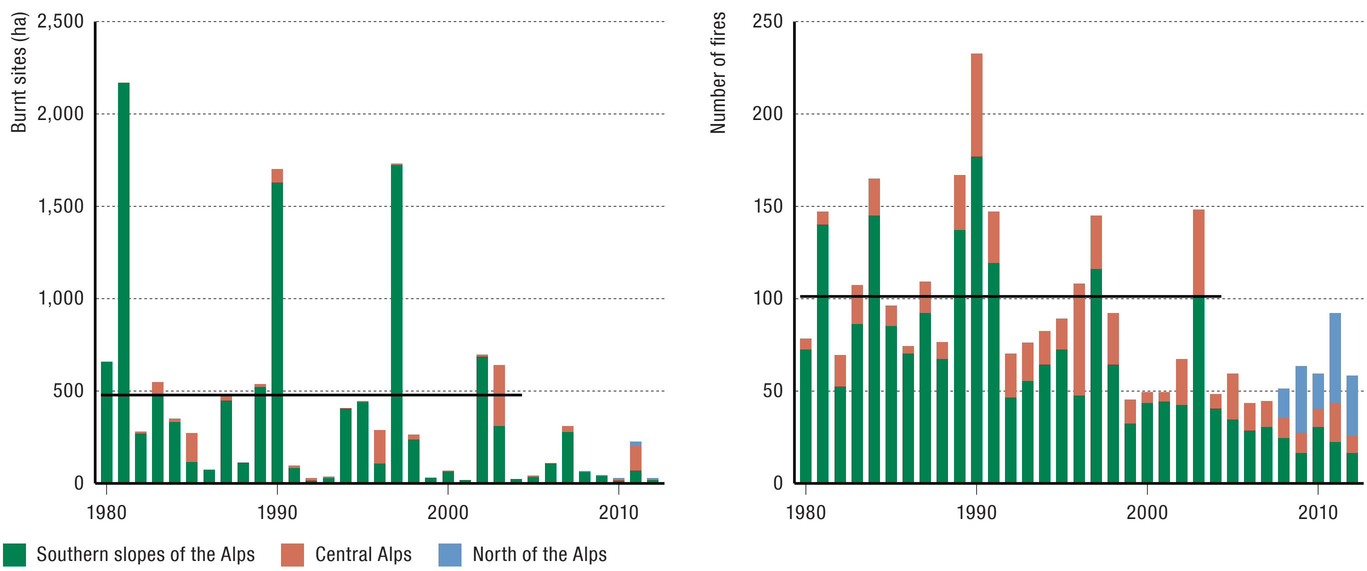


Fig. 2.4.1 *Burnt areas (left) and number of forest fires (right) in Switzerland from 1980 to 2012 in 3 regions. The horizontal lines show the mean values of the period considered for the Central Alps and Southern slopes of the Alps. Fire records North of the Alps have only been consistently kept since 2008 and are presented accordingly. Source: Forest fire data-bank*

Regeneration on damaged sites

The hot summer of 2003 showed clearly the levels temperatures and droughts may, with more frequency in future, reach. In dry regions like the inner Alpine valleys, higher mortality rates due to forest fires or severe droughts are already being recorded today. This raises the question of whether natural tree regeneration is threatened in the future. WSL is currently carrying out several investigations to try to find answers. A study of the site of a forest fire in 2003 near Leuk, Canton Valais, found that natural regeneration on plots with shallow soils under 1,100 m a.s.l. develops much less quickly than at higher altitudes. Experiments on cleared areas in the Rhine Valley near Chur indicate that the success of the regeneration of, for example, spruce and Scots pine, depends mainly on the available precipitation, especially at sites that can quickly dry out.

Droughts during the vegetation period are likely to become more frequent due to climate change. Forest regeneration on sites that are already dry today may not be successful so frequently. Climate change has also led to milder winter months. The phenological conditions for tree sprouting are thus changing. Pioneer species and neophytes benefit most from this development because they require a less pronounced winter cold for their buds to open. They therefore have an advantage over climax tree species. Warmer temperatures generally are likely to promote neophytes that are less frost resistant (Wohlgemuth et al. 2014).

Biotic forest damage

Long dry spells during the vegetation period weaken trees, which is why they are more susceptible to various root and bark diseases. Thus widespread Scots pine mortality was observed in Canton Valais in 2010, caused by the bark fungus *Cenangium ferruginosum*. Affected pines developed crowns with an intensive red colour and showed signs of dying (Fig. 2.4.2). Since hardly any rain fell between August 2009 and May 2010, these dry periods had probably weakened the trees considerably, which is why the disease broke out. *Cenangium* fungal attacks on pine have been repeatedly detected in Switzerland. A severe infestation was observed in Valais in 1999, which extended from Sierre to Visp. The dieback usually lasts only a year, after which the infestation rapidly declines.

Insect pests

Hot and dry periods increase the supply of weakened trees for bark beetles to breed in, and thus the risk that beetle epidemics will break out. After the winter storms 'Vivian' and 'Lothar', mass propagation of the spruce bark beetle (*Ips typographus*) occurred for several years each time with hundreds of thousands of cubic metres of infested spruce (Fig. 2.4.3). The hot summer of 2003 was a further strong boost for the epidemic triggered by 'Lothar', leading to a record quantity of infected spruce wood amounting to more than 8 million cubic metres.

Hot and dry summers, like that of 2003, can also cause population explosions of other insect species, which may lead to forest damage 1 or 2 years later. One example is the spruce bud scale (*Physokermes piceae*), whose populations profilerated locally on the Swiss Plateau in 2005, especially in stands growing on soil with a low water-storage capacity. The infested spruce trees were subjected to further attack by the small spruce engraver beetle (*Pityogenes chalcographus*) and the spruce bark beetle. The occurrence of spruce stands infested with scales and beetles led to the clear-cutting of 10,000 cubic metres of wood.

Invasive pests and pathogens

The introduction rates of non-indigenous organisms (Neobiota) worldwide have risen considerably in recent decades. In Switzerland over 800 non-native animals, plants and fungi have been identified. Fungi and invertebrates in particular are transported as 'stowaways' with traded goods and packaging wood. Around one hundred years ago, 7 new insect species per year were introduced into Europe. Today, the number is almost 20 species annually. The two introduced tree diseases, Dutch elm disease (*Ophiostoma ulmi* or *Ophiostoma novo-ulmi*) and 'chestnut blight' (*Cryphonectria parasitica*), show clearly what fatal consequences the introduction of exotic pathogens can have for indigenous forest trees. As global trade flows increase, the introduction rate is likely to rise even further.

Fig. 2.4.2 *Scots pine in Valais with conspicuously reddened crowns due to infestation with the* Cenangium ferruginosum *fungus in May 2010. Photo: Waldschutz Schweiz*

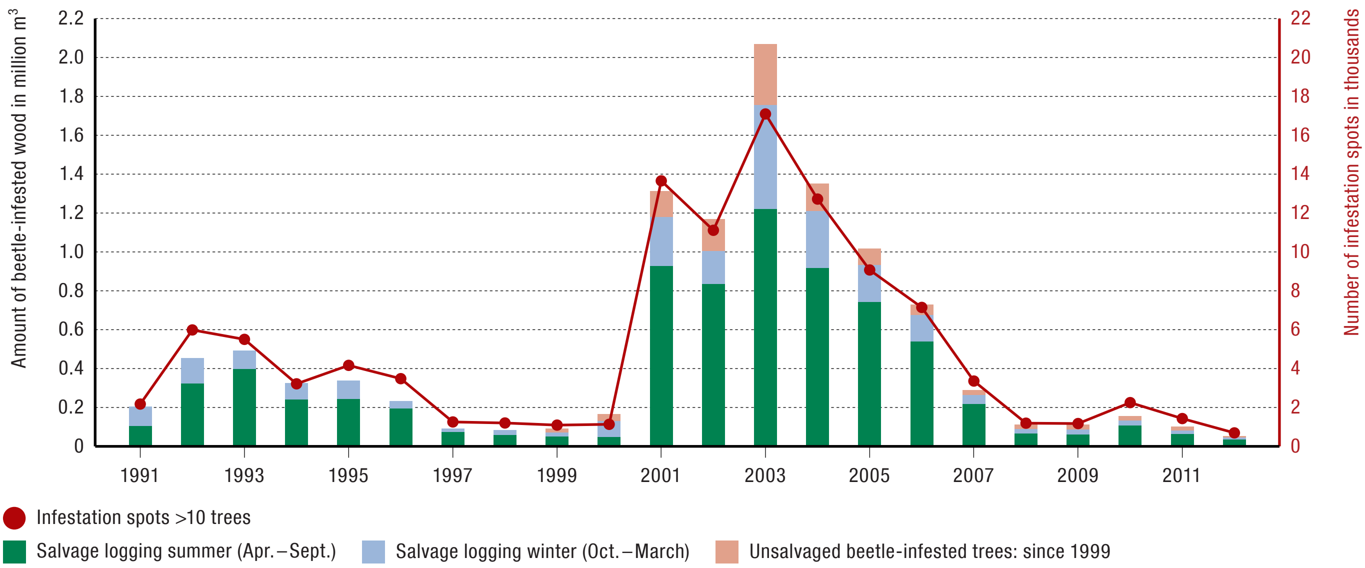


Fig. 2.4.3 *Bark beetle (*Ips typographus*): Amount of beetle-infested wood and number of infestation spots in Switzerland from 1991–2012. Source: Waldschutz Schweiz*

The most important introduction pathway for non-indigenous harmful organisms for woody plants is the trade with living plants. They are transported great distances from the countries where they are produced. Any harmful organisms that might by chance be transported with them find host plants in the import countries that have not adapted to them and can then cause much damage. Such invasive species often occur first in urban green spaces, where they become established and may well proliferate. As a result, some may become a threat for forest trees. Of the arthropods introduced into Europe so far, 15 per cent are also spreading in the forest. Climate change promotes the increase in neobiota insofar as the milder winters are favourable for their survival and the increasing dry spells in summer may reduce host plants' resistance (Wermelinger 2014). Warmer conditions have also led to insect and fungi species spreading northwards and/or to higher altitudes because of climate.

Of the fungi and insects that have recently been observed for the first time on woody plants in Switzerland and that have become established in urban green spaces or in the forest, several species are considered invasive. A few, like the Asian longhorned beetle (*Anoplophora glabripennis*), could endanger forest stands and are therefore classified as 'especially dangerous harmful organisms'. Their occurrence must be reported to the authorities and eradication measures are mandatory.

Invasive insects

The two Asian longhorned beetles introduced into Europe attack broadleaf trees of almost all species and sizes. Up until now they have preferred maple species. Only 4 cases of the citrus longhorned beetle (CLB; *Anoplophora chinensis*) in Switzerland are known, involving imported ornamental maple. The Asian longhorned beetle (ALB), however, attacked hundreds of indigenous trees in 2011 in Brünisried (Canton Fribourg), 2012 in Winterthur (Canton Zürich) and 2014 in Marly (Canton Fribourg) (Fig. 2.4.4). While the CLB attacks roots and the lower parts of the stem, and is mainly imported via living plants, the ALB attacks the whole length of the stem and branches of the crown. It enters Switzerland mostly in packaging wood, for example, in slatted crates for Chinese granite. Both beetle species must be officially reported. In Switzerland, no infestation of forest stands has occurred so far. Several infestations of copses and broadleaf stands are known from abroad. Eradication measures are being strictly implemented worldwide at the introduction sites with some success.

The Asian chestnut gall wasp (*Dryocosmus kuriphilus*) was first discovered in Ticino in 2009 (Fig. 2.4.5). It creates galls on leaves and flowers (causing a deformation). As a result, some shoots die and the production of leaves and fruit declines, sometimes drastically. Since then practically all chestnut-producing regions on the Southern slopes of the Alps have been affected. Infestation sites have also been identified in Chablais in the Rhone Valley (Canton Valais), as well as North of the Alps (Fig. 2.4.6). These can usually be traced back to imports of infested young plants.

The box-tree moth (*Cydalima perspectalis*) has been found in Switzerland since 2007, and has, until now, mainly attacked box trees in residential areas. It has spread within a few years throughout the whole of Switzerland through the sale of infested box trees. In the Basel area, natural box-tree

Fig. 2.4.4 *The introduced Asian longhorned beetle (ALB;* Anoplophora glabripennis*) attacks healthy trees of almost all broadleaf species. Photo: Doris Hölling*

Fig. 2.4.5 *Galls of the chestnut gall wasp (*Dryocosmus kuriphilus*). Photo: Beat Forster*

stands in the forest have also been affected. In 2010 they were completely defoliated and have not really recovered since then (Meier et al. 2013).

Invasive fungi

The pathogen causing ash dieback (*Hymenoscyphus pseudo-albidus*) was first identified in Switzerland in 2008, after which it spread rapidly. In the 1990s, the fungus, which originally comes from Asia, was transported unwittingly to Poland – most likely with infected young ash trees. Since then the pathogen has spread throughout Europe as its speed of propagation is between 30 to 40 kilometres per year. In 2015, 5 years after it was first observed in Switzerland, virtually all ash stands were found to be affected by this fungal disease. In young ash stands, losses of up to 90 per cent have been observed, and more infected old ash trees are also showing signs of dying (Fig. 2.4.7).

The red-band needle blight (*Dothistroma septosporum*) has spread from urban green spaces to the forest. This dangerous disease attacks the needles of pines and was first detected in Switzerland in 1989. Since then it has spread and is sometimes found today in residential areas in the northern part of Switzerland on mountain pine. In Canton Grisons and Canton Obwalden the disease was first spotted on Scots pine in forests in 2013.

Appropriate measures must be taken to protect the forest against damage from newly introduced harmful organisms. The number of new introductions must first be reduced, which means having stricter international and national regulations and border controls. In Switzerland the monitoring activities of the Plant Protection Service should be coordinated and extended in cooperation with the city park services. It is especially important to establish a form of monitoring in urban green areas, where new organisms first appear, as an early warning system for harmful organisms relevant to the forest. The earlier infestation sites are discovered, the more successful and less expensive it is to eradicate them. Once the neobiota have, however, already spread to the forest, it is virtually impossible to control them.

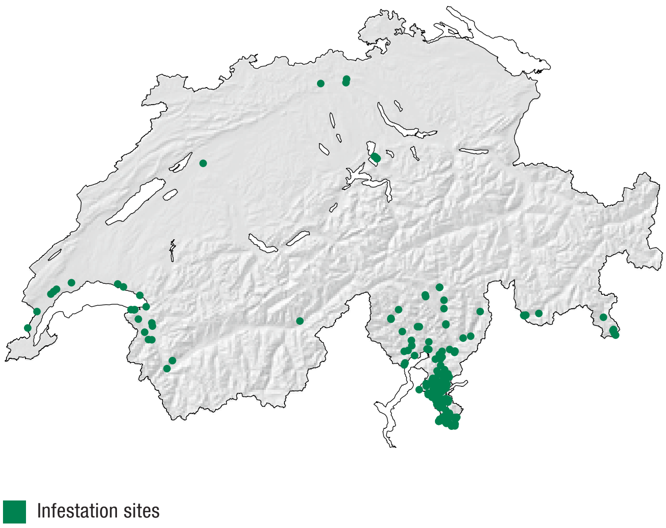


Fig. 2.4.6 *Infestation sites of the chestnut gall wasp (*Dryocosmus kuriphilus*) recorded by the end of 2013. Source: Waldschutz Schweiz*

Synthesis

Many of the factors that damage the forest are likely to become more important with the ongoing climate change, including storms and forest fires, as well as heat and droughts. Insects and fungi can multiply dramatically under the changed conditions and cause a great deal of damage, while invasive species find favourable conditions for dissemination. It is against this background that FOEN and WSL 2009 started a broadly based research programme 'Forest and Climate Change', in which the effects of various climate scenarios are identified and appropriate silvicultural strategies developed. To implement them, the Forest Act has been supplemented to allow various measures to, ultimately, support forest owners in keeping their forests vital and healthy in the long term, even under climatically changed conditions.

Fig. 2.4.7 *Ash infected with ash dieback.*
Photo: Roland Engesser

3 Use

Marc Hanewinkel, Alfred W. Kammerhofer

Since the Forest Report 2005, both the wood increment and the growing stock have continually increased, while the amount of harvested wood sold has decreased. During the same period, the harvest of logs and industrial timber has decreased and that of energy wood has increased. In addition to wood, non-wood products such as forest honey, venison or mushrooms can also be obtained in the forest. Of the non-wood products, the sudden drop in sweet chestnuts stands out: the harvest has really caved in as a result of damage caused by the sweet chestnut gall wasp. In Switzerland, the use of the forest is covered in the Forest Act. Forest planning implements this legislation and also ensures the sustainability of all forest functions.

Summary

More wood continues to grow in the Swiss forest than is harvested – the growing stock therefore continues to increase (gross and net increase). According to the National Forestry Inventory (NFI), the annual average net increase is 8 million cubic metres of wood. The amounts of conifer and broadleaf wood used differ. A high demand for conifer wood means that it is being used almost three times as much as broadleaf wood. As a result, on the Swiss Plateau, more spruce is being felled than is growing. This favours broadleaf trees, and furthers the aims of near-natural silviculture and biodiversity. In the Pre-Alps and the Alps, however, less spruce is being harvested than would be sustainably possible. It should be born in mind that both the NFI and the Forest Statistics assess the use of wood but with different methods (cf. Graphic II, pp. 16–17), which are not directly comparable (sections 3.1 and 3.2). Basically, NFI measures the changes in the forest stands, while the focus of the Forest Statistics is on how much timber has entered the market.

Selling wood is the major source of revenue for Switzerland's forest enterprises, providing them with about 260 million Swiss francs per year. According to the Forest Statistics, the forest enterprises sold between 4.7 and 5.2 million solid cubic metres of timber every year from 2006–2013, but currently quantities are tending to fall. The wood from Swiss forests is not only sustainably produced and harvested, but is also processed in Switzerland. This means that fewer greenhouse gases are produced and less embodied energy is used than in imported wood. Additionally, the carbon is stored for a longer time in durable wood products. Using Swiss wood and replacing fossil fuels with wood therefore contributes to climate protection.

Forest honey, venison, mushrooms, Christmas trees and sweet chestnuts are the most important non-wood forest products. The value of all the collected and used non-wood products is estimated to be about 90 million Swiss francs annually. The economic importance of non-wood products has declined in recent decades. One reason for this decline is the drop in the chestnut harvest in Canton Ticino.

The Swiss forest is being used sustainably and has to fulfil numerous functions. Legislative requirements ensure a sustainable use, and this is mainly implemented via forest planning. In the cantons, this planning is defined in the Forest Development Plans (Waldentwicklungsplan WEP) and the forest enterprises define their plans in forest management plans. Voluntary incentives, such as forest and wood certification, are meant to help produce a financial added value. So far, however, this has not been possible because raising the price of wood products with labels is not feasible. Currently, half the Swiss forest has been certified; however, the trend is downwards. The label of origin 'Swiss Wood' (Herkunftszeichen Schweizer Holz – HSH) is new on the market.

3.1 Timber use and increment

Christoph Fischer, Paolo Camin

> *The growing stock in the Swiss forest is increasing since the net increment is higher than the amount of timber used annually.*
> *In Switzerland, an average of 8 million cubic metres of new wood grows every year. Spruce and beech make up more than half of this increment.*
> *Conifer wood is used more than three times as much as broadleaf wood.*
> *On the Swiss Plateau, the use of spruce is intensive and exceeds its net increment. In the Alps and the Pre-Alps, spruce is being used less and its net increment exceeds its use.*

Use and increment

The wood from Swiss forests has been used more and more in the last 30 years or longer. Between the National Forest Inventories 1983/85 and 1993/95, the annual use of wood was 5.4 million cubic metres (Brassel and Brändli 1999). Today (NFI 1993/95 to NFI 2009/13) it is 7.3 million cubic metres annually. However, the regional differences are large: the forest on the Swiss Plateau is being used most intensively (Fig. 3.1.1), the forest in the Jura, in the Pre-Alps and in the Alps less and that on the Southern slopes of the Alps least. Almost three times more conifer wood is used than broadleaf wood (Fig. 3.1.2).

According to the National Forest Inventories 1993/95 and 2009/13, the wood increment has remained almost the same. The inventories distinguish between the gross and net increments: the gross increment measures the wood increment of both living and dead trees, while the net increment measures only that of the living trees. The gross increment in Switzerland is 9.9 million cubic metres of wood per year, which is equivalent to 9 cubic metres per hectare per year (m^3/ha/year). This means that, in comparison to other European countries, Switzerland has the most increment (Forest Europe et al. 2011). The net increment is decisive for the development of growing stock and provides an important parameter for comparison with use. In Switzerland, the average annual net increment is 8,1 million cubic metres, or 7.4 m^3/ha/y.

The regional differences are considerable. The net increment is highest on the Swiss Plateau, where there are nutrient-rich soils (Fig. 3.1.1), but closer to the Swiss average in the Jura and Pre-Alps. In the Alps and on the Southern slopes of the Alps, the annual net increment is, in comparison, significantly lower than in the other regions.

Conifers contribute 4.9 m^3/ha to the annual net increment and thus almost twice as much as broadleaf trees, for which the increment is 2.4 m^3/ha. More than half of the annual net increment is accounted for by only two tree species: spruce (3.1 m^3/ha) and beech (1.4 m^3/ha; Brändli et al. 2015).

Use in comparison to increment

An important indicator for judging the sustainability of forest management is the comparison between the wood increment and wood use. Forest management can be considered sustainable if the use and the increment are in equilibrium in the long term.

The annual net increment in the Swiss forest is 7.4 m^3/ha, which exceeds the annually used amount of 6.6 m^3/ha. For-

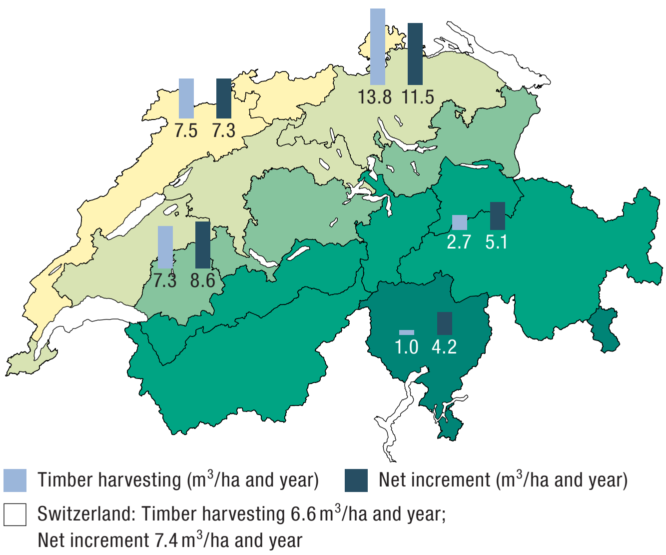


Fig. 3.1.1 *Use and net increment of wood between 1993 and 2013 in the 5 production areas in Switzerland. Source: NFI*

est management activities therefore do not fully exploit the annual net increment and the growing stock is increasing (section 1.2). An important reason for this is that access to the resource wood is difficult in some regions. The access infrastructure in the forest in mountainous areas is poor, and the cost of wood harvesting there is consequently high. Other important reasons why the sustainable wood potentially available is not all used everywhere include the way organisational structures tend to cover only small areas, the low prices for wood, the requirements of the public, ecological restrictions in, for example, reserves, the promotion of biodiversity and the preservation of the landscape area. The regional differences here are also large: on the Swiss Plateau, up to 122.6 per cent of the net increment is being used, but on the Southern slopes of the Alps only up to 20.4 per cent. And there are also differences in the types of trees: on the Swiss Plateau 3.2 m^3/ha more spruce is felled every year than grows. This has led to a decrease in the spruce stocks on the Swiss Plateau (section 1.2).

In comparison to other European countries, the Swiss forest has a large growing stock (section 1.2). The amount of wood used can be above the net increment regionally and over short periods of time without endangering sustainability. A study on the wood use potential in Switzerland (Hofer et al. 2011) developed several usage scenarios and explored their consequences for forest management for the period 2016 to 2026. The study shows that 7.5 to 9 million cubic metres of wood can be felled annually without endangering sustainability. Harvesting can even be increased for short periods to 10 million cubic metres per year (these values are not, however, directly comparable to the NFI results). It is an aim of the federal forest policy to increase the annual use of wood to 8.2 million cubic metres by 2020.

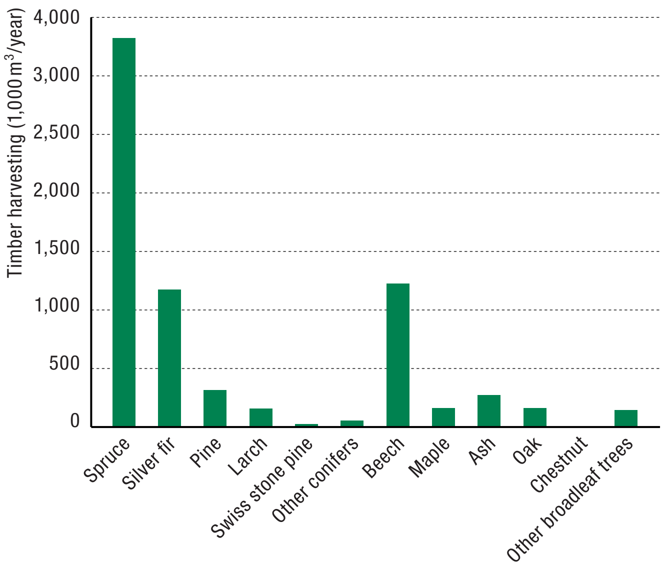


Fig. 3.1.2 *Timber use in Switzerland according to the main tree species. Source: Holznutzung NFI 2009/13*

3.2 Roundwood

Claire-Lise Suter Thalmann, Alfred W. Kammerhofer

> *Roundwood includes all of the logs, industrial timber and energy wood available in the forest.*
> *The sale of wood is the main income source of the Swiss forest enterprises, which sell between 4 and 6 million solid cubic metres of wood every year.*
> *Roundwood is mostly used in the construction industry and for fittings, furniture and paper and cardboard production.*
> *Since 2005 there has been a shift in the types of wood used. In particular, more broadleaf wood has been used as a source of energy and less has been harvested in the form of logs.*

Sale of wood

The sale of wood is the main source of income for Swiss forest enterprises. Since 2005, it has provided the mainly public owned forest enterprises with, on average, about 260 million Swiss francs[1] annually, equivalent to half of all their revenue. These figures are from the Forest Statistics, which collects data on the development of the wood market. The following types of wood are most frequently sold: logs for sawmills, industrial timber for paper manufacturing and for wood panel processing and forest energy wood for wood- and pellet-burning stoves and furnaces (section 6.9). According to the Forest Statistics, 4.66 million solid cubic metres of wood were harvested in Swiss forests in 2012 (FSO and FOEN 2013). Since the last Forest Report in 2005, the average annual harvest was about 5.2 million solid cubic metres of wood. The harvested quantities of logs and industrial timber have fallen below this average since 2009, while those of energy wood have risen (Fig. 3.2.1).

There are various reasons for the development in the use of wood as a material in the form of logs and industrial timber (for the development in its use as a source of energy, see section 6.9). Currently market prices are low and harvesting costs for wood relatively high (FOEN et al. 2012). The market conditions for Swiss wood have become more difficult in recent years (Fig. 3.2.2). Timber construction is currently experiencing a boom in Switzerland, but cheap semi-finished or finished goods are often imported. The costs, in particular wage costs, are considerably lower abroad. The current exchange rates also favour importing. The financial and economic crisis, and the corresponding strength of the Swiss franc over the Euro and the US dollar, meant that the prices for wood in Swiss francs had to be lowered. As a result, exporting wood is still viable.

There is little demand for beech wood for manufacturing, whereas the supply of broadleaf wood is relatively high. This means that wood prices for broadleaf trees – with the exception of valuable broadleaf wood – are fairly low.

Use of wood

Wood is used in a variety of ways – in construction (in particular for supporting structures and facades), for fittings and for manufacturing furniture (in particular for producing boards and panels), as well as for paper and cardboard. Consumers often do not know that many of the products they use contain wood. Wood is found, for example, not only in drinks but also

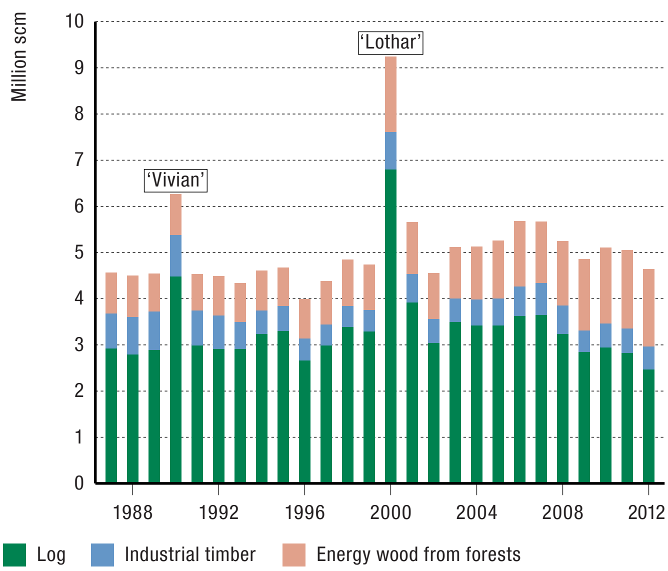


Fig. 3.2.1 *Development of the wood harvest according to types of wood used between 1987 and 2012 in solid cubic metres (scm). Source: FSO and FOEN 2013*

Table 3.2.1

Average wood harvest according to types of wood and use for 2005, 2008 and 2012 in solid cubic metres (scm). Source: FSO and FOEN 2013

	Conifer wood		Broadleaf wood	
	scm in 1,000	%	scm in 1,000	%
2005				
Logs	3,117	77	304	24
Industrial timber	390	10	194	15
Energy wood + residuals	518	13	761	61
Sum	**4,025**	**100**	**1,259**	**100**
2008				
Logs	2,886	78	356	23
Industrial timber	356	9	253	17
Energy wood + residuals	481	13	930	60
Sum	**3,723**	**100**	**1,539**	**100**
2012				
Logs	2,241	73	227	14
Industrial timber	284	9	219	14
Energy wood + residuals	555	18	1,133	72
Sum	**3,080**	**100**	**1,579**	**100**

in toothpaste, sanitary articles, clothing, perfumes, nail polish, 'silent' asphalt for roads or in heels for shoes.

In the last few years, many wood-processing enterprises have closed down, such as the large sawmill in Domat/Ems in Canton Grisons at the end of 2010, as have important manufacturers of mechanical and chemical pulp (Borregaard 2008, Deisswil 2010, Biberist 2011). This has led to a massive fall in the demand for logs and industrial timber, which has been partly compensated for by an increase in the use of energy wood – in particular broadleaf wood (Table 3.2.1; section 6.9).

Wood trading

Wood is freely traded as an industrial good. Overexploitation of many of the forests in the world has led to an illegal trade in wood and wood products. Switzerland, the EU and the USA have introduced measures to prevent illegal trading in wood, or make it more difficult. The European Timber Regulation (EUTR) regulates trading in wood, and has been in force in the EU since 3 March 2013. It forbids trading in illegally harvested wood and obliges all those on the market to meet certain due diligence requirements when they introduce timber and wood products for the first time in the EU. This also applies to timber and wood products imported from Switzerland. Switzerland plans to align its current due diligence system with that of the EU.

Wood is climate friendly

Wood has various ecological and economic advantages: Swiss wood processed in Switzerland contains almost no embodied energy since the transport distances are short. This means that few greenhouse gases such as CO_2 are produced and the carbon is stored in durable wood products. If wood is used for heating, the CO_2 released is only as much as the carbon absorbed by the tree while it was growing. Using Swiss wood is therefore climate friendly.

1 Adjusted for price on the basis of the Swiss Consumer Price Index (Yearbook 2013)

Fig. 3.2.2 *The development of the Wood Price Index of sawn roundwood from conifer and broadleaf wood from 1997–2013. Source: FSO and FOEN 2013*

3.3 Non-wood products

Silvio Schmid

> *Forest honey, venison, mushrooms, Christmas trees and sweet chestnuts are the most important non-wood forest products. According to estimates, they are valued at about 90 million Swiss francs annually.*

> *Nobody earns their main income from non-wood products in Switzerland. The forest may legally be freely accessed by anyone, and people can also gather fruits and berries in the quantities that are generally locally acceptable.*

> *In comparison with the Forest Report 2005, the amount of venison from the Swiss forest has remained unchanged. The figures for the other non-wood goods are not comparable due to the different data collection methods used.*

Products

The Swiss forest does not only provide wood but also the so-called non-wood products. The Food and Agriculture Organization of the United Nations defines them as 'goods of biological origin other than wood, derived from forests' (FAO 2010:18). Non-wood products are therefore almost all products that come from the forest except for wood (Table 3.3.1).

The exact amounts and value of all the non-wood products that are used and collected are only known to a certain extent. Thanks to the hunting statistics, there are at least reliable data for game. For the other non-wood products, only extrapolations or estimations are available. These estimate the value of the most important non-wood forest products in Switzerland to be about 90 million Swiss francs. Such goods include forest honey, venison, mushrooms, Christmas trees and sweet chestnuts (Fig. 3.3.1).

Every year, the honeybee produces on average 2,200 tonnes of forest honey, which has an estimated value of about 52 million Swiss francs. It is made from honeydew produced by millions of scale insects, which suck the sap from trees and then secrete the sugary honeydew that the bees collect.

Table 3.3.1

Examples of non-wood products and of other products that are not considered non-wood. Source: FAO 2010

Non-wood products	Other products and services
Mushrooms, fruits, berries, chestnuts, herbs, venison, animal fur, litter for animals, resin, decorative materials such as Christmas trees, mistletoe or moss, seeds from trees.	Recreation is one of the services. Wooden products such as shingles and fence posts. Gravel, sand and other products not of a biological origin.

The numerous hunters in Switzerland also make a rich haul, obtaining on average 180 tonnes of venison every year valued at 19.5 million Swiss francs. In 2010 alone they shot 40,000 roe deer, 13,000 chamois, 9,000 red deer and 7,000 wild boar (Fig. 3.3.2).

Collecting mushrooms in the forest is very popular. According to rough estimates for 2010, mushroom-collectors found 250 tonnes of boletus, chanterelle and morel, valued at 11 million Swiss francs. These figures do not include truffles, for which there are no reliable data.

Many people also decorate their homes or public places with a Christmas tree. Altogether about 1.2 million Christmas trees are used every year, of which about one tenth, i.e. as many as 120,000 trees, come from Swiss forests. These Christmas trees have an estimated value of 3.6 million Swiss francs.

Users

The Swiss Civil Code (Zivilgesetzbuch, ZGB) allows every person free access to the forest, where they can collect as many fruits and berries as is normal in the region. Wild animals ultimately belong to the cantons, which hold the hunting rights. Although the forest owners do not directly benefit from hunting, they benefit indirectly: the hunting stabilises the stocks of wild animals at a certain level and thus helps to limit browsing and stripping damage. The only products forest owners are allowed to sell are Christmas trees and sweet chestnuts from managed orchards.

Today, no-one still makes a living from selling or using non-wood products. In the past it was different: the non-wood products covered a significant part of daily food and raw material needs. This was particularly true for the poorer population. Sweet chestnuts – the fruit of the European chestnut –

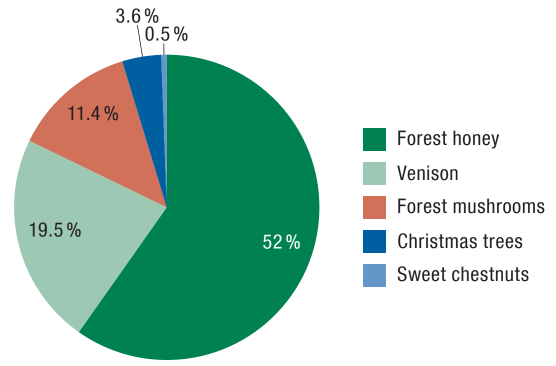


Fig. 3.3.1 *Percentage of the estimated value of non-wood products harvested in one year.*
Source: Limacher and Walker 2012

were thus called 'the bread of the poor' – and were a main food source up to the 20th century, particularly in Canton Ticino. A fully-grown sweet chestnut tree produces, on average, about 100 to 200 kilos of fruit every year, which covered one person's needs at the time almost exactly. Today, rough estimates suggest that 260 tonnes of sweet chestnuts are being harvested, with a value of half a million Swiss francs. This is only a fraction of previous quantities. In May 2009, the sweet chestnut gall wasp, which originally came from China, occurred for the first time in Italian-speaking Switzerland, with consequences for the commercial cultivation of sweet

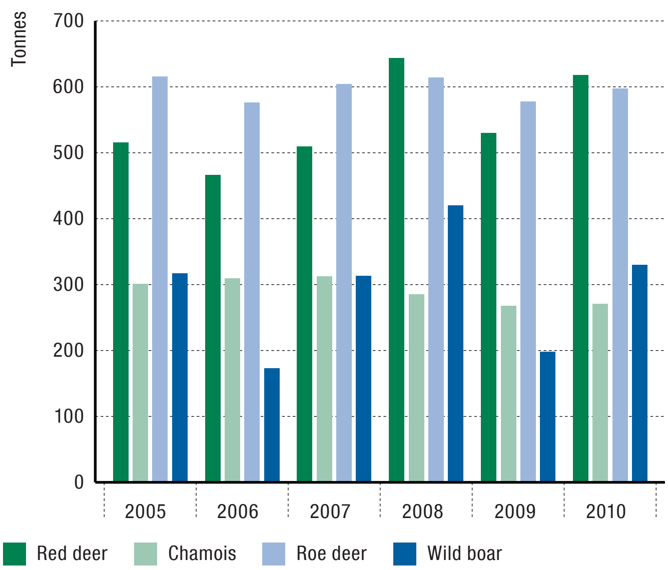


Fig. 3.3.2 *Game shot in Switzerland between 2005 and 2010: 1/3 of the meat is from red deer and 1/3 from roe deer, and 1/6th each from chamois and wild boar.*
Source: Limacher and Walker 2012

chestnuts. The long-term effects on marroni production cannot yet be estimated.

Today, hunting and gathering has become a hobby in line with a popular trend that can be described as 'back to the roots' or 'back to nature'. Many people enjoy going into the forest to collect mushrooms or other forest products. One sixth of those participating in a representative survey in 2010 said that the last time they had been into the forest had been to collect non-wood products (FOEN and WSL 2013), although exactly what, where, how and how much they collect in the forest are still largely unknown.

3.4 Forest management and certification

Matthias Kläy, Alfred W. Kammerhofer, Anton Bürgi und Erica Zimmermann

> *Most of the cantons have Regional Forest Plans applying to all of their forested areas that take into account the public demands placed on the forest.*
> *The Forest Development Plans (WEP) are co-ordinated with the cantons' guiding plans (Richtplanung).*
> *More than half of the forest area in Switzerland has been certified. Since the Forest Report 2005, the area of certified forest has almost doubled. The trend has, however, fallen slightly since 2009.*
> *Switzerland supports the campaign against illegal logging. The Label of Origin 'Swiss Wood' (Herkunftszeichen Schweizer Holz – HSH) stands for compliance with high legal standards.*

Forest planning

The Swiss Forest Act requires that "the forest shall be managed in such a way that it can fulfil its functions without interruption or restriction (sustainability)". Forest planning helps to implement this legislative requirement and is carried out at the two levels: cantonal forest planning (mainly Forest Development Plans) and forest enterprise planning (mainly forest management plans).

Cantonal Forest Plans

The cantonal Forest Plan is an important instrument for the forest service to document the sometimes competing demands on the forest (section 1.1), and find solutions to any conflicts that may arise. In this way, the demands can be taken into account at a higher level – mainly regionally or cantonally – and the aims to ensure a sustainable forest management defined. For this, many cantons draw up a Forest Development Plan (WEP) and co-ordinate this with their general guiding plans (Fig. 3.4.1). The forest owners are important partners in this process since they implement the official plans.

Forest enterprise management plans

Most of the cantons require the owners of forest over a certain size (15–50 hectares) to develop a forest enterprise management plan. For most of the private forest, this is not an obligation; however, it is obligatory for the approximately two-thirds of the Swiss forest that are publically owned.

The management plan includes an inventory of the forest resources, defines the enterprise's aims and strategies, and specifies the necessary infrastructure and personnel. The forest management plan also sets out the production aims and the silvicultural treatments for a certain period of time. They also take into account the higher-level requirements (in particular, those of the Forest Development Plan (WFP) and the canton's guiding plan). According to the National Forest Inventory (NFI) 2009/13, forest enterprise management plans have been produced for 54 per cent of the Swiss forest area. If the private forest area, which is usually not obliged to have a management plan, and the forest that is inaccessible or shrub or open forest according to the NFI are deducted from the whole forest area, then most of the usable forest area is covered by management plans (NFI 2009/13).

Certification

Illegal logging is a global problem with numerous negative consequences for ecosystems, the economy and society at

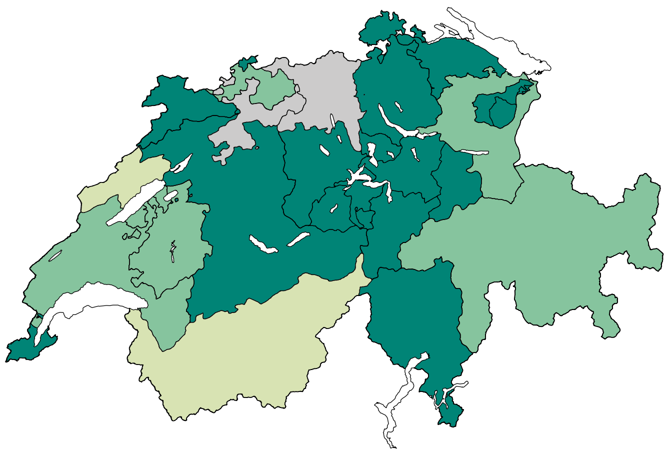


Fig. 3.4.1 *Cantons with current Forest Development Plans (WEP) and cantons where they are being developed. Two cantons use cantonal guiding plans to take into account public claims on the forest. Source: HAFL 2013*

large. Many measures have therefore been adopted, both nationally and internationally, to limit it. One of these involves voluntarily certifying forests and wood. This certification endorses the forest management as environmentally and socially responsible, as well as economically viable. For ecologically-minded consumers, this certification is an important motivation for buying wood with a label. Many of those who sell wood products want to attract such customers, whose numbers have grown over the past few years. Traders are therefore focussing on marketing wood with a label.

In Swiss forestry, two systems of certification are used: FSC (Forest Stewardship Council) and PEFC (Programme for the Endorsement of Forest Certification Schemes). They are based on the same national standards but have different requirements for silvicultural practice, for monitoring material cycles and for the organisation of forest enterprises. Internationally, 181 million hectares of forest area carry the FSC label and 244 million hectares the PEFC label. In 2012, the area with the FSC label increased by 16 per cent, while the area with the PEFC label remained the same.

In 1998, the first forest areas in Switzerland were certified. In 2012, 52 per cent of the forest area was certified with one or both of the systems. Since 2009 – the year with the highest level of certification – the forest area with a label has declined by about 7 per cent. This loss can be accounted for by the fact that many forest owners have stopped renewing their certification because it provides no economic added value. Bern University of Applied Sciences' School of Agricultural, Forest and Food Sciences HAFL (SHL 2009) carried out a study that identified a need for action with respect to the costs and benefits of certification. A large part of the forest area with a label – i.e. 61 per cent – belongs to public forest owners. Only 27 per cent of the private forest area is certified.

Worldwide, about 425 million hectares of forest had a label at the end of 2012, which is equivalent to about 10.5 per cent of the total global forest area. The area increased by 6 per cent in 2012. North America accounts for 52 per cent of the certified area, Europe 37 per cent and Asia and the Southern hemisphere the remaining 11 per cent.

Other instruments

Since 2010, an important legal instrument to control illegal logging in Switzerland has been the due diligence to declare wood and wood products, whereby the seller is obliged to inform the consumer about the type and origin of the wood (cf. section 3.2).

Switzerland has one of the most exemplary forest legislations in the world and received an award for it during the International Year of the Forest 2011. The forest services ensure the management of the Swiss forest is sustainable through supervision and monitoring throughout the country. This means that illegal logging can also be avoided. The label of origin 'Swiss Wood' (Herkunftszeichen Schweizer Holz – HSH) is a voluntary system indicating that 100 per cent of the labelled wood comes from Swiss forests and that the wood in labelled products is at least 80 per cent of Swiss origin. Additionally, the HSH label certifies that little embodied energy was used in manufacturing the wood product and hardly any greenhouse gases were emitted. The Coordinating Conference of the Construction and Real Estate Institutions of Public Builders (Koordinationskonferenz der Bau- und Liegenschaftsorgane der öffentlichen Bauherren, KBOB) and the Interest Group of Private Professional Builders (Interessengemeinschaft privater professioneller Bauherren, IPB) therefore specifically recommend purchasing wood with the HSH label. The HSH label is intended to make Swiss wood more visible for potential buyers of wood.

4 Biodiversity

Rolf Holderegger, Nicole Imesch

Forests play a central role in maintaining biodiversity in Switzerland. Since the Forest Report 2005, about half of the forest reserves planned for completion by 2030 have already been established, and the populations of forest birds, large carnivores and wild ungulates have grown. Despite these positive developments, some problem points still remain. Thus open forests and late phases of forest development with old trees and deadwood are rare in the lowlands, and the total number of vulnerable species has not decreased.

Summary

Biodiversity in the Swiss forest is in better shape than in other habitats for several reasons. Unnatural spruce stands are slowly disappearing due to near-natural silviculture and the diversity of tree species is increasing. Around 40 per cent of all the species that occur in Switzerland are dependent on the forest, but only 9 per cent of these forest species are actually vulnerable. Indeed, the populations of breeding birds, wild ungulates and large carnivores are growing. In recent years, half of the special forest and natural forest reserves planned for completion by 2030 have already been established, and cover nearly 5 per cent of the total forest area. In these reserves, stands can develop naturally until the decomposition phase. Valuable habitats are safeguarded and valorised in special forest reserves so that particular forest species can be specifically promoted, for example, in open forests or through special forms of use such as chestnut orchards, wooded pastures or coppice-with-standards forests. In addition, over 90 per cent of the regeneration in Swiss forests is natural. Natural regeneration and reserves both help to safeguard the local genetic diversity.

The development of biodiversity in the forest is thus basically positive, but there are nevertheless still problem points. The forest at higher altitudes in Switzerland continues to spread, and abandoned open land is becoming overgrown, which leads to a decrease in the landscape's structural diversity and to biodiversity loss. In the Swiss lowlands, late phases of forest development with old trees and large quantities of deadwood are still rare, as are open forests. A comparably small proportion of forest species are actually vulnerable according to the Red List, but Switzerland has a special responsibility to protect around 1,500 forest species with national priority. Many of these species are dependent on old trees and deadwood. Increasing populations of wild ungulates also endanger planned natural regeneration through browsing, and non-native woody plants in Ticino are displacing the native species of woody plants.

In comparison with forests in other European countries, the Swiss forest is well-prepared for future challenges such as climate change because of its wide variety of tree species and the high proportion of natural regeneration it contains. In forestry organisations, however, a subject of discussion is whether more non-native tree species should be planted in future to mitigate the negative impact of climate change on forestry. Currently, non-native tree species do not yet play a big role in wood production. Moreover, the trend towards more old trees and deadwood in the Swiss forest could be reversed if more wood is used for fuel as a result of the energy transition. It is therefore essential to reinforce the various current promotion measures, to find good compromises and to use the synergies between promoting biodiversity and other forest services.

4.1 Species diversity

Urs-Beat Brändli, Kurt Bollmann

> *The forest is of exceptional importance for biodiversity because, proportionally, it covers such large areas and is used in a very near-natural way in comparison to other habitats. It is likely to become even more important with climate change.*
> *A sizeable part of Switzerland would, in its natural state, be covered by beech and spruce forests, with few other tree species. Humans have increased the diversity of woody species in the forest by using it in a near-natural way and by promoting ecologically valuable tree species.*
> *A diversity of tree species promotes ecological niches for other forest species, creates more stable stands and mitigates the risks associated with climate change for the forest. Since 1995, the diversity of tree species has slightly increased and the proportion of broadleaf stands has increased markedly.*
> *Populations of wild ungulates, large carnivores, birds, snails and mosses have generally remained stable or shown a positive trend, and some species have even increased.*
> *Highly specialised forest species, however, are developing differently. They rely on forests with long-term natural life cycles and sufficient deadwood available. Their populations are often small and vulnerable.*

Diversity of tree species

Despite Switzerland's small size, the diversity of forest sites in the country is large. The forest extends from the warm lower areas in southern Ticino (shores of Lake Maggiore, 193 m a.s.l.) up to the timberline (in the Matter Valley in Valais at 2,450 m a.s.l.). Above this, even species specialised to cope with cold, such as the Swiss stone pine, can no longer grow. The diversity of sites is reflected in the species richness of the plant world. Nearly 700 vascular plants are typical forest species, including 7 native conifer and 39 native broadleaf species (Rudow 2014). The forest in Switzerland is largely formed by just a few main tree species (Fig. 4.1.1). Of these, shade-tolerant tree species have an advantage. They tend to displace light-demanding competitors in the course of a forest's development and dominate the stands. This is particularly evident with the three tree species, spruce, beech and silver fir, which make up two thirds of the trees counted in the National Forest Inventory NFI (Brändli et al. 2015). Normally, silver fir occurs naturally only in mixed stands, whereas beech forms almost pure stands in the lowlands, as does spruce at higher altitudes. Near-natural forests in Switzerland tend, therefore, to have a low diversity of tree species.

In managed forests, mixed stands with several tree species are more frequent and have several advantages over pure stands with only one tree species: they harbour a greater diversity of animal and plant species, and are less susceptible to storm damage and to attack from harmful organisms. Mixed stands also have an advantage in the context of climate change, as the risk of a species not being stress-tolerant is distributed across several species. Between 1995 and 2013, the diversity of tree species in the Swiss forest has changed slightly. Sites with just one tree species have tended to decrease (Brändli et al. 2015), while the proportion of near-natural broadleaf forest on the Swiss Plateau has increased (sections 1.1 and 4.3).

Promoting species through forest management

The diversity of tree species in a forest is influenced by the natural potential of the site, natural disturbances like windthrow and the method of forest management. On the Swiss Plateau, the tree species diversity is naturally greater than in the mountains because the higher the altitude, the less the species diversity. Thus species with an Atlantic or sub-Mediterranean distribution focus are limited to lower altitudes. A forest rich in tree species can also be the result of targeted management. On the sites where foresters promote light-demanding trees through stand thinning, these trees can withstand competition from the stronger species beech, spruce and silver fir. Tree felling ensures more light and warmth in the forest and thus encourages the diversity of particular plants and animals. In some areas, active forest management takes place less often. While 72 per cent of the forest area was actively managed on a regular basis in 1985, only 65 per cent was in 2013 according to the NFI. Forests are therefore becoming denser

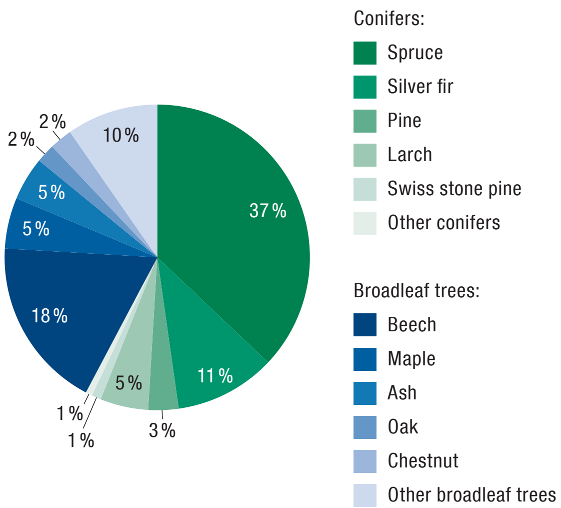


Fig. 4.1.1 *Proportional number of stems of different tree species in the Swiss forest. Conifers make up more than half of all tree species. Source: NFI 2009/13*

(section 1.3), and the diversity of light-demanding species will decrease in the short to medium term.

Rare tree species like yew (Fig. 4.1.2), wild service tree or small-leaved lime should be maintained. This is why FOEN, together with the Swiss Federal Institute of Technology ETH Zurich, launched a project in 1997 to promote rare tree species (SEBA) with the aim to create practical guidelines and to raise awareness among forest owners and managers. The federal and cantonal authorities are promoting the planting of rare tree species and of ecologically valuable oaks on, for example, windthrow sites, as part of the programme agreements in the revised National Fiscal Equalization NFE and their new division of tasks. Artificially created forests of young native tree species can enrich biodiversity, although in most places natural regeneration is preferable. Species-rich oak stands may also be the products of earlier forms of use, such as coppice with standards, while wooded pastures create open forests harbouring many animal and plant species that need light and warmth. Today, these traditional management forms are being deliberately continued or, in suitable places, re-introduced.

Forest species

The factors that determine the species communities in a forest are: the site conditions, climate and weather, natural disturbances and form of use. The communities are – in relation to the forest area – richer in species than average. Alluvial forests are particularly species-rich and are home to numerous rare species. Accordingly, over 1,500 of Switerland's around 3,150 vascular plants have been identified in alluvial areas of national importance. The endangered poplar admiral (*Limenitis populi*), for example, occurs mainly in alluvial and open broadleaf forests. It is one of the largest butterflies in the country, and its caterpillar mainly feeds on aspen and black poplar. Other species-rich forest areas are old stands, the transition zone between the forest and open landscapes, as well as open forests and shrubland. Typical species found in open forests are the asp viper (*Vipera aspis*) and the woodland brown (*Lopinga achine*). The caterpillar of this endangered butterfly species depends on grasses and sedges.

Forest species include animals that regularly inhabit the forest, as well as plants and fungi that mostly grow in the forest or depend on it for at least one of their developmental stages. Forest species make up a considerable part of the biodiversity. Of the estimated 64,000 species that occur in Switzerland, around 40 per cent live in or depend on forests. The proportion of forest species varies, however, between groups of organisms. The proportion is above average for bats, bark beetles, macrofungi and lichens (Fig. 4.1.3). Of the native vascular plants, 256 species are considered to be 'true' forest plants, and 412 other species partly depend on the forest as a habitat. Of the macrofungi, experts have classified 3,650 species as forest species. Of the around 190 bird species identified as breeding in Switzerland, 100 species depend on the forest for at least part of their life cycle. Of these, 59 species are totally dependent on the forest. Species that regularly occur in or along the edge of the forest include 428 species of moss, 130 species of snail and 27 species of butterfly or moth.

Many fungi and beetle species require old or deadwood during at least one developmental stage, namely 1,700 beetle species and 2,700 fungi species (Lachat et al. 2014). For in-

Fig. 4.1.2 *The yew (*Taxus baccatais*) is one of the species promoted as part of the programme "Rare tree species" (Seltene Baumarten – SEBA). Photo: Urs-Beat Brändli*

stance, the scarabaeid beetle (*Aesalus scarabaeoides*), which is critically endangered, prefers large rotten pieces of oak for its three-year larva-stage. Like many other soil organisms, worms also belong to the most species-rich groups in the forests. Despite their important ecological function, little is known about their direct relationship with forest habitats.

Development of species diversity

The populations of individual tree species have developed differently. Between 1995 and 2013, the numbers of spruce, Scots pine, hornbeam, common and sessile oak dropped, as did to a lesser extent the number of beech. In contrast, sycamore and Norway maples increased, as did small-leaved lime, white beam, rowan and larch (Brändli et al. 2015). The wych elm, which has been badly decimated since around 1975 by a fungal disease introduced into Switzerland, has, since 1995, stabilised for trees with diameters larger than 12 centimetres, and the trend is for it to further increase. The rare yew has had practically no regeneration for decades (section 4.2) due to game browsing (Brändli et al. 2009). According to the NFI, the number of young yews with a diameter up to 12 centimetres decreased between 1995 and 2013 by more than two-thirds.

Switzerland's Biodiversity Monitoring programme (BDM) has documented, since 2002, the development of selected animal and plant groups in different habitats and at varying altitudes. Its indicators show that, in forest habitats at all altitudes, mosses and snails are increasing and that vascular plants have remained stable (BDM 2009). Forests in the lowlands tend to be much less species-rich in some species groups, such as vascular plants and mosses, than mountain forests, where the forest canopies are less dense and forest structures richer. The BDM can only draw reliable conclusions about relatively frequent and widely distributed species. Rare species with special habitat needs (e.g. in relation to light, water, nutrients or deadwood) are insufficiently covered by the BDM. For such species, supplementary indicators are needed, for example, the Swiss Bird Index (SBI). This shows that forest bird species have increased since 1990 (Keller et al. 2013). Moreover, according to the SBI, the proportion of vulnerable forest breeding birds is 15 per cent. This percentage is considerably smaller than the average across all habitat types in Switzerland of 39 per cent.

Wild ungulates are generally doing well in Switzerland. The roe deer is the most frequent and widely distributed ungulate species. Its population is estimated at 115,000 animals (Federal Hunting Statistics, status in December 2013). Roe deer use all forests from the lowlands up to the upper timberline. The population of red deer is around 30,000 animals, and has increased by 23 per cent in the past 10 years. Even though 40 per cent more animals have been shot in recent years, the red deer is spreading further and is beginning to close the distribution gaps in the central, western and northern Pre-Alps, as well as in the Jura. The chamois population has remained stable during the past 10 years, amounting to 90,000 animals. This species is, however, increasingly visiting hilly areas in the lowlands. The size of the wild boar population is not known exactly. It is probably increasing because the boar is expanding its distribution area from the Swiss Plateau towards the Pre-Alps. Of the large carnivores, the lynx has established

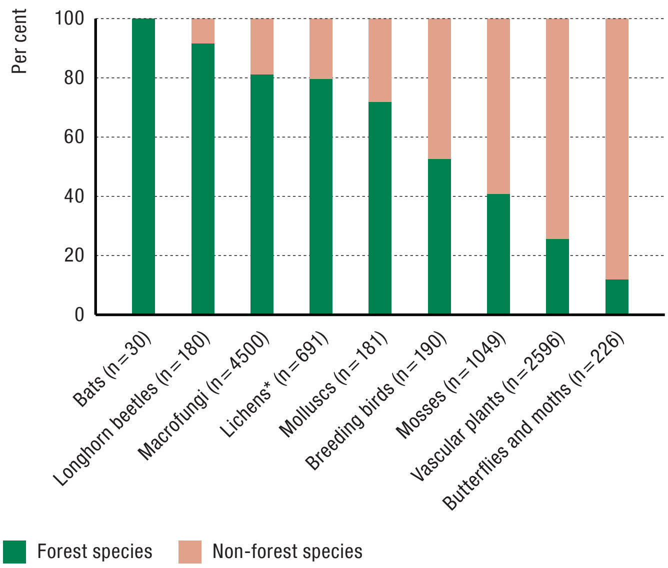


Fig. 4.1.3 *Forest species of different groups of organisms in Switzerland. n = number of species assessed, * tree- and ground-dwelling lichens. Source: Info Species (Status: August 2013)*

Fig. 4.1.4 *The endangered snail (*Bulgarica cana*) lives in near-natural broadleaf forests. Photo: Sigrid Hof*

two populations in Switzerland and now lives in the forests in the Jura and the Alps. While the wolf has reproduced for the first time in Switzerland since its extermination in the 19th century, the brown bear occurs only sporadically in the valleys of the middle and southern Grisons.

Specialised species

The Swiss forest provides a stable refuge for many species. This function will become more important in future with a changing climate. Over 80 per cent of forest plants are widespread and not endangered (Cordillot and Klaus 2011), which means that the proportion of vulnerable forest plants is much smaller than in other habitats. For some species groups like lichens, mosses, macrofungi or snails, the proportion of vulnerable species in the forest is, however, high (section 4.8). Some reasons for this are the changes in habitat through forestry interventions, lack of old wood and deadwood (section 4.5) and soil acidification due to site-inappropriate spruce stands. An example of a species vulnerable to soil acidification is the snail (*Bulgarica cana*, Fig. 4.1.4), which is one of the endangered species in near-natural broadleaf forests. One group of animals that suffer particularly from the lack of deadwood and of forests with natural life cycles are the so-called 'virgin forest relict species'. These are saproxylic beetle species, which depend on long developmental cycles and are strongly tied to the age and decomposition phases of the forest. They also have high requirements for deadwood quality and quantity (section 4.5). In Bavarian natural forest reserves, 22 such species occur, whereas in Switzerland, only 7 species have been found so far. There is also a difference in the virgin forest relict species on the Red List of European deadwood beetles, for which solid evidence comes from Germany. Of these virgin forest relict species, only 46 per cent have been found in Switzerland (situation in December 2013).

Bird species that have special requirements for forest habitats have developed differently. Populations of species like the woodcock, tree pipit, redstart and willow warblers have been dwindling during the past 25 years, and those of the grey-headed woodpecker and wood warbler have shrunk in the past 15 years, and have completely disappeared in some regions. In contrast, species like the hazel grouse, as well as the three-toed and middle-spotted woodpecker have increased. The reasons for this are various. Hazel grouse benefited from the forest development after the windstorms 'Vivian' and 'Lothar', while the three-toed woodpecker benefited from the larger supply of deadwood. Redstarts and tree pipits, on the other hand, thrive better in open forest with gaps or habitat mosaics where extensively used agricultural areas are interleaved with loosely structured forests.

4.2 Regeneration

Urs-Beat Brändli, Nicole Imesch

> *Unstocked regeneration areas are created through timber felling or through natural disturbances such as storms or forest fires and provide a habitat for species requiring light and warmth. Between 1995 and 2006 these areas doubled in size, partly as a result of the windstorm 'Lothar'.*

> *Natural regeneration has economic and ecological advantages over planting. In Switzerland it has increased markedly. Today, 90 per cent of forest stands in the regeneration and young forest phases developed from natural seeding. In this respect Switzerland is in first place among West European countries.*

> *Planting has continued to decrease considerably since 1995. Today planting is only done to reinforce protection forests, promote species diversity or produce timber from native tree species.*

> *The regeneration of some tree species has been severely affected by wild ungulates. Browsing of the sensitive silver fir has increased since 1995, and hardly any young growth of the rare yew has occurred for decades.*

Regeneration sites

Young forest stands form part of the diversity of habitats in the forest. They develop naturally in places where old trees have died, growing on small areas when single trees die, or on a larger scale when storms, forest fires and other disturbances produce large clearings. Forest managers imitate these natural processes and rejuvenate forests either through felling single trees (in mountain plenter, plenter and permanent forests) or felling trees on small areas up to half a hectare in area (in high forests with group selection).

Regeneration areas, i.e. temporarily unstocked areas where the young forest should grow, provide very good prerequisites for a varied forest sucession (Priewasser 2013). They not only enable a change in tree generation, but also provide habitats for animal and plant species requiring light and warmth, regardless of whether the unstocked areas have developed naturally or through small-scale felling. The regeneration areas in the Swiss forest doubled in area between 1995 and 2006, according to the National Forest Inventory NFI. The majority of them were created by the windstorm 'Lothar' in 1999. Large regeneration areas favour tree species requiring light, like willows, poplars, birches, rowans or oaks.

Natural regeneration or planting?

In principle, forests regenerate by themselves. Natural regeneration has many ecological advantages. Forests that regenerate naturally are more diverse because they consist of more tree species and have a higher genetic diversity. Moreover, the tree species in such forests are well adapted to the site. Both these factors reduce the risk of failure, particularly in the light of climate change. Even non-native (section 4.4) or tree species badly adapted to the site can regenerate themselves, which is often not desirable from the points of view of forestry management and ecology. Natural regeneration is therefore not necessarily better than planting, which often cannot be avoided if the aim is to transform pure spruce stands into near-natural forests. On windthrow and cleared sites, artificial regeneration may also be better if, for example, suitable 'seed trees' are lacking or competition from herbaceous vegetation is strong, or if a rare or economically interesting species needs to be promoted or a protection forest to be made effective quickly. Nevertheless, less planting than previously is done today for three main reasons: planting is costly; it may go against the principles of near-natural silviculture if applied to large areas; and wild ungulates are particularly fond of eating planted saplings (cf. *Browsing*).

Overall, more and more of the regeneration in the Swiss forest is natural. In forest stands that are in a regeneration or young forest phase, the proportion of natural regeneration rose from 81 per cent in 1995 to 90 per cent in 2013 according to the NFI. In the mountain forests of the subalpine zone, the proportion is as high as 98 per cent. If larger areas are regenerated – mostly in forests at lower altitudes – so-called young growth and thickets are formed. The proportion of purely natural regeneration in such areas rose from 64 to 79 per cent between 1995 and 2013 (Fig. 4.2.1). During the same period, the number of trees planted per year dropped from 4.4 to 1.2 million (FOEN 2013a).

Browsing by game

Only a few young plants manage to grow into adult trees. Many of them die due to competition between young trees, lack of light or water, frost, insects or diseases. Lack of light can be dealt with by felling trees. Where old stands are sufficiently thinned, enough saplings belonging to site-adapted species develop, as a rule, from the natural regeneration. In places with overly large populations of wild ungulates (especially of roe deer, red deer and chamois), regeneration is, however, endangered. The animals then eat many more of the saplings than normal and thereby impede or even prevent their growth. They prefer silver fir (Fig. 4.2.2), maple, ash, oak and yew, but are less keen on spruce and beech. For tree species that reproduce in large numbers, like maple or ash, the number of young saplings is usually high enough despite browsing. With the silver fir, which is an important tree species for protection forests, the ecologically interesting oak and the rare yew and wild service tree, browsing is often so severe that natural regeneration can no longer be guaranteed. Thus there has been practically no young yew growth in the Swiss forest for decades (Brändli et al. 2009). Browsing intensity is measured by counting the number of apical shoots browsed, and then dividing it by the total number of saplings and young trees. Overall, browsing intensity slightly decreased between 1995 and 2013 in the Jura, the Swiss Plateau and the Pre-Alps, but increased in the Alps, especially on the Southern slopes of the Alps. The increase in the Alps is due mainly to the heavier browsing of silver fir and, on the Southern slopes of the Alps, to more browsing of broadleaf species like maple and ash (Brändli et al. 2015). Even though the Forest Act requires natural regeneration of these species, it is, in many places, no longer possible without expensive protection measures, such as fences and individual safeguards. One important reason for the increase in browsing is the growth in red deer populations (section 4.1). Damage from fraying and bark stripping – mainly by red deer – has been found on 3 per cent of the saplings with a diameter of 1 to 11 centimetres (Brändli et al. 2015). A key factor in solving the problem is the regulation of the wild ungulate population through hunting. Moreover, measures to increase habitat quality that improve the food supply for game and reduce disturbances are important. Such measures involve not only the forestry services but also other 'actors' like tourism or agriculture. A prerequisite for solving the problem is a cooperative partnership between the hunting and forestry authorities, which the development of forest-game schemes is intended to promote (FOEN 2010).

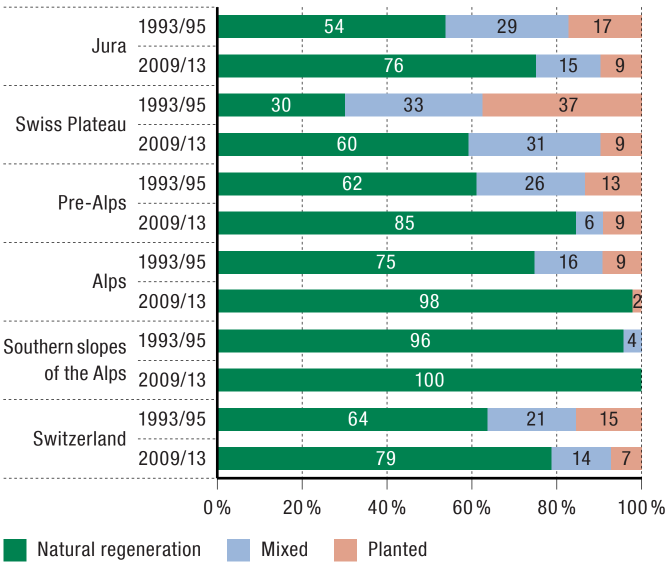


Fig. 4.2.1 *Proportional area of natural regeneration in young growth and thickets in the whole of Switzerland and in the 5 production regions. Source: NFI*

Fig. 4.2.2 *Browsing by roe deer of the apical and side shoots of a silver fir. Photo: Urs-Beat Brändli*

4.3 Naturalness

Urs-Beat Brändli, Peter Brang

> *The Swiss forest is part of a century-old cultural landscape. In Switzerland there is virtually no virgin forest left, but 19 per cent of the total forest area has not been used for over 50 years. Around 5 per cent of the total forest area has not been actively managed or grazed by livestock for as long as 100 years.*

> *Even managed forests may reach an almost natural state if they consist of tree species native to the site. However, in the lowlands, forests in old development stages, which are especially important for species diversity, are lacking.*

> *Forest management is increasingly promoting near-natural mixed broadleaf forests. Since 1995[1], pure spruce stands on the Swiss Plateau, which are not natural there, have decreased from 11 to 6 per cent.*

A forest's degree of naturalness indicates how much humans have influenced and changed its structure and processes. Two questions are central: how high is the proportion of original and undisturbed natural and virgin forest? And how natural are the managed forests thanks to near-natural silviculture?

Virgin and natural forest

In virgin forests, no changes due to humans have occurred. Such original habitats are valuable because all natural processes can take place without interference. Nevertheless, in central Europe, virgin forests often do not have more species living in them than used forests. Virgin forests are, however, home to more species that are sensitive to disturbance or that require old forests for their development, such as certain types of mollusc, moss and lichen (BDM 2009). In Europe (excluding Russia), virgin forests today make up only 4 per cent of the forest area (Forest Europe et al. 2011), and most of them are in Scandinavia and Eastern Europe. In Switzerland, virgin forests occupy only around 30 hectares, and thus, together with the forests in Derborence (Canton Valais) and Scatlè (Canton Grisons), make up less than 0.01 per cent of the total forest area. The Bödmeren Forest (Canton Schwyz) also has certain characteristics of a virgin forest.

Natural forests are forests that have grown from natural regeneration and have developed freely for a long time without human intervention (Commarmot and Brang 2011). The composition of their tree species corresponds to that of virgin forests. Such forests develop if they have a near-natural tree species composition and are no longer managed. With time, they go through all the stages of natural forest development. Today, this is increasingly happening on the Southern slopes of the Alps and at high altitudes. The proportion of forests that have not been used for at least 50 years rose from 14 per cent in 1995 to 19 per cent in 2013. The regional differences are, however, considerable. On the Southern slopes of the Alps, the proportion today amounts to 59 per cent, but on the Swiss Plateau to, on average, only 2 per cent (Fig. 4.3.1). Around 5 per cent of forest areas have been neither managed nor grazed by livestock for over 100 years (Brändli et al. 2010a). These are largely natural forests, which age in a natural way if they are not used. Stands in natural forest reserves (section 4.9) also develop gradually into natural forests.

Not all natural forests are ideal habitats. If they are close to civilisation with a dense network of forest paths and roads, their quality as a habitat will be negatively affected. For example, people and dogs disturb sensitive animals and birds like the capercaillie. Undisturbed habitats have become rare in Switzerland. Only 21 per cent of the forest area is more than 500 metres away from a forest road. Some of these isolated forests have not been used for over 100 years and are considered 'undisturbed forest wildernesses'. They make up around 3 per cent of the forest area (Brändli et al. 2010a).

Near-natural silviculture

In Switzerland, forests are managed primarily for wood production and for protection against natural hazards (section 1.1), using a near-natural management approach as required by the Forest Act. This is reflected in, for example, the composition of tree species, which is, to a large extent, near-natural (Fig. 4.3.2). In the lowlands, where broadleaf forests naturally occur, the proportion of conifers is, however, often larger than in natural forests. Today, stands in the broadleaf forest areas that are unnatural (>75 % proportion of conifers), or very unnatural, (>75 % proportion of spruce) still make up 21 per cent of the total forest area. A quarter of these are pure spruce stands where the proportion of spruce is over 90 per cent (Brändli et al. 2015). Such forests are ecologically and economically risky. They have low species diversity and are susceptible to windthrow and bark beetle infestations. Between 1995 and 2013, the proportional area in the whole of Switzerland of stands that are very unnatural decreased from 12 to 9 per cent, on the Swiss Plateau from 19 to 11 per cent, and that of pure spruce stands on the Swiss Plateau from 11 to 6 per cent. This development is the result of windthrow, bark beetle infestations and the near-natural silviculture practised for several decades. Another effect of this form of management is that natural regeneration with tree species adapted to the site has steadily increased (section 4.2). Near-natural silviculture is oriented towards the tree species composition of natural forests, but for economic reasons aims to have a slightly higher proportion of conifers.

In managed forests, trees and stands are harvested long before they die naturally. Normally, they live for barely half of their natural lifespan (section 1.3). To improve the conditions for species diversity, deadwood and habitat trees are left as they are, and old growth patches and forest reserves are created (section 4.5).

Certain forest types are especially important for habitat diversity. The federal government has produced a list of forest communities of national priority similar to that of the national priority forest species (section 4.8; FOEN 2015). Of the total of 121 forest communities found in Switzerland, 50 have a priority level of 1–3, occupying an estimated 3.4 per cent of the forest area. A further 26 forest communities, such as the larch-Swiss stone pine forest, have a lower priority of 4. While larch-Swiss stone pine forests are not endangered in this country, Switzerland does have a great responsibility for them in the context of the whole of Europe. Their quality can be maintained either through near-natural silviculture or by conserving natural forest reserves or special forest reserves.

1 Development since the publication of the Forest Report 2005, which refers to data from the NFI 1993/95.

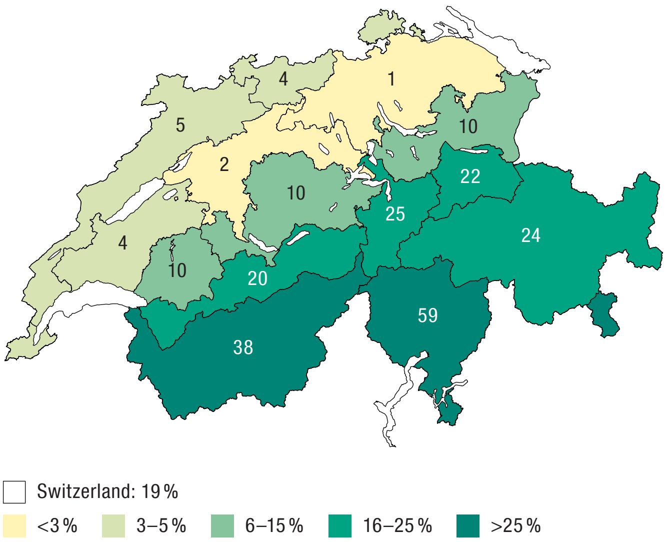


Fig. 4.3.1 *Proportion of forest areas where no forestry interventions have taken place for over 50 years in the 14 economic regions. Source: NFI 2009/13*

Fig. 4.3.2 *Near-natural managed forest with a tree species composition adapted to the site and with natural regeneration. Photo: Urs-Beat Brändli*

4.4 Non-native tree species

Marco Conedera, Urs-Beat Brändli

> *The planting of non-native tree species plays a small role in Swiss forestry. These species make up only 0.6 per cent of all trees, as the Forest Report 2005 also showed.*
> *Most of the non-native forest tree species were deliberately introduced and pose no threat to Swiss forests today.*
> *Under special environmental conditions, non-native species may spread invasively. An example of this is the tree-of-heaven, which, since the Forest Report 2005, has also been found to occur at the regeneration stage.*

Neophytes

Swiss flora today includes 300 neophytes. These have formed populations and therefore become more-or-less established (Landolt et al. 2010). They make up about 10 per cent of all Swiss flora (Lauber et al. 2012). In other central European countries, the proportions of neophytes relative to all the flora are similarly large. Neophytes also occur in the forest. Some of them are non-native tree species used in forestry and introduced by humans for this reason. They are useful, and their stands are controlled. Other neophytes spread without human involvement. If they spread so significantly that they compete with or even displace native species, thus disturbing the equilibrium in the forest habitats and natural forest communities, experts call them invasive. Those plants that prove to be particularly invasive are recorded in the list of prohibited invasive non-native organisms (Release Ordinance 2008, Appendix 2). The one tree species also listed is the staghorn sumac (*Rhus typhina*). In addition, two other tree species and three shrubs or liana are on the Black List of invasive species in Switzerland because of their invasive behaviour. The list contains 16 other plant species, most of which grow in the herb layer, and some of which have the potential to spread invasively in the forest (Nobis 2008).

Exotics in the Swiss forest

Non-native tree species are called exotics. Their proportion of 0.6 per cent in the Swiss forest has remained stable since 1985 (Brändli et al. 2015). If exotics make up more than 50 per cent of the growing stock in the species composition on an NFI sample plot, experts consider the exotic part to be dominant. Between 1995 and 2013, the proportion of the forest area dominated by exotics did not grow substantially according to the National Forest Inventory NFI, i.e. only from 0.4 to 0.5 per cent. Such forest stands are most frequent on the western and central Swiss Plateau and in the eastern Jura (Fig. 4.4.1).

Non-native tree species occur almost exclusively at lower altitudes up to 1,000 m a.s.l. Most exotics are species that were introduced for timber production (Table 4.4.1). Since they are managed, their regeneration is controlled. The NFI 2009/13 confirmed this as such species seldom occur in regeneration stages, with the exception of Douglas fir and red oak. The majority of introduced forest tree species do not behave invasively and thus currently pose no ecological threat to Swiss forests (Weber 2002). In some central European countries, the cultivation of exotic tree species is an important source of income in forestry. In Switzerland, in contrast, it is negligible as the amount of timber produced here from exotics is so small that there is only a niche market for the most frequent exotics. This may change in future since climate change could lead to more non-native tree species being planted or spreading naturally.

Douglas fir, for example in Germany, regenerates strongly on warm and dry sites with acid nutrient-poor soils, where it may displace other tree species (Tschopp et al. 2012). The invasion potential of non-native tree species and their resulting ecological and economic impacts on forests or forestry are today still difficult to estimate accurately. In order to understand this potential and its impacts better, also in relation to climate change, more research on these species is needed.

Invasive woody plants

For trees and other woody plants to be able to spread invasively, certain environmental conditions are needed, which are normally only locally present: for example, a mild climate combined with agricultural areas that have been left fallow or with disturbed or abandoned forest stands. Such conditions

Table 4.4.1

*Number and proportion of stems of exotics in the Swiss forest. Only trees with a diameter at breast height greater than 12 centimetres were measured. *Exotics introduced for timber production. Source: NFI 2004/06*

Species	Scientific Name	Number	Proportion (%)
False acacia*	*Robinia pseudoacacia*	1,065,000	0.21
Douglas fir*	*Pseudotsuga menziesii*	1,041,000	0.21
Black pine*	*Pinus nigra*	222,000	0.04
White pine*	*Pinus strobus*	77,000	0.02
Red oak*	*Quercus rubra*	141,000	0.03
Hybrid poplar*	e.g. *Populus x canadensis*	81,000	0.02
Tree-of-heaven	*Ailanthus altissima*	63,000	0.01
Other exotics		502,000	0.10
Total exotics		**3,192,000**	**0.64**

can today mostly be found in the lower parts of the Southern slopes of the Alps and in some of the main Alpine valleys.

One example of an invasive neophyte is the tree-of-heaven. This broadleaf species from China is displacing native plants on the Southern slopes of the Alps. It colonises mainly immature soils such as fallow meadows bordering a forest. The tree's winged seeds can be transported in large quantities over hundreds of metres, and thus spread to disturbed and temporarily open forest sites, such as those that have been cut or where forest fires have occurred. The NFI 2009/13 recorded the tree-of-heaven in regeneration stages.

Many areas on the Southern slopes of the Alps no longer used by people are becoming grown over, in particular, former vineyards and abandoned chestnut coppice forests close to lakes. The herb and tree layers on such sites are colonised by both native and non-native plant species. The main native species are holly and ivy, while most of the non-native species are evergreen shrubs from nearby gardens, for example, camphor, laurel, cherry laurel, thorny oleaster and windmill palms. A similar trend in spread is also evident on the Northern slopes of the Alps, where cherry laurel and Henry's honeysuckle may behave invasively. The latter is a woody liana, which can suppress tree regeneration in the forest (Weber 2005).

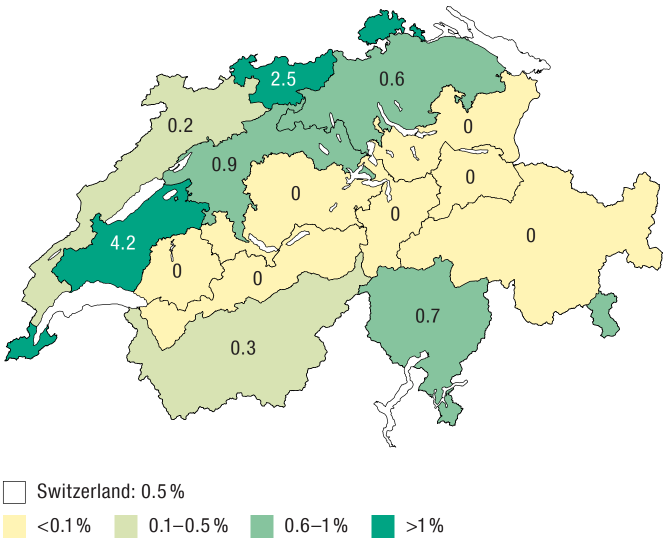


Fig. 4.4.1 *Proportion of the forest area dominated by exotics per economic region. Source: NFI 2009/13*

4.5 Deadwood

Thibault Lachat, Urs-Beat Brändli, Markus Bolliger

> *Deadwood and habitat trees are irreplaceable habitats and sources of food for more than 20 per cent of the species living in the forest. Many of these 6,000 species are threatened.*
>
> *The increase in habitat trees and the volume of deadwood is the result of storms, greater understanding of ecological interactions and lower prices for timber.*
>
> *According to the National Forest Inventory NFI, the volume of deadwood doubled in the period from 1995 to 2013 and has reached a level in the Swiss forest today of 24 cubic metres per hectare. This quantity is not, however, sufficient everywhere to maintain endangered species – considerable deficiencies are particularly apparent on the Swiss Plateau and in the Jura. Deadwood with a large diameter and in later stages of decomposition is still rare throughout Switzerland.*
>
> *With the intensified harvesting of energy wood, habitat trees and fresh deadwood could become economically more valuable again. Special measures are therefore needed to ensure they are maintained in the forest.*

Deadwood and habitat trees

Deadwood is defined as dead trees or the dead parts of trees. These may be standing or lying, and in the form of branches or large stems. Deadwood is either produced through the natural death of a tree or a part of it – for example, due to ageing, windthrow, diseases or pests (section 2.4) –, or as residuals from harvesting during forest management. Habitat trees are defined as living trees with habitats for specialised species, for example, hollow trees with mould for certain beetles or trees with cracks for bats (Fig. 4.5.1).

Deadwood and habitat trees are important for the forest as an ecosystem because around 6,000 species depend on them as habitats or food sources. These include over 1,700 beetle species and 2,700 higher fungi, as well as many birds, amphibians, mosses and lichens. More habitat trees and deadwood are therefore good for biodiversity. Deadwood has additional functions. It can, when properly arranged, provide protection against rockfall or serve as a seedbed for tree seeds and thus promote natural regeneration (section 4.2) in mountain forests.

Deadwood is increasing

The development of deadwood in Swiss forests is gratifying as its volume and the number of snags have increased since the 1980s. According to the NFI, the volume of deadwood more than doubled from 11 to 24 cubic metres per hectare (m^3/ha) between 1995 and 2013. Moreover, the number of giant trees with a diameter of more than 80 centimetres has risen (section 1.3). This increase in deadwood is, among other things, a consequence of the windstorm 'Lothar'. Another contributing factor is that timber harvesting in inaccessible areas is no longer profitable and numerous stands have not been actively managed for decades (section 4.3). In addition, acceptance among forest owners and managers of deadwood and habitat trees has grown in recent decades. This has led to more deadwood being tolerated in forests and habitat trees being deliberately left standing.

Many animal and plant species can benefit from the larger quantities of deadwood, snags and large old trees in the Swiss forest, for example, most woodpecker species (Mollet et al. 2009) and some wood-dwelling species. Thus populations of the Alpine longhorn beetle (*Rosalia alpina*) have grown since the 2nd World War (Lachat et al. 2013), partly due to the good supply of dead beeches exposed to the sun at lower and medium altitudes.

Threshold values

How much deadwood is needed to conserve endangered species? This question can be answered with the help of so-called threshold values. These describe the minimum amounts of deadwood needed to conserve specialised species. Most saproxylic species require between 20 and 50 m^3/ha, but this depends on the forest type. In montane-subalpine conifer forests, 20 to 30 m^3/ha are needed, whereas in oak-beech forests, 30 to 50 m^3/ha are necessary (Müller and Bütler 2010). Particularly demanding species like the rare fungus *Antrodiella citrinella* need over 100 m^3/ha deadwood. Such large quantities are found only in forests that have not been actively managed for a long time. In certain regions, the threshold values of the deadwood volumes for conserving most saproxylic species are reached. Nevertheless, there are many forests in which this is not the case. These are mostly located in easily accessible areas at lower altitudes in the Jura and on the Swiss Plateau, where the deadwood volumes are smallest and, correspondingly, the ecological deficiencies highest (Fig. 4.5.2). On the Swiss Plateau, only those forests that have been affected by a storm have large quantities of deadwood.

With deadwood, it is not only the quantity but also the quality that counts. The diversity of size classes and stages of decomposition determines the composition of the species communities (Lachat et al. 2014). Experts estimate that at least 5 to 10 snags or habitat trees per hectare forest must be conserved for the species that depend on them to survive (Bütler et al. 2013). In addition, the deadwood and habitat trees should be well distributed and interconnected in the forest, as well as permanently available. From the point of view of biodiversity, a network of large and small forest stands with a large quantity of deadwood and many habitat trees is ideal. They should be embedded in a near-natural forest landscape, where all forest areas contain some deadwood. Establishing and protecting natural forest reserves and old growth patches (section 4.9) is thus an important measure to ensure that demanding species survive in the long term.

It is difficult to predict how the quantity of deadwood and the number of habitat trees in the Swiss forest will develop in future. The growing demand for energy wood could stop the trend towards more deadwood. The great challenge will be to meet the needs of the species that require habitat trees and deadwood despite the intensified use of wood. Here, compromises between economic and ecological goals are needed, which is what forest managers have been trying to achieve for decades with the help of comprehensive forest planning (Forest Development Plan – Waldentwicklungsplan WEP).

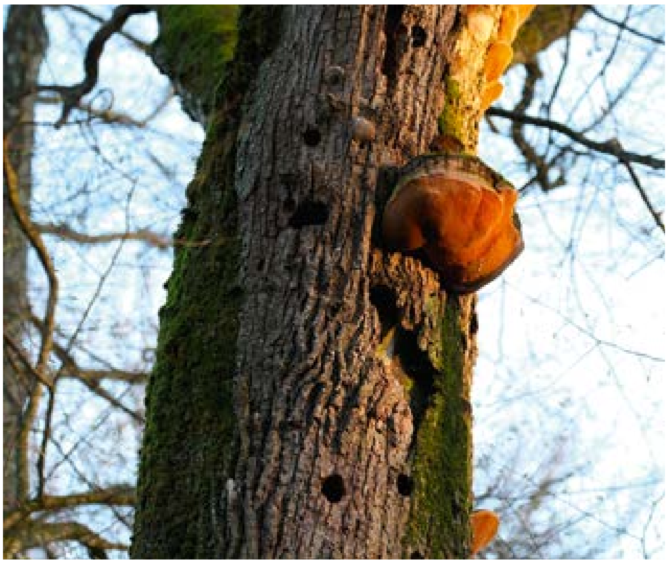


Fig. 4.5.1 *Habitat tree with small-scale habitats such as woodpecker holes, console fungi and bark pockets, which are particularly valuable for specialised species. Photo: Andreas Rigling*

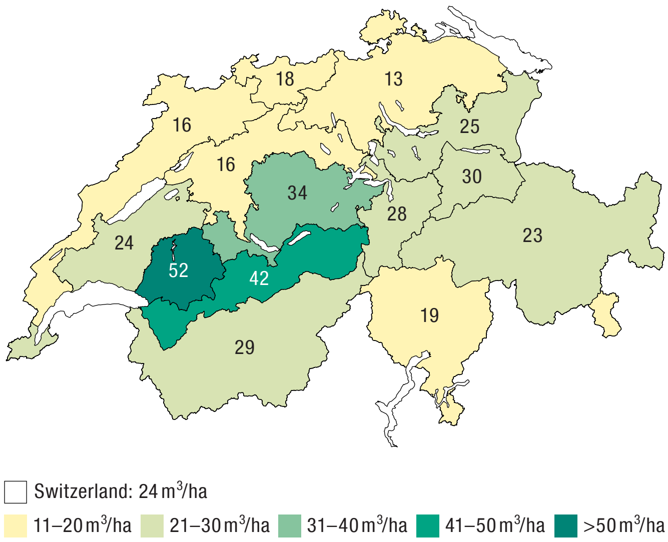


Fig. 4.5.2 *Average volume of deadwood in the Swiss forest per economic region. Source: NFI 2009/13*

4.6 Genetic resources

Felix Gugerli, Rolf Holderegger, Markus Bolliger

> *High genetic diversity helps maintain biological diversity and is a prerequisite for tree species to be able to adapt to future climates.*
> *Switzerland relies largely on natural regeneration in the forest, which helps to maintain the genetic diversity and at the same time to select genetically adapted trees.*
> *Special and natural forest reserves fulfil many of the requirements for conserving genetic resources. Particularly valuable forest reserves can, in addition, receive the internationally recognised status of gene conservation units.*
> *For new plantings, seeds from selected regional seed-harvest stands are used so that the genetic diversity, which has developed naturally, can be preserved.*

Genetic diversity

Genetic diversity is an important part of biodiversity and contributes to conserving tree stands adapted to different sites. It is, moreover, a prerequisite for native tree species to be able to adapt to changing environmental conditions, as well as for them to survive in future and reproduce successfully. High genetic diversity is thus a prerequisite for the Swiss forest to be able to fulfil its functions and to continue to do so even under changed environmental conditions. How can genetic diversity be kept high? As many trees as possible must contribute to the next generations through their pollen and seed. An exchange of genetic variants between the stands helps to interconnect them and thus maintain the genetic diversity in the region (Fig. 4.6.1).

Conservation measures

Switzerland has committed itself internationally to protect its genetic resources in the forest. As one of the signatories to Forest Europe, the pan-European forest policy process at the ministerial level, Switzerland is obliged to implement the corresponding resolutions. The resolution "Conservation of forest genetic resources" adopted at the first Ministerial Conference in Strasbourg 1990 is decisive for genetic diversity. It is implemented through the programme EUFORGEN (European Forest Genetic Resources Programme), and Switzerland is participating in its technical working groups. Currently, a European information system to record forest genetic resources is being set up (EUFGIS). Participating countries are called upon to identify – at the national level – stands of priority tree species selected for the conservation of genetic resources, so-called *gene conservation units* (GCUs).

The genetic resources in the Swiss forest are conserved and promoted through numerous measures. Natural regeneration helps maintain not only the species diversity but also the genetic diversity of native tree species (section 4.2). Forest reserves (section 4.9) also serve to conserve genetic diversity. In special forest reserves, certain species are specially fostered, whereas in natural forest reserves, human interventions are stopped completely. Some forest reserves are particularly valuable for conserving the genetic diversity of single or several tree species, and can therefore be assigned the status of

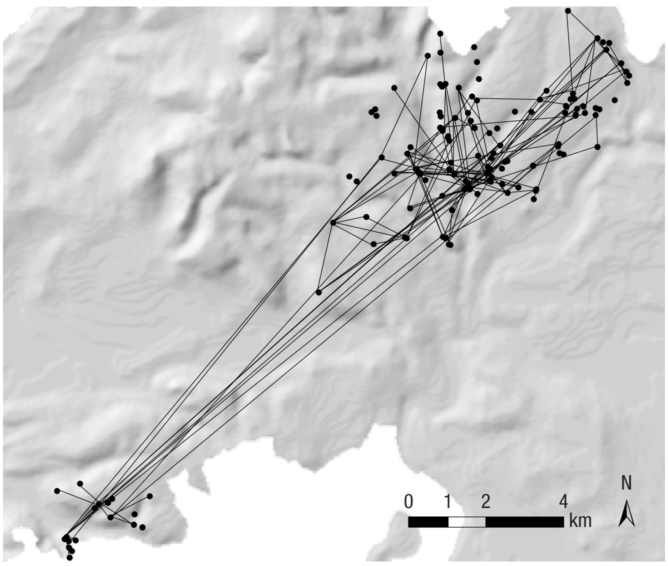


Fig. 4.6.1 *Genetic connectivity of the wild service tree, a rare tree species, in Canton Schaffhausen. The lines represent the pollen dispersal between individual trees (points).*
Source: illustration based on Kamm et al. 2012

Table 4.6.1

*Forests of special genetic interest, seed-harvesting stands and seed plantations in Switzerland. * Stands with limited documentation on characteristics and few trees for seed collection. Source: Rudow et al. 2013, Nationaler Samenerntekataster 2014*

Category	Number of objects	Area	Number of species
Forests of special genetic interest	5	1,157 ha	3
Selected stands for seed-harvesting	402	>2,782 ha	34
Seed-harvesting stands with known sources*	1,281	867 ha	35
Ex-situ seed plantations and clone archives	15		13

gene conservation units. These replace the "woods of special genetic interest", as they were called in the Forest Report 2005. Currently, the ETH Zürich has a FOEN assignment, together with the cantons, to establish gene conservation units for the following tree species: Swiss stone pine, beech, silver fir, spruce, yew, black poplar and wild service tree.

Switzerland has a special responsibility for the genetic diversity of tree species whose distribution is concentrated in the country, for example, for the Swiss stone pine or the yew. This obligation applies also to stands whose occurrence is on the geographical or ecological periphery of their natural distribution in Switzerland, such as inner-Alpine silver fir stands.

For many tree species, so-called seed-harvesting stands exist in Switzerland. These are forests where the trees have special characteristics and seeds adapted to the site are harvested for planting seedlings. The seed-harvesting stands were selected according to certain traits, such as growth or shape, which is why the genetic diversity of their trees may be rather limited. This is, however, partly compensated for by the fact that the seeds harvested in these stands were pollinated by pollen whose origin cannot be controlled. Specially created seed plantations and other forms of ex-situ conservation are confined to small areas and to just a few tree species in Switzerland (Table 4.6.1). Only exceptionally do they provide an alternative to natural seed-harvesting stands.

Exploiting genetic resources

The climate in Switzerland will become warmer and drier in future. Genetic resources provide the basis for the adaptability of forests to these changes and should be exploited. Thus genetic variants of native tree species can be chosen that have adapted to aridity or warm conditions. A prerequisite for this is that, when planting, the ecological origin and not just the regional origin should be taken into account. The ongoing research programme "Forest and Climate Change" should yield new findings. Economically important species like spruce, beech and silver fir, but also oak, are the main focus of these genetic investigations. In future, it may be possible to plant more tree species in mixed broadleaf forests that already occur in Switzerland, but that have hardly been used in forestry so far, such as the Italian maple or the wild service tree.

4.7 Forests in the landscape

Christian Ginzler, Felix Kienast

> *Forests in Switzerland have been spreading in the Alps for decades, and the trend is continuing.*
> *The pattern of the forest is also changing as small patches of forest merge. This leads to the loss of sparse and structure-rich habitats, as well as of recreation areas for people.*
> *The increase in forest area does, however, improve the forest's protection service.*
> *Disturbances like the windstorm 'Lothar' create open areas, but generally existing forest areas are becoming denser and darker.*

Forest patterns

Nearly a third of Switzerland's surface area is covered with forests. They form patterns in the landscape that have developed through their large-scale distribution and the small-scale configuration of individual forest areas. These forest patterns have been substantially shaped by humans. For many centuries, human activities have been leaving their mark on the distribution of the forest through clearing it long ago, building settlements and roads, as well as agriculture and forestry. The forest patterns thus reflect the cultural inheritance of the region. For example, the forests in the Alps have been spreading for several decades at the cost of open landscape. This is changing forest patterns in many places.

The aerial photos taken for the land-use statistics indicate that the woodlands (groups of trees and hedges) outside the forest shrunk by 2 to 7 per cent, depending on the region, between the surveys in 1992/97 and 2004/09 as a result of clearances on agricultural land and widespread building. The development varies from region to region, but has been particularly pronounced on the Swiss Plateau. The forests there have become an important refuge area for many animal and plant species because suitable habitats in the open landscape are increasingly lacking. According to the National Forest Inventory NFI 2009/13, the forest area has grown further. The regional differences are large. It has remained unchanged on the Swiss Plateau, but increased by a few per cent in the Jura and in the Pre-Alps, and by as much as 13 per cent in some places in the Alps and on the Southern slopes of the Alps (section 1.1; Table 4.7.1). The area pattern of the forest, which consists of numerous patches of forest, has also changed. The number of forest patches has remained constant in the Jura and on the Swiss Plateau, and in the Pre-Alps only a few forest patches have merged. In the Alps and on the Southern slopes of the Alps, however, many patches of forest have amalgamated, and numerous gaps and clearings have thus become overgrown and closed.

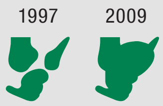
How people experience the landscape is influenced by how much the forest has ingrown. Most find half-open forest landscapes in medium stages of reversion to forest more attractive than closed homogeneous forests (Hunziker et al. 2012). Dense continuous forests, however, provide better protection against avalanches and rockfall (section 5.2), and more effective connectivity for many forest species (section 4.1). Moreover, large and dense forests safeguard the good quality of the drinking water because forest soils are rich in humus and roots and thus an optimal water filter (section 5.1). Forest patterns therefore have numerous ecological, social and economic effects. This is why the implementations of the Forest Devel-

Fig. 4.7.1 *Wooded pasture with sycamore on the Chasseral (BE) – an attractive landscape with many forms of use. Photo: Markus Bolliger*

Table 4.7.1

Development of the forest area and number of patches of forest in Switzerland. Source: NFI and Land-Use Statistics (Arealstatistik)

	Change in the forest area 1993/95 to 2009/13 in %	Change in the number of patches of forest 1997–2009 in %	Trend in the development of the forest pattern: larger patches of forest, fewer edge effects
Jura	→ −0.2	→ +0.1	
Swiss Plateau	→ −0.1	→ +0.3	
Pre-Alps	↑ +3.6	↓ −1.5	
Alps	↑ +10.3	↓ −5.0	
Southern slopes of the Alps	↑ +16.8	↓ −11.9	
Switzerland	↑ **+5.9**	↓ **−2.5**	



opment Plans (Waldentwicklungspläne WEP) (section 3.4) and Landscape Development Schemes (Landschaftsentwicklungskonzepte LEK) are important instruments to help harmonise the various functions of the forest.

Forest edges and light availability

Comparing the development of the forest area and the number of patches of forest (Table 4.7.1) indicates that everywhere where the forest area has greatly increased, the number of individual forest patches has decreased. As a consequence, ecologically valuable forest edges, which provided habitats for numerous animal and plant species, have disappeared. Since 1997, this development has slowed as, by that point in time, many patches of forest had already grown together. What is gratifying is that, during the past 20 years, the width of forest edges has increased, particularly at higher altitudes. The width of the shrub belt has stayed more or less constant, while that of the herb fringe has slightly increased. A shrub-belt width of 5 to 10 metres is optimal for species diversity. According to the NFI 2009/13, only around 16 per cent of the 170,000 kilometres of forest edge have an optimal width. On the Swiss Plateau and in the Jura and Pre-Alps, the width of most forest edges is less.

The availability of light in the forest has slightly decreased since 2000. The stand density has increased, particularly in the Alps and on the Southern slopes of the Alps (section 1.3). Sparse stockings close gradually. Open areas have been created, especially at lower altitudes, as a result of the damage to the forest and the intensified use of wood after the windstorm ‘Lothar’, the hot summer of 2003 and regional events.

Table 4.7.2

Area and forest distribution of the wooded pastures in the Jura and in the whole of Switzerland. Source: FOEN-Erhebung 2006

Region	Area of wooded pastures in ha	Proportion of Switzerland’s forest area in %
Jura (VD, BE, NE, JU)	45,000	3.6
Rest of Switzerland, especially the Alps	42,000	3.4
Switzerland	**87,000**	**7.0**

Wooded pastures and orchards

Chestnut orchards and wooded pastures are two typical examples of culturally influenced forest patterns that developed historically (Fig. 4.7.1). According to Switzerland’s Forest Act, they are part of the forested area, providing a diverse habitat for many species, with a varying mixture of grazing land, single trees, groups of trees and small patches of forest. Chestnut forests make up 0.13 per cent, i.e. just a small part of Switzerland’s forest area.

Wooded pastures were originally present in many mountain regions, but today they are mostly found in the Jura (Table 4.7.2). They are maintained through the grazing of horses and cattle, which graze not only on the open pastures but also in the forested parts, where they eat the seedlings of young trees and thus prevent the forest advancing. This results in an open forest landscape, which is important for nature conservation and attractive for tourists. Despite their usefulness, there are fewer and fewer wooded pastures today. The pastures are gradually becoming overgrown in many places because they have been abandoned and the cattle graze on more productive meadows. The federal government is supporting the improvement and maintenance of wooded pastures by implementing its forest policy (the programme “Forest Biodiversity”) and its agricultural policy (landscape quality and biodiversity subsidies).

4.8 Threatened species

Christoph Scheidegger, Silvia Stofer, Beatrice Senn-Irlet

> *In 2011, FOEN produced the Swiss List of National Priority Species. This is based on the Red Lists of threatened species and on how responsible Switzerland is for these species. It identifies a total of about 3,600 species, of which 1,582 species are closely connected with forest habitats.*

> *Of these, 304 species are so-called forest target species, which must be specially protected and promoted through additional measures.*

> *It is difficult to assess how threatened species have developed since the Forest Report 2005. Although additional Red Lists are available for species conservation, changes in the risk situation have only been documented for a few forest species. For most other species, revisions of the Red Lists that would provide evidence of a change are lacking.*

> *The populations of certain birds, butterflies and flowering plants have increased thanks to the promotion of open forest structures.*

Forest species of national priority

In comparison with other habitats, the proportion of endangered species in the forest is small, amounting to just 9 per cent of all forest species (section 4.1). Expressed in absolute numbers, however, many species are involved because forest habitats are very rich in species. In 2011, FOEN produced a List of National Priority Species in Switzerland (FOEN 2011a). This is based on the threat category of the species according to the Red Lists, as well as Switzerland's responsibility for these species in terms of their overall distribution (Cordillot and Klaus 2011). It indicates the need for conservation action for these species and thus provides valuable information in addition to the Red Lists. The List of National Priority Species in Switzerland includes 1,582 forest species, of which 1,548 species are endangered or potentially endangered. Most of the priority forest species belong to the macrofungi (47 %), lichens (18 %), beetles (8 %) or mosses (8 %). Other groups of organisms make up around 20 per cent. Some of the national priority forest species, which experts call target forest species, require special conservation measures. These amount to 304 species (Table 4.8.1) including, for example, the middle spotted woodpecker (*Dendrocopos medius*) or the greater horseshoe bat (*Rhinolophus ferrumequinum*). Measures favouring the national priority forest species also promote biodiversity in the forest in general because they improve the environmental conditions of other species as well.

Diversity under threat

The main ecological deficiencies in the forest that affect species diversity are: 1) insufficient expanses of special forest communities, especially in alluvial areas; 2) small proportional areas of open forests and of structurally varied stands with plenty of old growth; and 3) insufficient quantities of deadwood in different stages of decay (sections 4.1 and 4.5). Many of the threatened forest species can be conserved by maintaining their habitats. Here the brochures of the national species data centres are helpful as they describe the habitat requirements of numerous species, as well as measures to improve their habitats. They thus support the implementation of appropriate measures (Info Species 2012).

Protecting a species' habitat is not always enough to conserve it, as the example of the nationally protected gilded domecap (*Lyophyllum favrei*) shows. This fungus occurs predominantly in hardwood-alluvial forests, whose expanse has been greatly restricted by the interventions of earlier river corrections. Hardwood-alluvial forests are today increasingly coming under pressure again as watercourses are being revitalised, creating more space for gravel banks and softwood-alluvial forests. When this happens, it is often at the cost of hardwood-alluvial forests since building and agricultural areas are very seldom handed over to allow room for the river basin to expand.

Many species, especially plants and lichens, live in the same place for a long time even though the habitat quality may be too low for them to successfully reproduce. With such species, a 'delayed' extinction can be expected. While they

Table 4.8.1

Number of priority and target forest species in Switzerland, classified according to group of organisms (AGAF 2014, FOEN 2015). The list has been supplemented with data on deadwood-dwelling lichens.

Species group	Priority forest species	Target forest species
Macrofungi	735	27
Lichens, excluding lichens living on rock	266	134
Vascular plants	136	44
Mosses	122	11
Mammals, excluding bats	7	3
Bats	22	12
Birds	46	14
Reptiles	11	5
Amphibians	9	7
Beetles	125	34
Butterflies	66	11
Grasshoppers	4	1
Dragonflies	1	1
Land snails	32	
Species total	**1,582**	**304**

may still be found, they no longer reproduce and will become locally extinct in the near future. Moreover, biological interactions between different species in a habitat may be broken off, which can lead to an 'extinction cascade'. Three lichen species illustrate this: the lungwort, green satin and parchment lichens (*Lobaria pulmonaria*, *L. virens* and *L. amplissima;* Fig. 4.8.1), which are associated with the same algal species. When colonising a new habitat, the green satin and parchment lichens rely on being able to take over the algal symbiont of the lungwort lichen. The marked decline of the Lungwort lichen has therefore had an impact on the reproduction of the other two species. As a result, the green satin lichen has already become extinct in Switzerland, and the parchment lichen is endangered.

Conservation measures

Numerous measures have been implemented in the forest during recent decades to promote biodiversity. Today they are already showing some effects. Thus thanks to the promotion of open forest structures in special forest reserves (section 4.9), the populations of certain birds, butterflies and flowering plants have grown over the past 25 years. The development of beetle and fungus species has been mixed, and with lichens, populations of endangered species are continuing to decline.

For many endangered species, natural forest reserves and special forest reserves provide refuges where they can survive. They may, however, also occur in managed forests, where they are linked with rare forest communities (section 4.3) or with habitat trees and old-growth patches (section 4.5). Mobile species, like birds and butterflies, can benefit from scattered old-growth patches and habitat trees in managed forests. Sessile species, in contrast, need connected old-growth patches within small areas because their ability to disperse is limited and they therefore have difficulty spontaneously reaching habitats that are isolated or newly created. In the long term, they will only be able to survive in an interconnected habitat network. Protecting existing occurrences of sessile endangered species is therefore a matter of priority. The promotion of threatened forest species can be based on existing instruments for promoting biodiversity, in particular on near-natural silviculture (section 4.3) and forest reserves (section 4.9; Bollmann et al. 2009). At the same time, numerous species will increasingly depend on specific promotion measures in future to be able to persist. Ensuring that different use and conservation aims are cooperatively pursued requires finding ways for the forestry services, environmental experts and national species data centres to work together constructively.

Fig. 4.8.1 *The lungwort lichen (left) forms granular propagation units. Once distributed, the algae it contains can also be used by the green satin lichen (top right) and parchment lichen (bottom right). Photos: Christoph Scheidegger*

4.9 Forest reserves

Peter Brang, Markus Bolliger

> *In 2012, 4.8 per cent of the forest area in Switzerland were protected in the form of reserves. This is almost twice as much as in 2005.*
> *It is also nearly halfway to fulfilling the aim of Swiss forest policy to have reserves on 10 per cent of the forest area by 2030. There is, however, much to do, especially on the Swiss Plateau, and in particular, in the case of large forest reserves.*
> *In natural forest reserves, the forest is denser and contains more deadwood and giant trees than the rest of the forest.*
> *In special forest reserves, targeted silvicultural interventions promote particular habitats and species to ensure high biodiversity.*
> *Some traditional forms of forest use have been continued or reintroduced in special forest reserves: coppice with standards, wooded pastures and chestnut orchards enrich the landscape and provide ideal habitats for light-demanding species.*

Types of reserve and target size

There are two types of forest reserve in Switzerland: natural and special forest reserves. In both, the promotion of biodiversity has priority over other forest functions. Natural forest reserves are left alone, whereas in special forest reserves targeted interventions create and improve habitats for particular plants and animals. In 2001, Switzerland set a forest policy target for the size of reserves: By the year 2030, 5 per cent of the forest area should be protected as natural forest reserves and 5 per cent as special forest reserves. In 2012, a total of 4.8 per cent of the forest area was protected: 2.7 per cent as natural forest reserves and 2.1 per cent as special forest reserves. This is almost halfway to meeting the goals for the year 2030 (Fig. 4.9.1; Bolliger et al. 2012), and shows progress in comparison with the Forest Report 2005, when only 2.5 per cent of the area was under protection.

The proportional area of forest reserves is largest in the Jura. On the Swiss Plateau and in the Pre-Alps, the forest reserves established up to now have been mainly small special forest reserves. In contrast, extensive natural forest reserves have been created in the Alps and on the Southern slopes of the Alps. The greatest need for action for natural forest reserves is thus on the Swiss Plateau.

A further goal of Switzerland's forest policy is to set up 30 large forest reserves at least 500 hectares in size. Today, there are 17 such reserves, and efforts to provide protection are well underway. Enormous regional differences are, however, evident. It is difficult to create large reserves on the Swiss Plateau as its forests are productive and easily accessible. Moreover, they often belong to different owners (section 6.1), who all decide themselves whether to establish a reserve in their forest. The federal government and cantons advise them accordingly and promote forest reserves by providing financial compensation for refraining from using the timber. In addition to the forest reserves, part of the Swiss forest has not

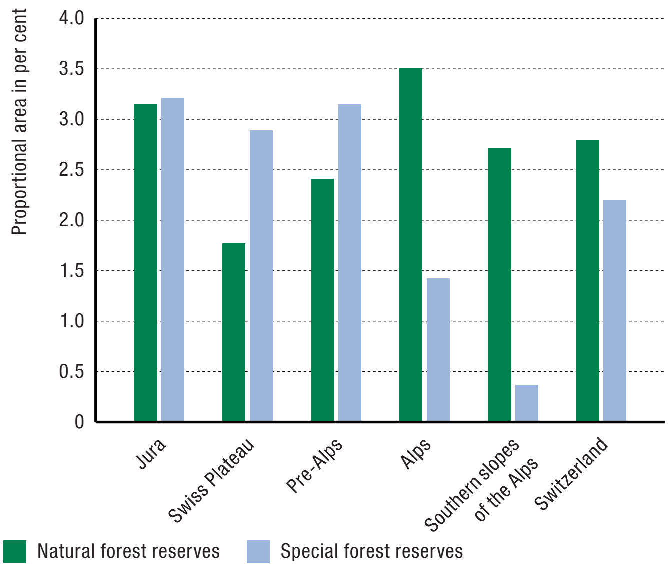


Fig. 4.9.1 *Distribution of natural forest and special forest reserves in relation to forest area. Source: FOEN*

been used for decades (section 4.3). It thus includes similar habitats to those in natural forest reserves, even though it is not under protection.

Natural forest reserves

Natural forest reserves should provide habitats also found in virgin forests, which show natural forest development in that the trees grow, regenerate themselves, age and die. During this process, varied habitats for flora and fauna are formed.

The forest reserves include the two remaining virgin forests in Switzerland, namely Derborence (Canton Valais) and Scatlè (Canton Grisons) (section 4.3). The other natural forest reserves were used and shaped by people for centuries before they were placed under protection. A monitoring programme in natural forest reserves showed that these forests are gradually becoming more natural in that the basal area and the deadwood are increasing, and large trees are becoming more common (Heiri et al. 2012). As a measure of stand density, the basal area is around 30 square metres per hectare in managed forests and 40 square metres per hectare in reserves. In natural forest reserves, the forest is thus denser than in managed forests. The volume of deadwood (section 4.5) is around 50 cubic metres per hectare and thus higher than the Swiss average of 24 cubic metres per hectare (Herrmann et al. 2012). Morevover, deadwood in natural forest reserves occurs more often in the form of large trees and in more advanced stages of decay than in the rest of the forest. It is thus biologically more valuable. Giant trees with stem diameters of 80 centimetres and more are 2 to 3 times more frequent in natural forest reserves than in managed forests (Fig. 4.9.2; section 1.3; Heiri et al. 2012). In natural forest reserves of beech, light-demanding woody plant species disappear with time as the forest becomes denser, and the species diversity of the trees diminishes slightly. This development is evidence of the increasing near-naturalness of the natural forest reserves. It will probably take centuries, however, before they can be classified as virgin forests (Brang et al. 2011).

Special forest reserves

In special forest reserves, targeted silvicultural interventions promote biodiversity, for example, thinning pine forests so that rare orchids, butterflies and reptiles can live there (Fig. 4.9.3). Harvesting timber in some conifer forests in the Alps helps to keep them open so that they remain attractive for grouse. The federal government and cantons provide financial aid for those measures that must be carried out regularly. In special forest reserves, historical cultural forest forms can also be maintained. Many light-demanding species prefer traditional forms of use, such as coppice with standards, wooded pastures or chestnut groves (section 4.7).

Fig. 4.9.2 *Over 10 giant trees per hectare grow in the natural forest reserve Leihubel (OW). Photo: Markus Bolliger*

Fig. 4.9.3 *An open pine forest on a steep slope near Kyburg ZH. It is regularly thinned so that rare light-demanding forest plants can thrive. Photo: Albert Krebs*

5 Protection Forest

Peter Brang, Arthur Sandri

Forests protect groundwater, an important drinking-water resource, from impurities by retaining pollutants in the soil and allowing the cleaned water to percolate deep into the ground. Drinking water from forest areas is therefore of good quality. Forests provide people with protection against natural hazards, like avalanches, rockfall and debris flows. Their protective effect has improved since 2005 because the forests have grown denser. The increasing lack of regeneration and more browsing of young trees by wild ungulates mean, however, that the forest's long-term protective effect is uncertain.

Summary

In Switzerland around 80 per cent of the drinking water comes from groundwater. In comparison with the groundwater from agricultural or residential zones, the groundwater from forest areas generally contains much fewer pollutants and can usually be used as drinking water without further treatment. The main reason for the good water quality of the seepage in forest areas is that the forest is managed with great care and without the use of pesticides, fertilizers or mechanical soil tilling. In addition, clear-cutting is forbidden and the forest vegetation absorbs a considerable proportion of the nitrogen deposited from the atmosphere. In groundwater from forest areas, the nitrate concentration is therefore mostly low. Nevertheless, a further reduction in nitrogen deposition from the air is essential to maintain the good quality of the seepage in forests.

According to the National Forest Inventory (Brändli et al. 2015), around 42 per cent of the Swiss forest provides people and their infrastructure with protection against natural hazards like avalanches, rockfall and debris flows. In mountainous regions the proportion of protection forest is much higher. Most protection forests are in areas with flowing water, where the tree roots stabilise the ground and help to prevent debris flow and bank erosion. The forest often provides protection against several natural hazards at the same time. Targeted silvicultural treatments help to ensure the forest has a long-lasting protective effect. About half the Swiss protection forest was treated accordingly between 1993 and 2013.

During this time the protection forest developed in part positively, but in part with shortcomings. The composition of tree species improved in that the extent of pure conifer forest, which is particularly vulnerable to natural disturbances like storms and insect infestations, decreased. The forests became overall denser, which improved their protective effect in the short term, but at the same time prevented regeneration and led, therefore, to an increasing lack of young trees. Moreover, in many places ecologically important tree species like silver fir were browsed by wild ungulates such as red and roe deer, which threatens their maturation into adult trees. Browsing and the lack of regeneration raise questions about the protective effect of the forest in the long term.

5.1 Drinking water

Peter Waldner, Markus Huber, Elisabeth Graf Pannatier, Miriam Reinhardt, Sabine Braun

> *In comparison with the groundwater in agricultural and residential areas, the groundwater in forest catchment areas usually contains much fewer pollutants and can mostly be used as drinking water without any further treatment.*
> *The main reasons for the good quality of the seepage in forest areas are the widespread exclusion of pesticides, fertilizers, large-scale tree-felling and mechanical tilling of the soil, as well as the ban on industrial activities.*
> *Air pollution leads, in some places in the forest, to high nitrogen deposition, of which a substantial part is absorbed by the vegetation and soil. Their absorption capacity is, however, not unlimited, and a reduction in nitrogen deposition from the air would be an important preventive measure for maintaining the good quality of the water.*

Groundwater and water quality

Around 80 per cent of the drinking water in Switzerland is obtained from groundwater (SVGW 2012). The quality of the groundwater is generally high, as the findings of the national groundwater monitoring body, NAQUA, indicate (FOEN 2009b). Around 40 per cent of the water can be fed into the drinking-water network without any treatment, and a further 30 per cent after a simple one-step treatment (e.g. disinfection) (Freiburghaus 2012). In agglomerations and intensively used agricultural areas, the groundwater may, however, contain traces of fertilizer, pesticides or other micro-pollutants (FOEN 2009b). The water-soluble nitrogen compound, nitrate, is the most prominent of these as filtering it out is only possible with a complicated and expensive process.

Groundwater that is not replenished through the infiltration of river water is only recharged with water from precipitation that seeps through the soil. The seepage in forest areas is of special significance here as it is normally of good quality. The nitrate concentration in groundwater from forest areas is mostly 5 to 10 milligrams per litre (mg/l), whereas the nitrate concentration in groundwater from agricultural areas may often exceed 25 mg/l. The Waters Protection Ordinance (WPO) specifies a maximum nitrate level of 25 mg/l as a quality target for groundwater. How good the quality of the groundwater in a catchment area is depends on the relative proportion of different types of land use. An investigation of Swiss groundwater in the year 2005 revealed that, at 20 per cent of all measurements points, the WPO quality target for nitrate was not met (FOEN 2009b). The groundwater in unproductive Alpine regions is, in comparison, hardly affected and consistently has a nitrate concentration of less than 5 mg/l.

Careful silvicultural treatments

The water in forest areas is qualitatively better than that in arable agricultural areas for several reasons (Hegg et al. 2004):

> In forests, fertilizers and plant protection products may only be used in exceptional circumstances and strict security measures must be taken.
> A large part of the forest area has closed vegetation cover. This removes a substantial proportion of the substances that are produced during the decomposition of organic material or deposited from the air.
> Unlike arable land, forest soil is not mechanically tilled. As a result, soil activity is promoted and the soil structure left undisturbed, both of which are advantageous for the filtering of seepage.
> No large-scale tree-felling is carried out.
> Incidents with pollutants are rare in the forest because industrial and agricultural use, which could affect the groundwater quality, is forbidden.

Groundwater in forest areas is often used as drinking water. According to NFI 2009/13 (Brändli et al. 2015), 12 per cent of the forest area in Switzerland is within the catchment area of a drinking-water intake facility, and as much as 10 per cent in a groundwater protection zone. In the Jura, the percentages are particularly high and may be even 22 or 24 per cent.

Nitrogen cycle

In drinking-water catchment areas with different kinds of land use, seepage containing nitrates from agricultural areas is mixed with water low in nitrates from forest areas. The quality of the resulting drinking water is therefore generally good. The nitrogen deposition from the air (section 2.1), which is deposited through precipitation and subject to regional variation, is partly filtered out and accumulated in the forest soil or absorbed by the vegetation. If the nitrogen deposition remains for a long period so high that the soil becomes saturated with nitrogen, excess nitrogen is passed on, in the form of nitrate, into the water that seeps into the groundwater. If the nitrogen deposition is over 20 kilograms per hectare and year (kg/ha/year), high nitrate concentrations in the seeped water are more frequent than with medium or low nitrogen deposition up to 20 kg/ha/year (Fig. 5.1.1; Braun 2013, Graf Pannatier et al. 2012). Experimental studies have shown that higher nitrogen deposition can lead to an increase in nitrogen saturation.

Experiments abroad indicate that tree-felling can result in heavy nitrate leaching during the following 5 years. This applies even to small cleared patches, but even more so to windthrow and large-scale tree-felling areas as a larger proportion of the drinking-water catchment area is then affected (Hegg et al. 2004).

Maintaining water quality

The regulations in force include the prohibition of large-scale clear-cutting and only restricted chemical treatment of stored timber. Using biodegradable lubricants and increasing the proportion of broadleaf trees are recommended. Complying with these regulations and recommendations gives rise to greater forest management costs, but contributes considerably to the quality of the groundwater and thus to ensuring the supply of clean drinking water (Blattert et al. 2012). Forest owners are requesting better compensation for the extra maintenance costs involved. A further reduction in nitrogen deposition from the air as a preventative measure is also important for maintaining a good water quality.

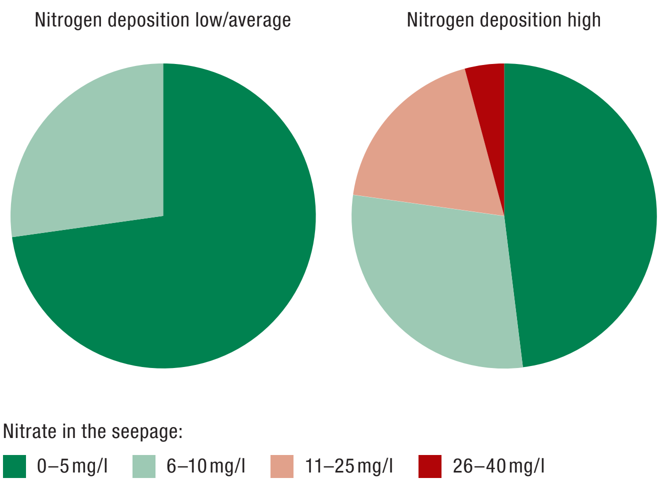


Fig. 5.1.1 *Mean annual nitrate concentrations in seepage from forest areas with low to average nitrogen deposition from the atmosphere (<20 kg/ha/year) and from forest areas with high nitrogen deposition (<20 kg/ha/year).*
Sources: FOEN/Meteotest; LWF, WSL; IAP

5.2 Protection against natural hazards

Markus Huber, Peter Brang, Arthur Sandri

> *According to the National Forest Inventory, 42 per cent of the forests in Switzerland provide protection against natural hazards. In mountainous regions, the proportion is considerably higher.*
> *A forest can reduce several hazards at the same time. The majority of protection forests avert natural hazards that involve flowing water.*
> *The silvicultural treatment of a protection forest ensures it is effective. This is why around half of the protection forests in Switzerland were treated between 1993 and 2013.*
> *During the same period the protection forest has become denser, and the proportion of pure conifer forest has dropped. This has improved the protective effect.*
> *Lack of natural regeneration and increasing wild ungulate browsing of important tree species threaten the long-term effectiveness of the protection forest.*

Protection forest

Avalanches, rockfall, debris flow, landslides and floods are natural hazards for people and their infrastructure. In Switzerland, 26 per cent of the railway network and 24 per cent of the first- and second-class roads, for example, are threatened by natural hazards (Losey und Wehrli 2013). In mountainous regions, the proportion of infrastructure at risk is often much larger. A forest can help to reduce the risk of damage from natural hazards so long as it has a particular composition.

Fig. 5.2.1 *Protection forest near Adelboden (BE). The protective effect of the forest was reinforced with steel-snow bridges (top right) and steel nets (bottom left). Photo: Peter Brang*

This is why the protection forest is an important element in integral risk management to provide protection against natural hazards. The protection forest can be supplemented with technical measures, such as avalanche barriers. It is inexpensive, and protects large areas often against several hazards at the same time. Technical measures, on the other hand, are expensive and are therefore used in unforested areas or in places where the protective effect of the forest is insufficient (Fig. 5.2.1).

The cantons designate, as part of their forest planning, which forests are protection forests according to objective criteria developed by the federal government together with the cantons (Losey und Wehrli 2013). The cantons are responsible for managing their protection forests, but receive support from the federal government set out in programme agreements.

The following information about protection forests is based, unless otherwise specified, on the National Forest Inventory NFI surveys (Brändli et al. 2015).

Natural hazard processes

The Swiss forest provides protection against natural hazards on 42 per cent of its area according to the NFI 2009/13 (section 1.1), with the most protection forests in the Alps and on the Southern slopes of the Alps (Fig. 5.2.2). Much of the protection forest – namely 85 per cent of the area – diverts so-called ‘channel processes’. These include all processes that take place in connection with flowing water (channels), such as debris flows, overbank sedimentations and bank erosion. The trees help to prevent them by stabilising the soil with their roots. As a result, when a land-slide, hillslope debris

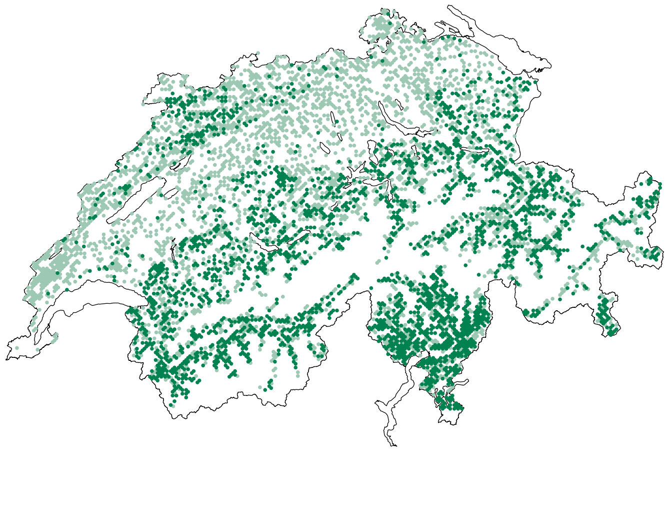


Fig. 5.2.2 *Distribution of protection forest and other forest. Source: NFI 2009/13*

flow, avalanche or rockfall occurs, less material reaches the channel. Thus less of the material that can lead to sediment deposits forming downstream is released if there is flooding.

The forest does not only provide protection against natural hazards involving flowing water. 24 per cent of the area of protection forest keeps people, buildings and facilities safe from hillslope debris flows and landslides. This flowing or sliding of soil material down a slope may be fast or slow. It is triggered by heavy precipitation, long periods of rain or intensive melting of snow. Avalanche protection forests make up 19 per cent of the protection forest area. They prevent the build up of an unstable snow pack, thereby reducing the risk of snow movements that could lead to an avalanche forming. 8 per cent of the protection forest provides protection against falling rocks and boulders as the tree roots stabilise the ground and thus prevent rockfall occurring. Furthermore, contact with trees can break the fall of tumbling and rolling stones, or even bring them to a standstill. If all the sections of protection forest are added together, the result is over 100 per cent because about a quarter of the protection forest area is effective against several natural hazard processes at the same time.

Managing protection forests

The effectiveness of a protection forest can only be maintained permanently if it is regularly tended, as stand structures form during the natural development of a forest that over decades do not provide sufficient protection, particularly during the forest's early and late development phases. Silvicultural treatments help to prevent the occurrence of such phases so that the forest can have a long-lasting protective function. For example, cutting out gaps promotes the occurrence and development of natural regeneration, and felling individual trees gives their neighbours more room, enabling them to develop better and thus become more stable. Such interventions are the tasks of the forest owners. The Forest Act specifies that at least some management of the protection forest is mandatory. The owner is then reimbursed by the federal government, the cantons and other beneficiaries (including the municipalities and infrastructure operators). Stakeholders can find information on this in the guidelines on "Sustainability and monitoring in protection forests", which set standards for minimum tending according to standardised criteria (Frehner et al. 2005).

Since 1995 1.9 million cubic metres of timber have been removed from Swiss protection forests each year. This corresponds to 26 per cent of the annual harvest yield. Between 1993 and 2013 nearly half of the protection forests were treated (Table 5.2.1). The favourable climate of the Swiss Plateau, the Jura and the Pre-Alps means that the forest there develops faster than in the Alps, and silvicultural treatments are performed at shorter intervals. On the Southern slopes of the Alps, the intervals between treatments are much longer than in the other regions. The reasons for this difference are that the proportions of broadleaf and coppice forests are greater, and the terrain is very steep (90 % of the slopes have an inclination of over 40 %). Moreover, the access network is much less dense. Timber from more than half of the sites is transported by helicopter, which is, in comparison with other forms of haulage, relatively expensive. In the Alps, the amount of steep terrain is proportionally roughly the same, but access to the protection forest via forest roads is better. On almost half the areas there, timber can be hauled with cable cranes, on around 21 per cent with forestry tractors and on about 29 per cent by helicopter.

Table 5.2.1

Proportion of protection forest areas in per cent according to the time of the last intervention. Source: NFI 2009/13

Production region	Time of last interventions		
	Up to 20 years ago	21–40 years ago	More than 40 years ago
Jura	70	14	15
Swiss Plateau	74	16	10
Pre-Alps	68	16	15
Alps	44	22	34
Southern slopes of the Alps	17	14	68
Switzerland	**46**	**18**	**35**

Tree species mixture and stand density

For the protective effect to be long-lasting, the tree composition must be suitable for the site as this reduces the risk that the protective effect will be diminished as a consequence of, e.g windthrow or an infestation of bark beetles. Around 47 per cent of the protection forests are pure conifer forests and about 25 per cent pure broadleaf forests, with the rest mixed. Pure conifer forests grow mostly in the upper montane and subalpine vegetation belts, while broadleaf forests occur mostly at lower altitudes (section 1.1). The proportion of pure conifer forests fell between 1995 and 2013 by 2 per cent, whereas that of mixed and broadleaf forests rose. At lower altitudes, conifers, which used to be planted and are not well adapted to the local site conditions, are today increasingly being replaced by broadleaf trees, which are better suited (section 4.3).

To provide protection against rockfall, the density of a stand is crucial because only in sufficiently dense stands will frequent contact with the trees break the fall of descending stones and eventually bring them to a standstill. Experts measure the density of a stand on the basis of the so-called 'basal area'. If this is at least 25 square metres per hectare (m^2/ha), the protective effect of a forest is sufficient (Volkwein et al. 2011). Between 1995 and 2013, the proportion of protection forests that had at least this density increased by 5 per cent to 64 per cent. Today 19 per cent of the protection forests with a basal area of under 15 m^2/ha are still insufficiently stocked. A further 17 per cent of the protection forest areas have a basal area of between 15 and 25 m^2/ha, so that their protective effect is at a critical level.

For protection against avalanches, hillslope debris flows and landslides to be optimal, the ground must be covered with living trees with as few gaps as possible. In the NFI, the degree of cover is determined with the help of aerial photos. This involves measuring how much of the forest area has canopy cover. Experts call this proportion the degree of canopy cover. In a protection forest it should amount to at least 40 per cent (Frehner et al. 2005). This requirement is met by most of the protection forests, and on 48 per cent of the protection forest area the degree of cover is even twice as high. Only on 6 per cent of the protection forest is this minimum value not reached.

Risks for the protection forest

Disturbances like windthrow, snow break and bark beetle infestations are part and parcel of the forest ecosystem. They may, however, endanger the protective effect of a forest by causing extensive tree mortality or even ripping large holes in the protection forest. The protective effect of the stands affected is therefore reduced or may even be lost altogether.

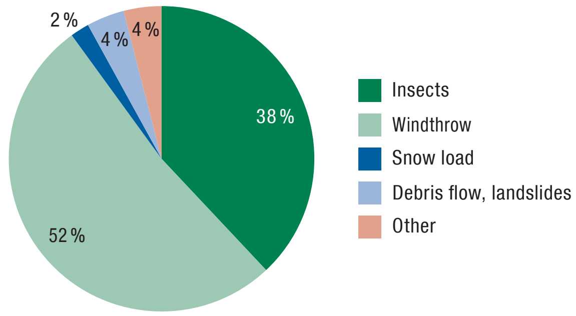


Fig. 5.2.3 *Main reasons for salvage logging between 1995 and 2006. Source: NFI 2004/06*

Protection forests should, therefore, be as resistant to disturbances as possible. According to NFI 2009/13, the protection forest has become more stable since 1995. The proportion of the forest area with critical or diminished stability has sunk by 4 per cent and today is 53 per cent.

Since 1995, disturbances have resulted in an average of 509,000 cubic metres of timber per year having to be cut without prior planning. This so-called 'salvage logging' corresponds to around a quarter of the total annual use. Such disturbances occur, however, irregularly and with differing magnitudes. The amount of salvage logging during the period from 1995 to 2006 was exceptionally high, particularly as a consequence of the storm 'Lothar', which created large areas of windthrow (Fig. 5.2.3). The Jura, Swiss Plateau and Pre-Alps were especially badly affected. Between 2006 and 2013 the amount of salvage logging was less, and roughly half of it was due to insect pests like the bark beetle.

Forest regeneration is a prerequisite if the forest is to have a long-lasting protective effect. It ensures that the next tree generation can perform the function of the trees that today provide protection after these older trees die. If young trees grow on less than 10 per cent of the stand area in a protection forest, the regeneration is considered to be critical or even insufficient (Brang and Duc 2002). The regeneration situation in protection forests deteriorated between 1995 and 2013, as the proportion of the protection forest area with critical to insufficient regeneration rose from 36 to 41 per cent.

The composition of tree species is also important for regeneration, as only tree species adapted to the site can ensure that the stands are stable in the long term. Wild ungulates can influence the tree species composition because the animals prefer to browse on certain species like silver fir, maple and rowan and thus affect their growth. Silver fir is particularly sensitive as a browsing intensity of 9 per cent is already critical (section 4.2, Eiberle und Nigg 1987). If this value is far exceeded, the silver fir saplings cannot usually grow to maturity and will therefore not reach the upper layer. Since 1995, the browsing intensity on silver fir has increased from 14 to over 20 per cent. Protection measures like fences or individual plant protection (section 4.2) are expensive or even infeasible in protection forests because of the steep terrain and deep snow. The recruitment of silver fir is therefore severely endangered. This tree species is, however, particularly important in protection forests for the development of stable stands. It can regenerate in shade and its roots penetrate deep into the ground, thereby contributing to the layered structure of the forest and to stabilising and draining the ground.

Altogether, the protection forest has developed in different ways over the past few years: while the tree species composition and the forest structure have improved, the regeneration situation has deteriorated. The regeneration is often too sparse and the occurrence of ecologically important tree species is threatened by browsing ungulates. To ensure an adequate protective effect in the long term, great efforts will need to be made in the coming decades to manage the protection forest and ungulate populations appropriately.

6 Social Economy

Oliver Thees, Silvio Schmid

The criterion 'social economy' describes how forestry and the wood industries relate to society. The emphasis here is on the economic and social aspects of sustainable forest management. Since the last Forest Report in 2005, the importance of these aspects and the complex relationships between them have noticeably increased – for example, the way the general public influences forest management. Conflicts over how to use the forest are increasingly the cause and the result. The forest service of wood production and other services such as protection and recreation are increasingly being viewed as related to each other, with wood production re-gaining importance. This development is caused, among other things, by both the energy transition and the generally difficult economic situation of the owners and partners in Swiss forestry.

Summary

The effects and services of forestry and the wood industries are declared in the national accounts (NA). They are mainly related to the production and use of wood as a sustainable raw material. The NA do not, however, take other services involving the forest as a whole into consideration. These include, in particular, services for the general public, such as protection against natural hazards and recreational opportunities.

For the individual forest owners, the forest and its wood are part of their assets. Additionally, forestry and the wood industries provide employment and an income for thousands of people, in particular in rural areas. Two-thirds of the Swiss forest is managed by public forest owners, such as municipalities, local citizens' communities, corporations and co-operatives. Forest work itself is physically demanding and dangerous. Thanks to modern wood-harvesting machines, such as harvesters, the work can now be completed at lower cost and more safely than was possible a decade ago. Nevertheless, commercial exploitation of Swiss forests remains expensive. The most important reasons for this are the fragmentation of the management structures, the difficult terrain in mountain forests and the requirement to provide substantial protection and recreational services. The costs associated with commercial use cannot usually be covered by the income from the wood. Certain services in the public interest are paid for by the Swiss government and the cantons. These include, in particular, protection against natural hazards and the conservation and promotion of biodiversity.

The demand for wood as a sustainable raw material is increasing. It is not only used as a basic material – for example, as timber for construction purposes and for furniture – but also as a source of energy in the production of heat and electricity and, possibly, in the future as a transportation fuel. The use of wood as a source of energy has increased in Switzerland since 2005 mainly due to energy supply systems switching to renewable sources. Timber and wood products are also traded. If the amount of wood used in these products is added up, then almost the same amount is imported as is exported. However, the monetary value of the imports is much greater than that of the exports.

The forest is valued highly as a recreational area. This can lead to conflicts, particularly over forests in agglomeration areas, among those looking for recreation opportunities, as well as between recreation-seekers and the forest managers. The forest is also closely connected to the cultural heritage. Tangible and intangible traces of how it is used create cultural identity and continuity. Forest-related education provides information about the ecosystem and its use, as well as about the relationship between humans and the forest. In the forest classroom, young people can get first-hand experience of forest habitats.

6.1 Forest owners

Matthias Kläy

> *Ownership and management of the forest in Switzerland is very fragmented.*
> *Around 70 per cent of the Swiss forest is publicly owned, while 30 per cent is in private hands.*
> *There are approximately 240,000 private forest owners. Each of them owns, on average, about 1.4 hectares of forest, covering an area approximately the size of two football fields.*
> *The number of forest owners and the types of ownership have hardly changed since 2005.*
> *The extensive fragmentation of the Swiss forest makes managing it laborious and costly. Through increased co-operation and improved management methods, however, it can be made more cost-effective and efficient.*

Forest owners

Unlike the forest in many other countries, the Swiss forest is legally accessible to everyone. Many people therefore forget that every patch of forest belongs to someone. Indeed, the forest has many owners, with around 250,000 in total sharing the Swiss forest. Most of the forest owners – 97 per cent to be precise – are private individuals. The majority own only a small patch of forest much less than 50 hectares in area, with an average size of only 1.42 hectares. The publicly owned forest is much less fragmented. Approximately 3,300 public forest owners manage 70 per cent of the entire forest area and are responsible for 64 per cent of all wood used. However, there are large regional differences. In Canton Lucerne, 70 per cent of the forest is in private hands, whereas in Canton Valais it is only 9 per cent.

In Switzerland, most of the public forest areas belong to the local governments: 40 per cent to the municipalities and 31 per cent to the local citizens' communities. A further 11 per cent is owned by corporations and co-operatives, and a total of 7 per cent belongs to the federal state and the cantons (Fig. 6.1.1). Forest ownership has a tradition, and the number of forest owners and the types of ownership has hardly changed in recent years. Since a large part of the Swiss forest is publicly owned, many people think that it is not managed for profit, but rather for the public good. But this can only be true for those forest owners who charge and collect taxes, i.e. the federal government, cantons and local municipalities, who together only own about 50 per cent of the public sector forest. This means that a large part of the forest is managed according to economic market criteria, whereby the owners have to be able to cover their costs.

Management

The Swiss forest is managed by public forest enterprises, specialised forestry service entrepreneurs and private forest owners. However, some owners do not use their forests and leave them to develop naturally. The forest enterprises manage about 70 per cent of the forest area in Switzerland and are supported by forestry service entrepreneurs. The extreme fragmentation of the Swiss forest is not only reflected in the forest ownership, but also in the forest enterprises. More than half of the enterprises manage together less than 10 per cent

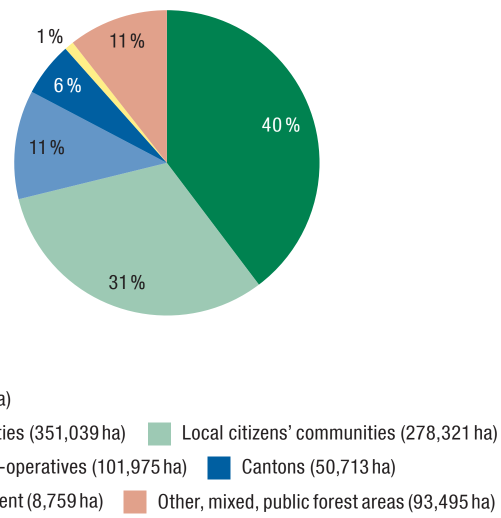


Fig. 6.1.1 *Public forest areas in Switzerland in hectares and percentages according to owner type. Source: FSO and FOEN 2012*

Table 6.1.1

Number of forest enterprises according to size (excluding private forest enterprises <50 ha) for the period 2004–2012. Source: FSO and FOEN 2013

Size of the forest enterprises	2004	2005	2006	2007	2008	2009	2010	2011	2012	Change 2004 to 2012
<50 ha	1,236	1,201	1,178	1,101	1,026	999	980	937	912	**–324**
51–100 ha	464	455	446	436	412	399	389	371	370	**–94**
101–200 ha	435	426	421	412	406	383	381	352	355	**–80**
201–500 ha	467	454	444	442	435	423	419	374	368	**–99**
501–1,000 ha	262	264	267	261	252	251	247	242	242	**–20**
1,001–5,000 ha	174	174	175	178	190	188	192	192	193	**19**
>5,000 ha	2	2	2	3	4	5	5	7	7	**5**
Total	**3,040**	**2,976**	**2,933**	**2,833**	**2,725**	**2,648**	**2,613**	**2,475**	**2,447**	**–593**
Development in absolute numbers		**–64**	**–43**	**–100**	**–108**	**–77**	**–35**	**–138**	**–28**	
Development as a percentage		**–2.1**	**–1.4**	**–3.4**	**–3.8**	**–2.8**	**–1.3**	**–5.3**	**–1.1**	**–19.5**

of the productive forest area, while a few large enterprises manage extensive parts of it (Fig. 6.1.2).

The economic pressure on forest enterprises has increased in the past few years, partly because the world trading prices for wood have fallen while at the same time the pressure on public administrations to save has risen. The deterioration of the economic situation has meant that economically viable management has become more important and there is a greater need for efficient working methods. Since 2004, many forest owners have therefore joined forces and formed larger management units or enterprises. A glance at the development in the number of forest enterprises shows that this has decreased by about 20 per cent since 2004 (Table 6.1.1). The largest decline is in the number of small forest enterprises of up to 50 hectares, while the number of large enterprises with a size of 1,000 hectares and more has increased slightly. Specialized forestry service entrepreneurs serve as important partners in the use of the forests. They work under contract to forest enterprises, felling the wood and performing other forest tasks. Their modern equipment and methods and their specialist knowledge help to make forest management more efficient and economically viable. Co-operation between forest owners and external management enterprises is the key to improving forestry's economic performance.

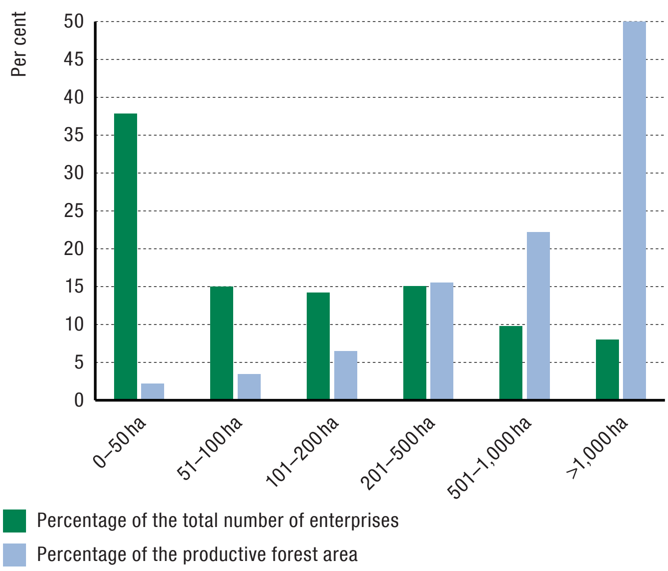


Fig. 6.1.2 *Distribution of the forest enterprises according to their size and their proportion of the forest area in 2011. Source: FSO and FOEN 2012*

6.2 Economic importance of forestry and the wood industries

Roland Olschewski

> *Forestry and the wood industries account for slightly less than 1 per cent of Switzerland's economic output. Most of that income is generated in the wood industry.*
> *In addition to wood production, the forest also provides unremunerated ecosystem services. Thus the economic significance of forestry is greater than that shown in the national accounts.*
> *In comparison to the figures in the Forest Report 2005, the gross value added of the paper industry has fallen, while there has been a nominal increase for forestry and for wood-handling and -processing.*

Value added

Forestry and the wood industries include numerous private and public enterprises in various areas of production. Forestry includes public forest enterprises, private forest owners, forestry service entrepreneurs and forest tree nurseries. The wood industries are divided up into enterprises that use wood directly and those that use it to produce other goods and the cellulose, paper and cardboard industry. What all these enterprises have in common is that their production is based, either directly or indirectly, on wood. Figure 6.2.1 provides a summary of the forestry and wood-industry production processes.

The national accounts (NA) help to calculate and show how much forestry and the wood industries contribute to the Swiss economy (Table 6.2.1). Gross output refers to the total value of all goods and services produced in one year. The gross value added (GVA) is calculated by subtracting the cost of all prior services, i.e. of the goods and services used, processed or converted in the production process, from the gross output. In 2011, forestry and the wood industries had a GVA of just under 1 per cent of the total Swiss GVA. Two-thirds of this was generated in the wood industries, one quarter in the paper and cardboard industry and almost a twelfth through forestry. Figure 6.2.2 shows how the GVA has developed in various production areas. The GVA (not inflation-adjusted) of forestry has risen by about 50 per cent since 2001 – from approximately 250 to almost 400 million Swiss francs. During the same time, the wood industries experienced an increase of about 30 per cent, while the output of the cellulose, paper and cardboard industry sank by about 15 per cent. This drop was caused, amongst other things, by the closure of renowned paper and cellulose factories in Switzerland. Additionally, the dampening effect of the international economic crisis after 2008 can be seen in all production areas.

Forestry

The nominal value-added increase in forestry since 2001 is mainly a result of a 'catch-up effect' because the current value-added level was also reached before the windstorm 'Lothar'. The extent of forest damage caused by the hurricane meant that a great deal of wood had to be used all at once. This led to a dramatic drop in prices and thus to a decrease in the value added. It was not until the following years that both the prices and the quantity of wood used increased again. If the GVA of the last ten years is calculated taking the prices from 2000 as constant, then it has an annual average value of 220 million Swiss francs, with a slight downward trend from 2008 onwards. These figures indicate that forestry's contribution to Switzerland's economic output remains at a low level and the economic situation of the forest enterprises

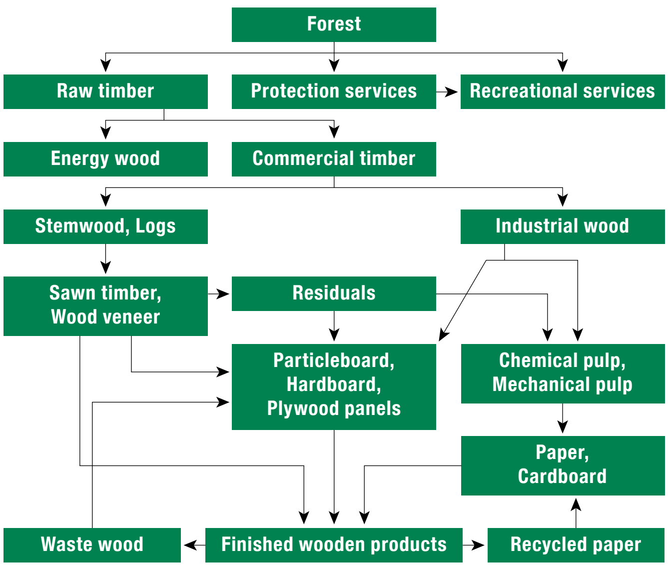


Fig. 6.2.1 *Production processes in forestry and the wood industries. Source: illustration based on Bergen et al. 2013*

Table 6.2.1

Economic performance of forestry and the wood industries in 2011 in million Swiss francs and as a percentage of the total Swiss gross value added. Source: FOEN 2013a

	Forestry		Wood industries		Paper / Cardboard / Pulp		Swiss total
	Million CHF	%	Million CHF	%	Million CHF	%	Million CHF
Gross production value	872	**0.07**	8,494	**0.73**	3,874	**0.33**	1,167,377
Prior services	509	**0.08**	5,177	**0.84**	2,588	**0.42**	614,172
Gross value added	363	**0.06**	3,317	**0.57**	1,287	**0.22**	585,102

is still difficult (section 6.3). However, the national accounts (NA) only consider the marketed goods and services, and do not reflect the level of the forest's real economic importance. Thus, in addition to raw wood production, the forest also provides numerous services such as climate, biodiversity and soil protection, as well as recreational opportunities and protection against avalanches (Fig. 6.2.3; section 1.1). These services are often public goods and are much more of a benefit to the general public than they are to the individual forest owner (cf. Box 1; Fig. 6.2.4). They are also called 'ecosystem services', a term from the 'ecosystem approach' used in the Millennium Ecosystem Assessment (MEA 2005). The MEA report distinguishes between the supporting, provisioning, regulating and cultural services of ecosystems. This classification requires thinking in economic categories, facilitates an economic evaluation and enables a better classification into sectors (Bergen et al. 2013).

An important step in this direction was made in 2008, when the National Fiscal Equalisation (NFE) and the division of tasks between the federal government and the cantons were introduced. The aims of the NFE include using tax money more efficiently for the environment, removing misguided incentives and giving the cantons more room to manoeuvre. It emphasises the services that must be provided (FOEN 2011b; section 6.4). Between 2008 and 2012, this reform led to, on average, about 225 million Swiss francs of public money being spent per year on services in the four areas: forest protection, protection structures and hazard mapping, biodiversity and forestry. This figure only partially reflects the economic value of the forest. A more exact calculation would require a comprehensive economic evaluation taking into account the value of public goods within the framework of an environmental accounting system. This calculation could show that forestry has a much higher value added than has so far been evaluated statistically. Compensating for environmental services and taking them into account in the production process can significantly contribute to an efficient and sustainable use of resources.

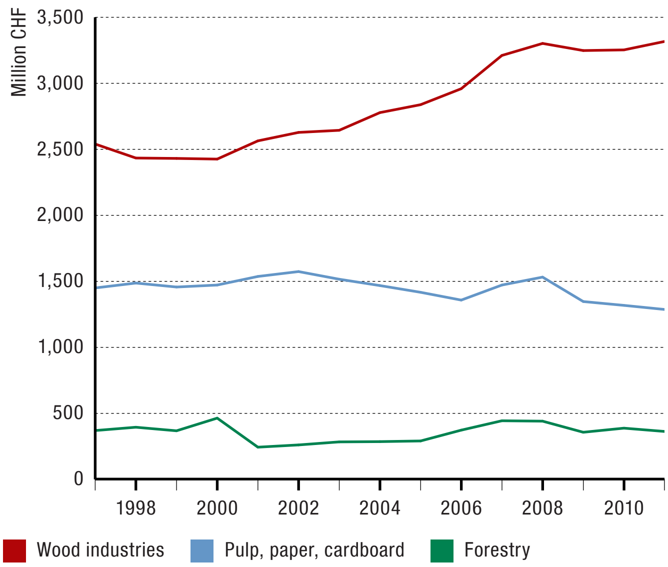


Fig. 6.2.2 *Development of the nominal gross value added in million Swiss francs. Source: FOEN 2013a*

Box 1: Forest and climate protection

When forests grow, they remove CO_2 from the atmosphere since half of the dry biomass produced consists of pure carbon (section 1.4). From an economic point of view, this carbon sequestration in forests is a public good, as reducing the CO_2 concentration in the atmosphere counteracts climate change. It is difficult to market this good of 'forest climate protection' because nobody can be excluded from this good and there is no competition for its use.

Within the framework of the international Kyoto Protocol, several industrial nations decided to use their forest's contribution to climate protection as part of their national CO_2 balance. This means that they can reduce some of their CO_2 emissions through building up carbon stocks in their forests, and thus fulfil their international commitments (section 1.4). However, forest owners have not yet been compensated for this contribution to climate protection. The contribution is therefore not included in the national accounts (Bergen et al. 2013).

Table 6.2.2

Amount of timber used in cubic metres (solid volume) and the wood value added in million Swiss francs and in per cent for the various types of production in 2010. Source: FOEN 2013b

Types of production	Material use				Use as energy source				Total		
	Million m^3	%	Million CHF	%	Million m^3	%	Million CHF	%	Million m^3	Million CHF	%
Extracted as raw material, or recycled	5.3	**54**	250	**71**	4.6	**46**	100	**29**	9.9	350	**6**
Used in 1st and 2nd processing stages	2.8	**72**	850	**94**	1.1	**28**	50	**6**	3.9	900	**15**
End use of wood	4.4	**52**	4,170	**87**	4.1	**48**	610	**13**	8.5	4,780	**79**

Value added of wood according to processing stage

The way in which wood is used can be divided up into various processing types (FOEN 2013a). Table 6.2.2 shows the amount of wood used in each type of processing and the resulting value added for the whole of Switzerland. Cluster analyses can be performed to identify regional value-added chains (cf. Box 2). Only about 6 per cent of wood's total value added comes from extracting raw materials and recycling. About 70 per cent of the value added comes from using stemwood, industrial wood and recycled paper as materials, and about 30 per cent from using them for energy. Around 15 per cent of the wood's value added comes from the first- and second-stage processing. The material use of wood accounts for the largest proportion, with 94 per cent of the value added coming from, for example, sawn timber or plywood and from hardboard and chipboard (first-stage processing), or as windows and parquet flooring (second-stage processing). The value added of wood used as an end product is largest, amounting to 79 per cent of the total. This includes using the timber for the construction industry and the production of furniture, paper and cardboard. The material use of wood makes up the largest proportion, while the use of wood as energy, which involves almost entirely wood for heating, contributes little to the value added. The figures in Table 6.2.2 show that the value added on producing other goods increases the higher the stage of processing, but falls on using the wood for energy. This effect becomes particularly clear when wood is used as an end product. Almost half of the wood is used for producing energy, but this contributes only 13 per cent to the value added. In comparison, using wood as a material contributes 87 per cent

Box 2: Regional importance of forestry and the wood industries

The economic importance of closely connected areas of production can be investigated through regional 'cluster analyses'. These analyses reveal, for example, the wood's value-added chain, which goes from obtaining the raw material from the forest owners, to processing it in the sawmill, and to carpenters or joiners producing windows or furniture. The analyses help in identifying competitive production areas and regional potential for development (Lehner et al. 2014).

In Switzerland, the economic importance of these regional clusters varies, and is, in some cantons, considerably above the national average. These economically successful clusters have often gone through a historical development, and their ability to compete is based on many factors specific to the region. Only to a certain extent is it possible to derive general recommendations from them for supporting forestry and the wood industries in other regions in a targeted and long-term way.

Fig. 6.2.3 *Forests provide not only timber production but also opportunities for sport activities. Photo: Manuela Di Giulio*

to the value added. This use of energy wood means that a relatively large amount of wood is used for a comparatively small value added. The so-called 'cascade use' promises a more efficient exploitation. In this process, wood is first used to produce other goods, which are then used to produce energy when the products have come to the end of their life cycle.

Fig. 6.2.4 *This autumn forest is an inviting place for recreation as well as an important carbon sink. Photo: Hanne Gössi, FVA*

6.3 Economic situation of forest enterprises

Matthias Kläy

> *The economic situation of Switzerland's forest enterprises remains difficult: they have been working with an annual deficit since the 1990s.*

> *The conditions on the international market are not favourable for Swiss forestry and the wood industries. Forest management costs cannot be reduced to the extent required to compensate for falling revenues from selling wood.*

> *Forestry and the wood industries both need better market conditions and further measures for reducing costs and developing new sources of income.*

Sources of income and costs of forest enterprises

Since the 1990s, the expenditures of most of the Swiss forest enterprises have been greater than their incomes. On average, they are thus making a deficit, despite subsidies from the public authorities (Fig. 6.3.1). In 2012 alone, the declared deficit was 58 million Swiss francs. Results from Switzerland's forest accountancy network (Testbetriebsnetz der Schweiz – TBN) show that the uncovered management costs of using 1 cubic metre (m^3) of wood amount to 77 Swiss francs. An important reason for this is that the European market conditions are unfavourable for the Swiss wood industries: the margins and revenues have come under pressure (section 3.2). Semi-finished and finished goods can be produced abroad at a lower cost and can, as a result of the strong Swiss franc, be imported more cheaply. This means that Switzerland's forestry and wood industries can barely take advantage of the current boom in constructing buildings made of wood.

To some extent, pricing pressure is passed on to the forest owners, whose greatest source of income is revenue from selling wood. One of the biggest items of expenditure for forest enterprises is covering the cost of wages. Wood revenues and wages have developed in opposite directions since the 1960s, i.e. while the wood prices have fallen considerably in recent decades, wages have been rising (Fig. 6.3.2). Swiss forest enterprises have been able to reduce their forest management costs, but cannot keep step with the fall in revenues from the

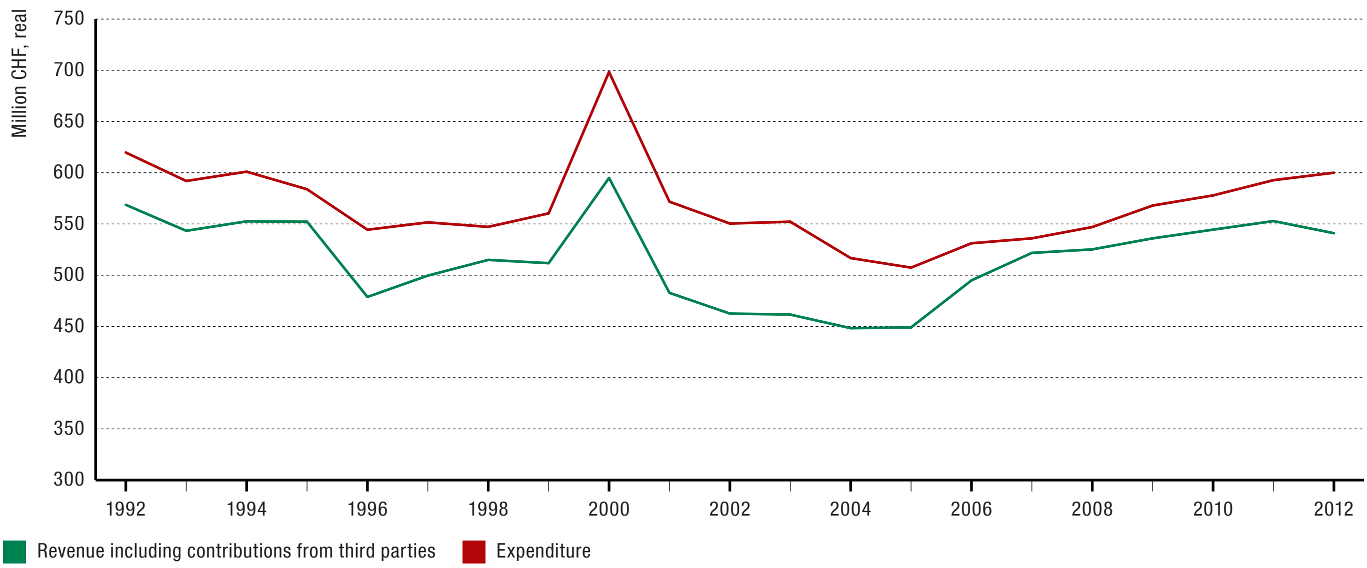


Fig. 6.3.1 *Development of the revenue and expenditure of Swiss forest enterprises (total operation) in million Swiss francs between 1992 and 2012. Source: FSO and FOEN 2013*

sale of wood. This is largely due to the strong fragmentation of both the ownership and the management of the forests (section 6.1), the effort involved in maintaining protection forests and the high standards of services for social wellbeing (e.g. forests as recreational areas).

Forestry

Forestry's services to foster public wellbeing (in particular for recreation, forest biodiversity, drinking water and CO_2 reduction) are currently not sufficiently economically valued and reimbursed. Improved framework conditions are needed in this area (section 6.2). However, increased efforts on the part of the forest owners and their forest enterprises are also necessary to make forest management more efficient. The future currently may seem bright for wood as a renewable resource for not only construction and energy but also as a raw material for numerous other applications, in particular for the textile and chemical industries. Nevertheless, it is unlikely that wood prices will reach the level of the (golden) pre-1990s era in the near future. The market conditions for Switzerland's forestry and wood industries are therefore likely to remain difficult for the next few years. The following measures could, however, improve the economic situation in forestry:

> The forest enterprises need a clear strategic orientation. This requires a detailed investigation of the economic parameters. The focus should be placed on the core products, and only diversified once the demand and willingness to pay have been established.
> The number of employees and machines should be aligned with the core task of forest management. The most efficient methods should therefore be used to harvest the wood and maintain the forest.
> There should be more co-operation among the owners and with specialised forestry service entrepreneurs.
> Forest access must be optimised and new policies for managing access must be developed and implemented.
> The services related to general wellbeing must be evaluated in monetary terms.

The federal Forest Policy 2020 (FOEN 2013c) contains several measures that should support the forest owners in their efforts to improve the forests' economic viability. For example, both the federal government and the cantons have agreed on programmes that promote collaboration between forest owners.

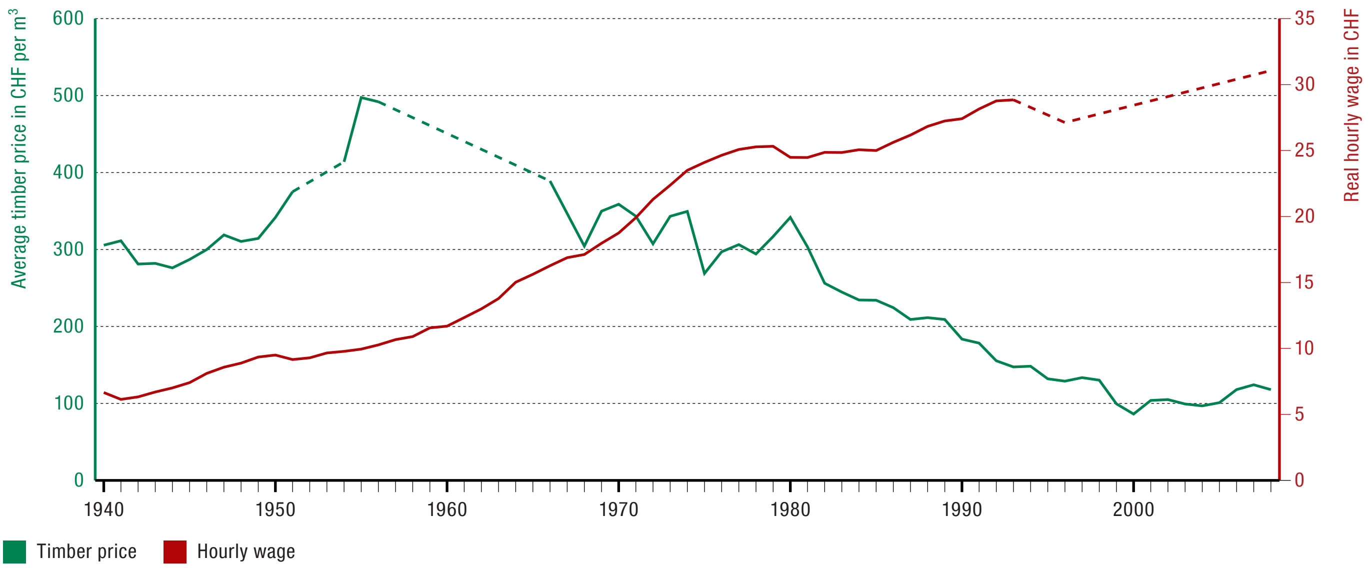


Fig. 6.3.2 *The development of the real timber prices for long spruce and silver fir logs (in CHF per m³) and the real wage costs (in CHF per gross hourly wage) in Swiss forestry from 1940 to 2008 (some data interpolated – dotted line).*
Source: based on Nellen 2011 and Hess 2011

6.4 Federal support for forestry

Willi Zimmermann

> *Swiss forestry has been supported since a national forest policy was first initiated.*
> *Subsidies have continually increased since the beginning of the 1980s. They reached a peak in the years 1999 and 2000 with an annual sum of about 270 million Swiss francs.*
> *Since the National Fiscal Equalisation (NFE) was implemented in 2008, federal contributions have been reduced to measures carried out in six categories, and the total sum has stabilised at about 135 million Swiss francs per year.*
> *According to the Forest Policy 2020, the annual contributions should be raised by 20 to 30 per cent to account for the new aspects 'adaptation to climate change' and 'protection against harmful organisms'.*
> *As a result of the National Fiscal Equalisation (NFE), changes since the Forest Report 2005 have primarily been made in the processes and not in the content of subsidy measures.*

The development of the forest support policy

Switzerland's forest policy is federally organised. It focuses on maintaining both the existing forest areas and the forest quality, and consists of various instruments. The elements are based on those implemented at the beginning of the Swiss forest policy towards the end of the 19th century and are thus not new. The Federal Constitution and the former Forest Police Law enabled the federal government to enact legislation with requirements and prohibitions enforcing the maintenance or restoration of the forest and to provide financial support. The Forest Act, which came into force in 1993, adopted most of these policies; for example, central points of the current federal forest policy are still the prohibition of forest clearances and clear-cutting, and support for various forest measures. Unlike this type of legislation on maintaining the forest, the support policies have been continually refined (Fig. 6.4.1).

When the national forest policy was first implemented, the federal government mainly supported afforestation and building structures, as well as the construction and acquisition of forest infrastructure and equipment in mountain forests (e.g. forest roads or cable cranes). The support policy was first extended in the 1940s, when the parliament supplemented the Forest Police Law of the time so that the federal government and the cantons could also subsidise the consolidation of forests and co-operative forest management. A real paradigm change followed in the middle of the 1980s. The Swiss parliament then decided that, in the future, not only the infrastructure but also the management of mountain forests should be supported by government subsidies. The discussion about the forests dying (Waldsterben) led the parliament to adopt two fixed-term federal resolutions that provided subsidies from both the federal government and the cantons for managing the forest. These two resolutions laid the cornerstone for financial support for forest management in all forests throughout Switzerland. The state subsidies were increased in terms of both the amount of financial support given and the number of measures (Fig. 6.4.1). At times, there were more than 20 measures, reaching a peak in 1990 and 2000 with subsidies of about 270 million Swiss francs in each of those years (FOEN 2009a).

The current forest support policy

The 1993 Forest Act remains the central legislative basis for the current forest policy. Various amendments have been made to it, but it has never been fundamentally changed. The greatest changes in the federal support legislation happened with the modification of the National Fiscal Equalisation (NFE) and the division of tasks between the federal government and the cantons. These changes merged several measures into larger subsidy categories and, for most of the categories, introduced longer-term programme agreements between the federal government and the cantons. The federal government and the cantons now mainly provide comprehensive subsidies that favour the categories listed in Fig. 6.4.2. Altogether the federal government provides on average about 135 million Swiss francs of financial support to Swiss forestry annually. About 30 per cent of these subsidies are not, however, for the forest management measures themselves but for the provision and maintenance of protection structures against natural hazards. Together with

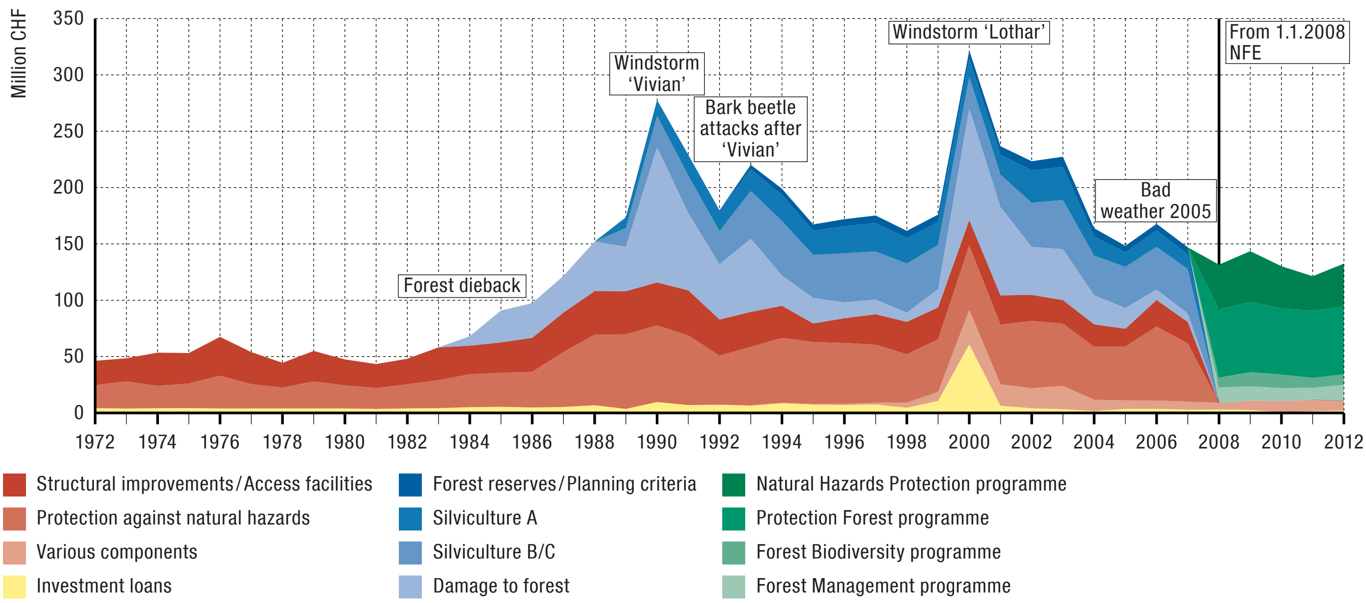


Fig. 6.4.1 *Federal contributions paid to forestry 1972–2012 in million Swiss francs. Source: FSO and FOEN 2013*

the contributions from the cantons, state subsidies for the forest probably amount to about 230 million Swiss francs. Most of the federal funding is directed at maintaining protection forests (46 per cent), followed by contributions to providing protection against natural hazards (30 per cent). Far less is spent on the programmes Forest Management (10 per cent), Forest Biodiversity (7 per cent) and other aspects (7 per cent). These include mainly financially supporting wood promotion, which, unlike the other categories, is not dependent on subsidies from the cantons. Generally the contributions from the cantons are as high as those from the federal government. However, the cantons vary greatly in the requirements they have for their forests and what kinds of forest they have. These differences mean that the cantons also vary greatly in how they distribute their contributions across the categories.

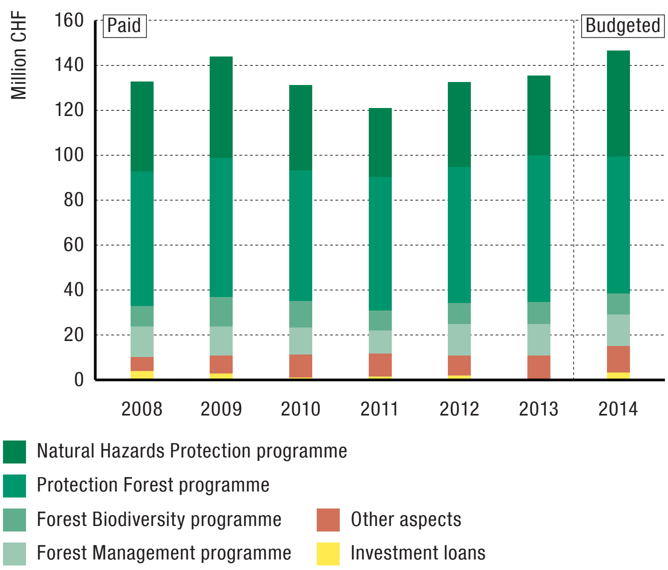


Fig. 6.4.2 *Federal government support for forestry since 2008 in million Swiss francs. Source: Zimmermann 2014*

The existing categories will remain basically unchanged at a federal level until 2020 in line with the Forest Policy 2020 approved by the Federal Council (FOEN 2013c). Existing federal subsidies for maintaining protection forests and young forests are to be increased to cater for the modifications necessary to cope with climate change. Furthermore, increased funding for promoting biodiversity in the forest and new subsidies for measures to deal with harmful organisms outside the protection forest are envisaged. From 2016 onwards, the federal government plans to annually increase its support for adapting to climate change by 20 million Swiss francs, and for preventing and combating biotic hazards by 2 million Swiss francs. As part of the action plan Biodiversity Switzerland, further subsidies should also become available for forest biodiversity. Subject to the political process and general cutbacks, it is conceivable that federal government support for the forest, and therefore indirectly the cantons' subsidies, will increase appreciably in the next few years. There are currently (July 2014) no plans for further measures such as more financing for the promotion of forest access schemes outside the protection forest or compensating for forest products and services that cannot compete on the market, such as the forest's use as a carbon sink or for water filtering (section 6.2).

6.5 Employees in forestry and the wood industries

Otto Raemy

> *Almost 7,000 people work in the forests in Switzerland.*

> *In 2011, more than 90,000 people worked in the wood industries, which, at the time, consisted of about 15,300 enterprises.*

> *The employment figures for 2005 and 2011 are not based on the same calculations and can therefore not be compared.*

> *The basic apprenticeship for working in forestry ends with the award of a Confederate Certificate of Competency as a qualified forest worker. Once completed, numerous other career paths are open. The academic path can be followed after completion of the high school diploma and is offered at the ETH Zurich (Swiss Federal Institute of Technology) or at the School of Agricultural, Forest and Food Sciences HAFL.*

> *The structural changes described in the Forest Report 2005 are still being implemented. As a result of these changes, the number of forest enterprises fell from 3,040 in 2004 to 2447 in 2012.*

Jobs in forestry and the wood industries

Almost 7,000 people work in the forest in Switzerland. The forest enterprises provide about two-thirds of the jobs. In 2011, there were 3,780 full-time jobs in forest enterprises and 1845 working for forestry service entrepreneurs (FSO 2013a). Major structural changes have taken place in Swiss forestry since 2000, which have led, among other things, to forest enterprises amalgamating. Their number was reduced by a total of 593 between 2004 and 2012, i.e. from 3,040 in 2004 to 2447 in 2012 (FSO 2013a).

In 2011, there were slightly more than 15,300 enterprises in the wood industry, employing more than 90,000 people. They are mainly small and medium-sized companies such as carpentry and cabinet-making enterprises and sawmills. On average, each enterprise has 6 employees. A structural re-alignment of the stemwood-processing industry (in particular

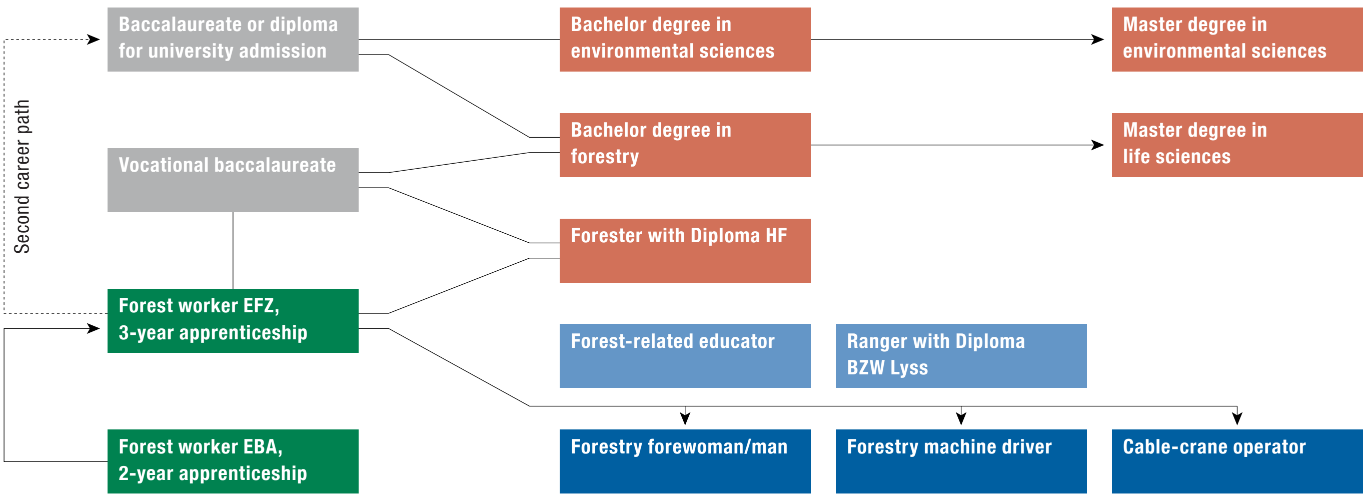


Fig. 6.5.1 *Summary of the vocational paths for jobs in forestry. * EBA: Swiss Vocational Certificate. Source: CODOC Co-ordination and Documentation for Forest Education*

sawmills) led to a reduction in the number of enterprises, and the number of sawmills fell from 494 in 2002 to 303 in 2012 (FSO 2013b).

Professions in the forest

Technical training in forestry generally begins with a 3-year apprenticeship as a forest worker with a Swiss Certificate of Competence (EFZ). The qualified forest workers perform the practical work in the forest. They can also complete the many courses that are offered as further training and thus qualify for specialised work in the forest (Fig. 6.5.1). For example, they can train to become forestry foremen or forewomen and organise the work in the forest. Professional colleges (Höhere Fachschule, HF) also provide further training. This training is offered at the forestry education centres in Maienfeld (Canton Grison) and Lyss (Canton Bern) and provides a qualification as 'Forester HF'. Foresters with a vocational baccalaureate (Berufsmatura) can train as forest engineers at HAFL. This study course is also open to those who have completed other professional training or have a federal baccalaureate (Matura) and have completed a specialized pre-study internship. The ETH Zurich has degrees for environmental scientists and offers Master degrees with a specialisation in forestry and landscape management.

Even today, very few women choose a job in the forest. In 2013, only two women completed the forestry apprenticeship. Of the total of 965 apprenticeship contracts signed at the end of 2013, only 9 were signed by women. At the universities, only 6 of the 32 students who completed an internship especially for forestry in 2012/2013 were women.

Although the number of jobs in forestry is declining, about 300 individuals complete the technical training as a forest worker EFZ each year (Fig. 6.5.2). On average, 30 more people complete courses leading to forester HF, and 15 people continue their training to become forestry forewomen or foremen, 5 to become forestry machine drivers and just a few to become cable-crane operators. In the last few years, between 10 and 20 students per year have completed the degree at ETH Zurich and attained a Master of Science ETH in environmental sciences with a specialisation in forestry and landscape management. At HAFL, on average, 15 students have become forest engineers every year since 2006. Their versatile training ensures that these forestry specialists do not only find jobs in forests. They have good chances of finding work outside the forest, for example, in public administration, where they can do other jobs besides forestry work.

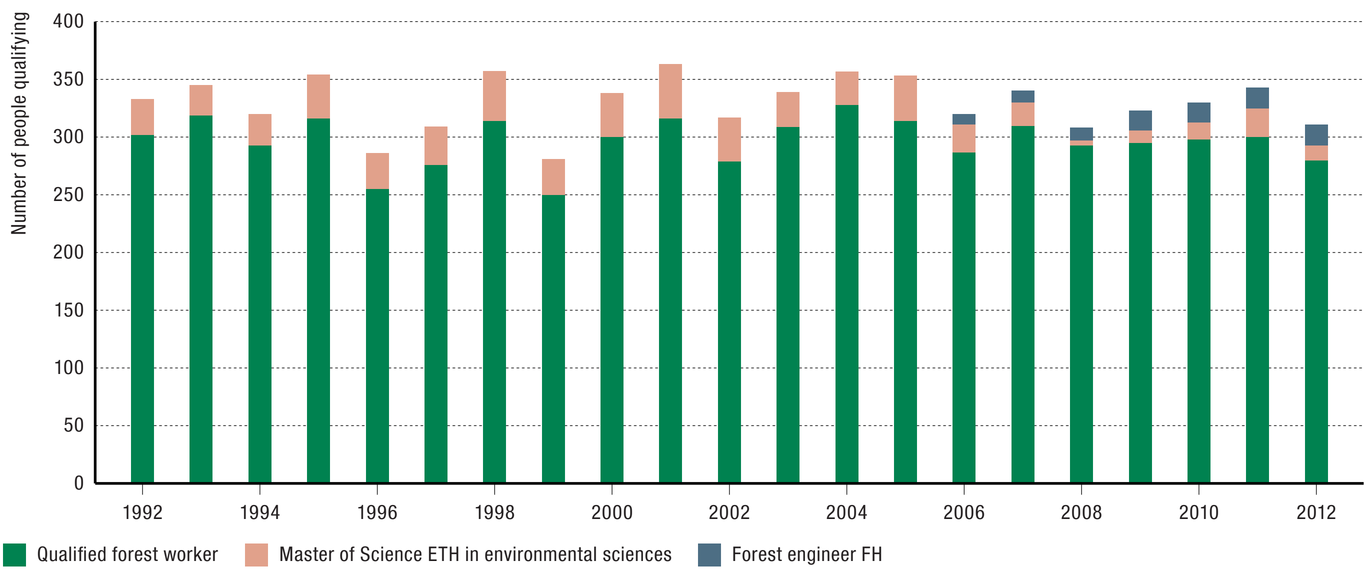


Fig. 6.5.2 *Number of people qualifying as a forest engineer FH, as a Master of Science ETH in environmental sciences with a specialisation in forest and landscape (up until 2007: forest engineer ETH), and as a qualified forest worker (EFZ).*
Source: FOEN 2013a

6.6 Accidents during forest operations

Philipp Ritter

> *Forest enterprises have one of the highest risks for serious accidents at work.*
> *On average, nearly every third person employed in the forest has a work-related accident each year.*
> *In comparison to the amount of harvested wood, 4-times more fatal accidents happen in the private forest than in forest enterprises.*
> *In comparison to the figures in the Forest Report 2005, the number of occupational accidents in the forest has been reduced, but the number of fatal accidents has, however, risen.*
> *The national campaign 'Vision 250 Lives' aims to halve the risk of a fatal occupational accident.*

Occupational accidents in public forest enterprises

In 2012, for every 1,000 people employed in forest enterprises, 299 had an accident at work (Fig. 6.6.1). This figure means that the accident frequency has sunk since 2003 by 11.8 per cent. In the same period, the number of accidents with a daily allowance that resulted in an inability to work for more than 3 days remained the same. The number of accidents that led to a permanent disability declined: between 2003 and 2008 there was an annual average of 14 accidents that resulted in permanent disability, and since 2008 there have only been 8 cases per year. No reduction could, unfortunately, be made in the number of fatal accidents: in 2012 alone, 6 people died, and since 2003, 48 forest workers have died at work (Fig. 6.6.2).

A nationwide campaign has been initiated that should halve the number of fatal occupational accidents by 2020. This is an ambitious aim for forest enterprises as forestry work is one of the most dangerous occupations in Switzerland (Fig. 6.6.3). Everyone working in the forest knows how quickly it can become dangerous. And that is the point where the Suva (the Swiss Insurance Agency for Work-Related Accidents) campaign 'Vision 250 Lives' starts in that it regularly reminds people that employees and employers have the right and the duty to stop working when it becomes dangerous. Part of this campaign is the 'ten life-saving rules for forest workers', which are being taught in in-service courses throughout the industry to all working trainees. If the trainees keep to these rules, they should be able to protect themselves against severe accidents.

Not only trainees can have severe accidents. Even trained and experienced specialists have accidents, in spite of their routine. Accidents that happen while working in the forest can be avoided when employees and managers regularly instruct their staff. Instructional material for doing this is available free-of-charge from Suva.

'Trust, but check' – this principle is also true for occupational safety. Employers are obliged to make sure that protective measures are implemented during work. This means that the employers and managers have to check their workplaces.

Suva, too, checks forest enterprises more than 200 times a year, making sure that the 'life-saving rules' are being kept. This is done as part of their legislative duty to ensure that the occupational safety regulations are being applied.

People working in the forests not only have accidents, they also become ill. Between 2003 and 2012, 20 people were ill, on average, every year as a result of an occupational illness (Fig. 6.6.2). Half of them suffered severe damage to their hear-

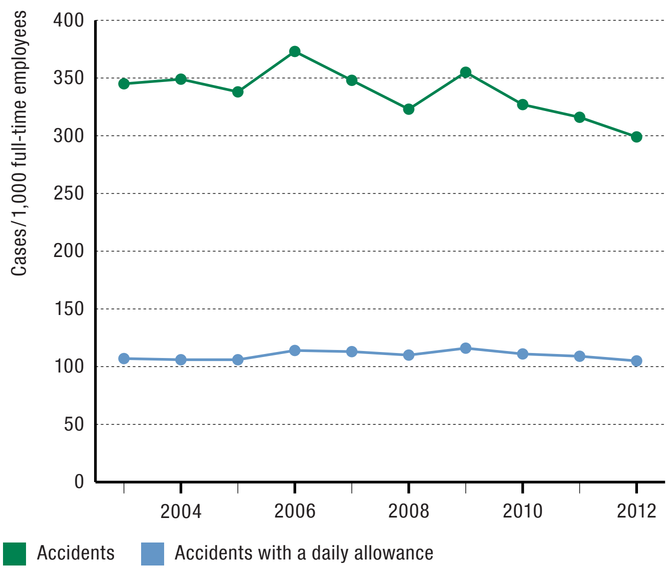


Fig. 6.6.1 *Occupational accidents and illnesses (cases per 1,000 full-time employees) in forest enterprises. Source: Suva*

ing, and this also caused most of the costs. A further quarter suffered from damage to their musculoskeletal system. The remaining occupational illnesses were related to damage to the eyes, skin or breathing apparatus, or resulted from an infection.

Accidents and occupational illnesses generate considerable additional costs. All enterprises insured by Suva are placed into classes. These classes have to cover their own costs: in each class the costs arising have to be covered by the premiums. Classes with higher costs have higher premiums than those with lower costs. In 2012, the average net premium of someone insured in a forest enterprise was 2,595 Swiss francs annually. This was equivalent to 3.74 per cent of the insured person's wage. In comparison: the Suva average net premium is about 1 per cent of an insured person's wage, and thus considerably lower than that in forest enterprises.

Accidents in private forests

Just under 30 per cent of the Swiss forest area is private forest (Section 6.1). Most of the private forest owners are farmers, often managing their forests themselves. Any accidents they have are not recorded in any standardised statistics because they are not insured by Suva.

Every year many accidents, some even fatal, happen when private forest owners harvest in their forest. FOEN (Federal Office for the Environment) estimates that, in comparison to the amount of wood harvested, 4 times more fatal accidents happen in private forests than in forest enterprises. Most of the accidents are a result of lack of knowledge, experience or practice. For example, the majority of those involved in an accident had no professional forestry training but were working in their free time or as a sideline in the forest. A working group commissioned by the Federal Council has therefore developed measures to improve the safety of those working in private forests. Through training courses, they should become able to work safely in the forest. All of the training courses can be found on the website *www.holzerkurse.ch*. Leaflets and information for spreading the word about the courses to as many forest owners as possible can also be ordered from the website.

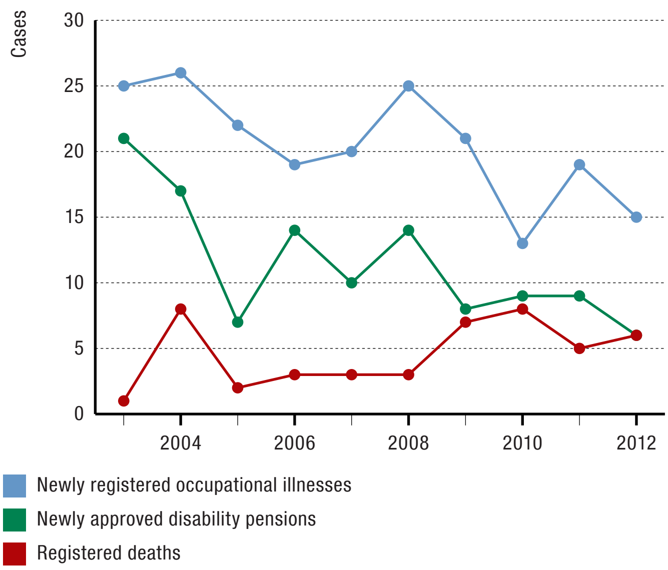


Fig. 6.6.2 *Number of occupational illnesses, disability pensions and deaths in forest enterprises per year. Source: Suva*

Fig. 6.6.3 *Logging by hand with power saws is one of the most dangerous occupational activities in Switzerland. Photo: Suva*

6.7 Wood end use

Ulrike Krafft

> *In 2009, a total of 9.6 million cubic metres of wood was used in Switzerland.*
> *52 per cent of the wood was used for wood products and for paper and cardboard production, and 45 per cent was used for energy.*
> *The construction industry has contributed most to the increase in wood products. For a few years now, the use of timber has been steadily increasing in both new buildings and in conversions and renovations.*

Use

In 2009, a total of 9.6 million cubic metres (m^3) of wood was used and 9.9 million m^3 of wood-based raw material were produced in Switzerland (Neubauer-Letsch et al. 2012). This amount meant that all of the wood used could theoretically be in the form of raw material from the home market. However, substantial amounts of wood are, in fact, also exported and finished wood products imported (section 6.8).

How is the wood used in Switzerland? In 2009, 52 per cent was used to manufacture other products and 45 per cent for energy. The remaining 3 per cent was used for other purposes, for example, in landscape gardening (Table 6.7.1).

An investigation in 2009 determined the specific use of wood as an end product in Switzerland (Neubauer-Letsch et al. 2012). This wood end use refers to the market volume of wood products that are not further processed. Wood that is used for energy or for producing paper and cardboard was not included. The study shows that wood is mainly being used in the construction industry, but also for outdoor constructions, for furniture and fittings and for packaging and wooden products (Table 6.7.2). The consumption of wood products has risen by about 10 per cent to 2.77 million m^3 since the last data collection in 2001.

Categories of use

In 2009, 1.25 million m^3 of timber was used in the construction industry, equivalent to 45 per cent of the total wood used. Most of this timber was used for constructing new buildings and for conversions and extensions to private homes (Einfamilienhäuser), followed by commercial buildings, construction aids and apartment blocks (Fig. 6.7.1). The figures for 2012 show that the amount of timber used for buildings in Switzerland has continued to increase. This increase has meant that timber now accounts for 14.2 per cent of the building material in newly built private homes and for 6.5 per cent of the material in apartment blocks. The amount being used in extensions and conversions is even greater: 31.4 per cent for private homes and 30.2 per cent for apartment blocks. The absolute amount of timber used for constructing new apartment blocks is now greater than the amount of timber used for constructing new private homes.

One of the main reasons for the increase in wood end use in the construction industry is the recent construction boom. But the state measures promoting wood are also showing effect. The year 2005 saw the introduction of new fire prevention regulations. The FOEN supported the development of these regulations as part of its programme 'wood21'. These regulations have opened up the market for wood in this area, and since then 1,500 apartment blocks with a timber construction have been built.

In Switzerland, the building sector contributes considerably to emissions that result in hazardous pollution for the environment and climate. It also consumes considerable resources: about 45 per cent of the energy is used when constructing buildings and for heating, air-conditioning and providing hot water. Construction methods that conserve resources are, therefore, of great importance. Wood conserves resources since it is renewable and climate neutral, as well as a versatile replacement for more energy-intensive materials. Using wood from Swiss forests means it does not have to be transported long distances, jobs can be kept in the region and a sustainable management of the Swiss forests is supported. The public is sensitized to using products made from domestic wood through the label of origin 'Swiss Wood' (Herkunftszeichen Schweizer Holz – HSH) and the FOEN campaign 'Proud of Swiss Wood' (2011–2013).

Using wood outdoors for terraces, garden sheds and other outdoor facilities is popular, and 72,000 m^3 of wood were used in this way in 2009. The market in this area is also developing dynamically, with DIY stores making most of the sales.

Table 6.7.1
Wood end use in 2009 according to type of use. Source: Neubauer-Letsch et al. 2012*

Use	m³	%
Wood products	2,392,000	25
Paper and cardboard products, printed matter	2,610,000	27
Energy	4,294,000	45
Other purposes, loss	339,000	3
Total wood and wood products	**9,635,000**	**100**

Table 6.7.2
Use of wood products in various areas in 2009. Source: Neubauer-Letsch et al. 2012*

Area of use	m³	%
Construction industry	1,245,600	45.0
Timber for outdoors	72,000	2.6
Furniture and fittings	862,200	31.1
Packaging	424,900	15.3
Wood products	165,600	6.0
Wood end use	**2,770,300**	**100**

**The difference between the wood end use in Table 6.7.1 (2,393,000 m³) and that in Table 6.7.2 (2,770,000 m³) is due to the different data-collection methods used.*

0.86 million m³ of wood was used for furniture and interior fittings, equivalent to about 31 per cent of the wood end use. More than half of this wood was used for furniture in private households and commercial buildings – from children's rooms to conference rooms and hotel fittings. However, a considerable proportion of the furniture was imported. The conversion and renovation of public and commercial buildings also play a large role in using wood for interior fittings.

Wood is an important raw material for packaging. In 2009, a total of 0.42 million m³ of wood were used for this, mainly for pallets and boxes. The development of the market in the packaging industry is strongly influenced by the economic climate. For example, in 2009 the amount of wood used for packaging was lower than that in previous years because the economy was doing badly. In the area of wood products, a variety of different products were manufactured from about 0.17 million m³ of wood – from kitchen utensils to decorative objects. In this area, many goods are imported and exported at an international level.

Fig. 6.7.1 *Apartment block Kirchrainweg in Kriens (Lucerne). The wooden construction made of Lucerne silver fir received the energy prize Watt d'Or. Photo: Gabriel Ammon, AURA*

6.8 Foreign trade in raw timber and wood products

Tatiana Pasi

> *Switzerland imports about the same amount of timber and products made of wood as it exports. However, the value of these imports is considerably higher than that of the exports.*
> *In 2012, the value of the timber and wood products accounted for about 3.4 per cent of the total goods imported and about 1.2 per cent of the total goods exported.*
> *The volume of the Swiss foreign trade with raw timber and wood products has risen since 1995, reaching a peak in 2006.*
> *Switzerland's most important trade partners for wood and wood products are the EU countries: more than 90 per cent of the Swiss imports and exports of wood and wood products either come from or go to EU countries.*

Raw timber and wood products

In comparison to the total Swiss foreign trade, the value of the imported and exported wood and wood products is low and has been sinking since the beginning of the 1990s, both for imports and exports.

The difference between trade with raw timber and with wood products is large. For raw wood, the value of the imports is about two-thirds of the value of the exports. For wooden products, this is reversed: the value of the imports is about five times higher than that of the exports. All in all, this means there is a foreign trade deficit for wood and wood products.

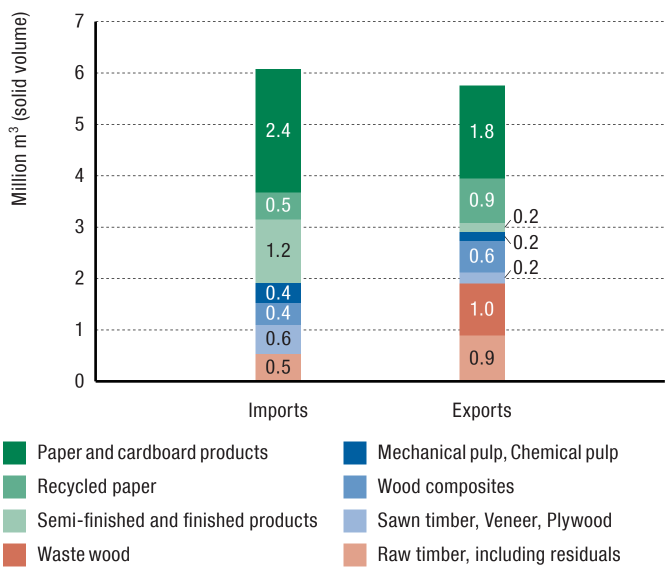


Fig. 6.8.1 *Imports and exports of raw timber and wood products in 2012 (in million m³ solid volume).*
Source: FSO and FOEN 2013

If the flow of raw timber and wood products is specified in cubic meters of solid wood, then the amounts imported and exported are about the same. Between 2008 and 2012, Switzerland imported on average 6.4 million cubic metres (million m³) and exported 6.2 million m³. Most wood is imported as paper and cardboard products: they account for about 40 per cent of the imports. In second place, amounting to about 20 per cent, are processed products such as semi-finished goods, construction and packaging material, furniture and prefabricated wooden houses. Their proportion has been increasing since the beginning of the 1990s. Paper and cardboard products also make up most of the exports, accounting for 30 per cent of the total. The next largest export products are waste wood (processed wood that has become waste), which accounts for 18 per cent of the exports, and raw wood and recycled paper, which account for 15 per cent each (Fig. 6.8.1). The amount of exported scrap wood is striking: approximately 1 million m³.

Roundwood, stemwood, logs and sawn timber

Since 1995, an average of 1.3 million m³ of roundwood from the Swiss forests has been sold abroad every year, amounting to almost a quarter of all the harvested wood. After the windstorm 'Lothar' in 1999, the amount of exported roundwood increased dramatically and then sank again to the level before the storm (Fig. 6.8.2). Over 90 per cent of the roundwood is exported as stemwood and the rest mainly as industrial wood. The exported amount of roundwood was about 18 per cent of all the harvested wood in 2012. Compared to exports, imports are low. Since 1997, 270,000 m³ of roundwood have been imported on average every year. Since 2008, the amount imported has been decreasing. In 2012, it was only 170,000 m³. Half of this is imported as stemwood that is then sawn up in the sawmills; the other half is industrial wood that is used to produce wood composites and paper. The amount of energy wood exported is negligible. The main reason for this is that the logistic costs are high and energy wood is therefore normally obtained in the region. Around 90 per cent of the trade in roundwood is with neighbouring countries. Tropical roundwood is being imported less and less: in 2012 it accounted for less than 1 per cent of the entire quantity of imported roundwood.

The trade movements of stemwood and sawn timber were greatly influenced by the largest sawmill in Switzerland, in Domat-Ems (Canton Grisons): it was founded in 2007 and stopped working in 2010. Additionally, since 2007, the weakness of the Euro in comparison to the Swiss franc has had a strong influence since it favours imports and makes exports more difficult, including in the trade in logs and sawn timber.

Imports of stemwood increased between 2007 and 2010 and then sank again, and in 2012 were almost 40 per cent lower than the average of the last 20 years. This development reflects the fall in the domestic market for spruce and pine logs following the closure of the sawmill in Domat-Ems. Exports, by comparison, increased after the windstorm 'Lothar' to 1.7 million m^3 and have fallen continuously ever since (Fig. 6.8.2).

Since 2000, sawn timber production has remained at an average of 1.5 million m^3. The exported amount of sawn timber rose between 2002 and 2010 from 14 per cent to over 32 per cent, and then decreased until 2012 to a level of 18 per cent. The proportion of hardwood diminished between the beginning of the 1990s and the year 2012 from 50 per cent of the sawn timber production to 7 per cent. The recipients of Swiss sawn timber are Italy, France and Germany. Imports of softwood sawn timber periodically rise and fall, but at a relatively high level. In 2012 it was almost 4,000,000 m^3 – twice as much as was exported. In comparison, the import of hardwood sawn timber has fallen slightly. This timber is increasingly coming from East European countries. Little tropical wood is being imported. It accounted for 4 per cent of the sawn timber imports in 2012.

Wood composites and paper

In 2012, there were only 4 factories in Switzerland that processed industrial wood: one producing hardboard, one producing chipboard and two manufacturing paper. A further 8 factories produce paper products using cellulose and not wood. The last factory that produced cellulose in Switzerland closed in 2008. Since then, all Swiss cellulose requirements have been covered by imports.

In Switzerland, paper and cardboard are being used, produced, imported and exported less and less. The amount consumed is broadly covered by domestic paper factories producing for the national market. Switzerland exports 0.91 million tonnes of paper and cardboard and imports 0.82 million tonnes.

The national hard- and particleboard industry is traditionally oriented towards exports. In 2007, 800,000 m^3 were exported, more than ever before. After that, the amount fell continually until, in 2012, it dropped to 610,000 m^3. Up until 2010, 80 per cent of the production was exported, but in 2012 it was only 60 per cent (a FOEN estimate).

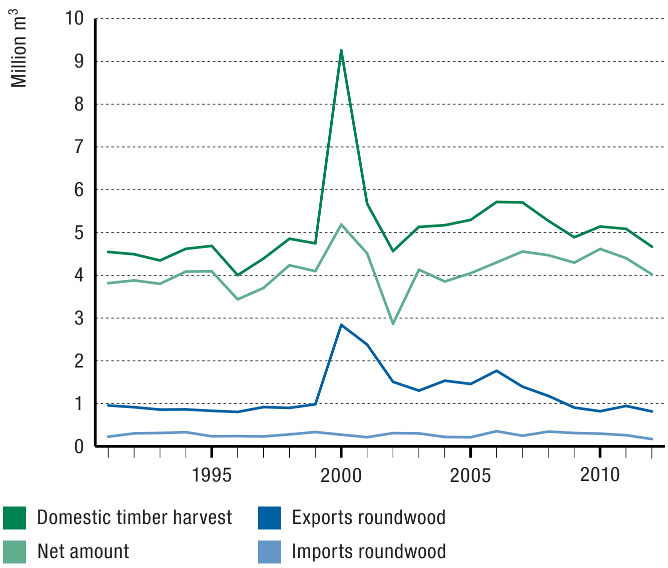


Fig. 6.8.2 *Roundwood balance of accounts between 1991 and 2012 (in million m^3). Net amount: domestic timber harvest plus imports, minus exports: Source: FSO and FOEN 2013*

6.9 Wood energy

Oliver Thees and Claire-Lise Suter Thalmann

> *In Switzerland, wood is currently the second most important renewable energy source after hydropower.*
> *In 2012 wood met 4 per cent of Switzerland's total energy requirements and about 8 per cent of its heating requirements. These percentages have risen considerably since 2005.*
> *Wood's contribution to Switzerland's total energy production is low, and obtaining it is relatively expensive. This means that using this raw material as a source of energy should be especially efficient and value-adding.*

Use of energy wood

In 2011, the Federal Council and parliament decided to phase out nuclear energy step-by-step as a first move towards an energy transition. The aim is to implement measures to fill the gap left due to pulling out of atomic power by improving energy efficiency and using sustainable energy sources. This political decision was a result of the environmental and atomic power catastrophe in Japan (Fukushima, March 2011) and has, in the meantime, led to wood energy becoming more important. Since 2000, the use of energy wood in Switzerland has been steadily increasing. In 2012, it accounted for 4.2 per cent of the total end energy consumption, making wood the second most important renewable energy source after hydropower. The energy transition will mean that, in the future, there will be a higher demand for wood and other renewable energy sources, and thus a larger proportion of the end energy consumption will be in the form of wood.

Wood can be used to produce heat, electricity and fuel. In 2012, an estimated 4.3 million m^3 (section 6.7) of wood was used as a source of energy. With this, about 8,103 giga-watt hours (Gwh, 29.2 petajoules) of useful energy were produced. Wood was used mostly to produce heat: 7,694 GWh (27.7 petajoule) of usable heat. A further 410 GWh (1.5 petajoule) of electricity was produced in special furnaces and combined heat and power plants (Fig. 6.9.1). About 95 per cent of energy wood is used for producing heat, covering about 8 per cent of Switzerland's total heating requirements. Energy wood is in the form of logs, chips and pellets. The demand for logs has remained the same since 2005, but the demand for chips and pellets is constantly increasing. Thanks to these energy wood products, automatic furnaces have increased in number. From the point of view of air pollution control, these are unproblematic because they have, among other things, air filters and lose less energy than the numerous, normally smaller and manually operated wood-stoves.

Wood is a climate-friendly source of energy because trees bind as much CO_2 as is set free when the wood is burnt. The CO_2 balance is improved when fossil energy sources are replaced by wood (section 1.4). Nevertheless, more particulate matter, nitrogen oxides (NO_X) and volatile organic compounds (VOC) are released. However, the way wood is used as a source of energy and careful planning when designing the heating can help to minimise the negative effects and environmentally optimise the use of wood as a source of energy.

Potentials of energy wood

The source of wood used for energy varies. Forest wood, the residuals of industrial wood (especially slats, shavings, sawdust and bark), woodland fragments and waste wood are all used. Forest wood accounts for 60 per cent, which is the

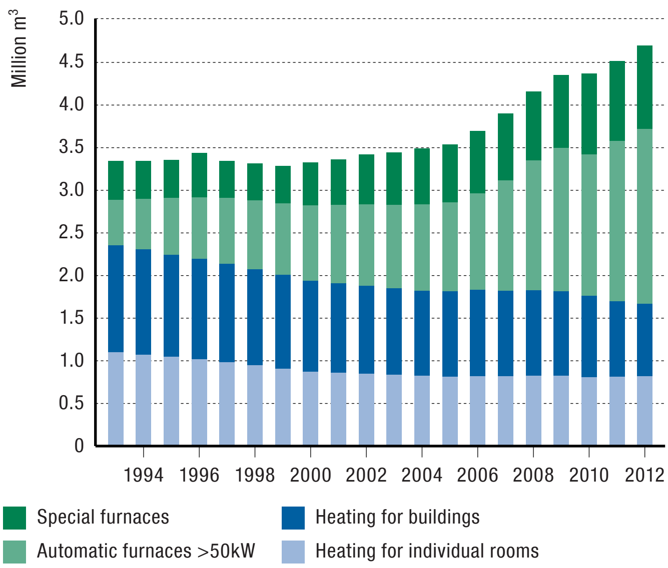


Fig. 6.9.1 *Total amount of wood used for energy in Switzerland between 1993 and 2012 for different types of furnace and heating (in million m^3). Source: FSO and FOEN 2013*

largest proportion. It consists of different parts of the trees: trunks, branches, twigs and needles. Basically, the wood market decides about which wood is to be used for energy, and also about cascade use. This involves using wood first as a material, for example as wood for the construction or furniture industries, and then for energy. Cascade use thus means using the resource several times. Using wood as a material binds CO_2, and its ensuing use as a source of energy replaces fossil resources and therefore saves CO_2. To optimally use the resource wood, this cascade use should be promoted. Given the current wood market situation, it is difficult to implement, especially as the demand for beech stemwood for use in the manufacturing industry is low and the price for wood as a source of energy is attractive. This situation has led, since 2009, to higher quality sorts of wood increasingly either been burnt, because there are no alternatives, or not even harvested.

Currently, an estimated 2.0 to 2.5 million m^3 of Swiss forest wood are used annually as energy. This is equivalent to about 40 per cent of the trees felled every year. The sustainable usable wood energy potential in the Swiss forest depends significantly on how much wood is felled – energy wood is often a by-product – and how the market for wood as a source of energy develops.

According to the latest estimates from WSL, on average of different scenarios of use, about 4.0 million m^3 of forest energy wood (solid wood greater than 7 cm in diameter and brushwood with bark) could be harvested each year (Fig. 6.9.2; Thees et al. 2013), equivalent to an energy volume of about 12,500 GWh (45 petajoule). An estimate from FOEN is that about 3.1 million m^3 of wood could be produced for energy (FOEN et al. 2014). In Switzerland, the largest additional potential for wood as a source of energy is to be found in the forests in the Alps and on the Southern slopes of the Alps. This wood is on very steep terrain, and is difficult to harvest and thus expensive (section 5.2). Ultimately, Switzerland's forest wood is limited. The contributions of wood and other biomass to the total energy production are currently rather low and will remain so in the future. For wood nevertheless to make a maximum contribution to the energy transition, the available potential must be tapped to the full by ensuring the most efficient and value-adding use of the raw materials. One approach is the trend towards increased use of combined heat and power.

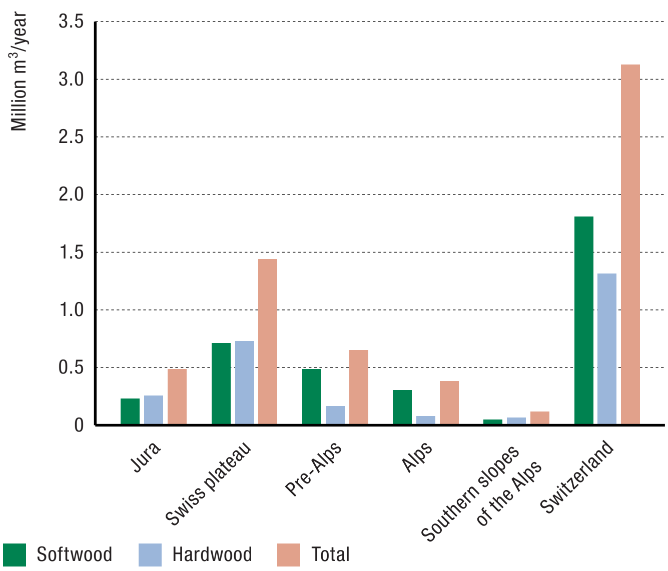


Fig. 6.9.2 *Energy wood potentials in Switzerland and in individual forest regions up to 2026 where the scenario of use is 'as until now'. Source: Thees et al. 2013*

6.10 Recreation in the forest

Marcel Hunziker, Eike von Lindern, Nicole Bauer, Jacqueline Frick

> *The forest is a popular place for recreation and leisure; this has not changed since the Forest Report 2005.*
> *Those who go into the forest value it the way it is and can really relax and recuperate there.*
> *As stated in the Forest Report 2005, this great popularity can cause problems. This is particularly so near cities and towns, where many people go to the forest. They feel disturbed by the others in the forest also seeking recreation. This has become even more of a problem since the last Forest Report in 2005.*
> *Conflicts among those visiting the forest and between recreation and nature conservation can usually be mitigated through steering and informative measures and through persuasion.*

Reasons for visiting the forest

Basically, anyone can go to the Swiss forests – whenever and wherever they want. This right is laid down in the Swiss Civil Code (Zivilgesetzbuch, ZGB). Since Switzerland has a large forest area and much of it is close to where people live, the forest is the most important near-natural recreational area. This can be seen in the frequency with which it is visited, as a survey conducted by WSL and FOEN in 2010 (cf. box) shows. In summer, respondents visited the forest once or twice a week on average, but in winter only once or twice a month. These figures have remained almost the same since 1997, obviously when the first survey was conducted (Fig. 6.10.1). These days, many have less time to spend visiting the forest, but they still go there regularly. One of the main reasons for this is that they need increasingly less time to get there because residential areas are moving closer to the forest edge. More than 69 per cent of respondents take less than 10 minutes to reach the forest. Walking is the most frequent and popular way to get there.

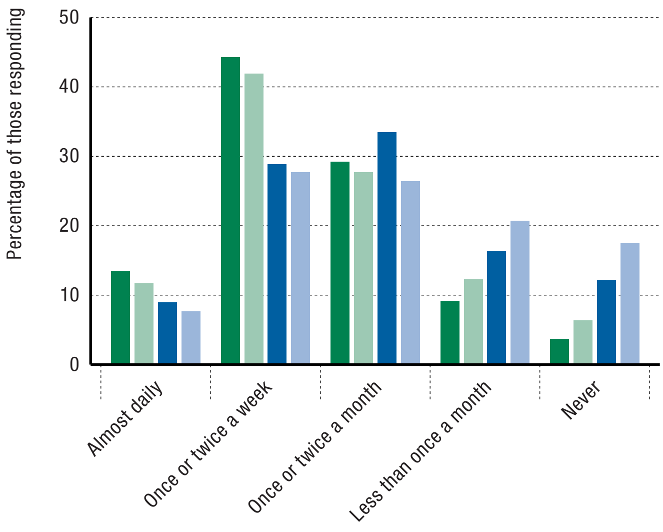


Fig. 6.10.1 *The frequency of forest visits in 1997 (WaMos 1) and 2010 (WaMos 2). Source: Hunziker et al. 2012*

Why do people visit the forest? The most important reasons given are their desires to experience nature and to keep fit (Fig. 6.10.2), as their activities indicate. They most enjoy going for a walk or hike and doing sports, followed by 'just being there', and observing nature. This has not changed since 1997. In comparison, the types of activities forest visitors engage in have become more varied.

What do people like about the forest? It seems it is mainly its variety and the way it activates different senses. If the forest also has a small stream or lake, then human aesthetic needs can be fully met. What infrastructure there is in the forest is of very little importance, even if some of the visitors would like a bench or two more to sit on. Certain infrastructure facilities are even disliked, for example, forest roads, bike trails and adventure rope parks (Seilparks). The way people judge these facilities depends, however, greatly on the interests of those being questioned. The forests' natural properties are positively judged, even if monocultures, undergrowth and a high level of deadwood negatively influence how the landscape is experienced.

Satisfaction and conflicts

Most of those questioned are very satisfied with their visits to the forest and feel more relaxed afterwards than they did before. This is generally independent of the quality of the forest and even disturbances do not change their opinion. However, forest visitors do tend to feel more disturbed now than they used to. In 1997, 18 per cent of those asked said that they felt disturbed in the forests, while by 2010 this number had

Box: 'Socio-Cultural Forest Monitoring' WaMos

'Socio-Cultural Forest Monitoring' is a periodic survey of the Swiss population about their relationship with the forest. The survey is detailed, ranging from attitudes to the environment to prioritising the forest functions, to views on the development of forest areas, forest health and on wood purchasing behaviour. Important aspects are recreation in the forest and forest preferences. The survey was completed for the first time in 1997 (SAEFL 1999), and for the second and currently last time in 2010 (Hunziker et al. 2012; FOEN und WSL 2013).

already risen to 27 per cent, with twice the number of reasons, on average, given. This change can be attributed to the growing population, with a comparable increase in the number of visitors in the forests close to residential areas, and the greater variety of activities people engage in when in the forest. People may, also, have become more sensitive to disturbances, in particular to new activities such as mountain biking, whose legitimacy many respondents questioned. The most important sources of disturbance, however, remained the same as in 1997 and 2010, namely biking and mountain bike riding, as well as dogs and noise. Other causes of disturbance are, in comparison, negligible, and even restrictions due to wood harvesting are not considered disruptive.

Conflicts occur not only between the people looking for recreation, but also between forest visitors and the natural environment (Baur 2003). Wild animals, in particular, are disturbed by the many people visiting the forest. This is why several institutions have developed and implemented measures to guide forest visitors. One example of this is the campaign of FOEN and the Swiss Alpine Club SAC 'Respect to Protect' (Respektiere Deine Grenzen). These measures – and the corresponding information provided – should convince forest visitors that it is important to be considerate to wild animals and to adapt their behaviour accordingly (Immoos and Hunziker 2014). The same is true of measures intended to mitigate conflicts between different types of recreation. Mutual tolerance can be greatly increased by separating the infrastructure needed or by providing information and convincing those involved (Freuler 2008; Hunziker et al. 2011).

Measures to guide visitors are thus important for reconciling free access to the forests and its recreational use with the other forest functions. This guidance has, however, to be kept in proportion so that the existing right to free forest access is not curbed. The most promising approach here is to encourage people to believe that they should not only consider their own freedom but also that of others.

a) Doing something for health
b) Doing sports
c) Being alone
d) Spending time with family/friends
e) Enjoyment, friends & fun
f) Experiencing nature
g) Enjoying some fresh air
h) Getting away from day-to-day routine

Fig. 6.10.2 *The most important reasons for visiting the forest in 2010. Source: Hunziker et al. 2012*

6.11 Forest and cultural heritage

Sandra Limacher

> *Switzerland has a rich cultural heritage that is closely connected to the forest in many ways.*
> *The intangible cultural heritage includes living trans-generational traditions, customs and practices that have been recognised as part of Switzerland's cultural identity. In 2012, the Federal Office of Culture published the first list of these 'living traditions in Switzerland'.*
> *The tangible cultural heritage includes cultural property created by humans such as pre-historic sepulchers or culturally historic transport routes through the forest.*
> *In comparison with the Forest Report 2005, which only described the historical and archaeological cultural property in the forest and the traditional types of forest management, this chapter includes aspects of the intangible cultural heritage. It thus takes into account developments since the UNESCO Convention for the Safeguarding of the Intangible Cultural Heritage came into force.*
> *The general public's knowledge about the existing cultural heritage relevant to the forest is increasing in Switzerland, but remains patchy. No comprehensive overview exists.*

Intangible cultural heritage

Switzerland's intangible cultural heritage contains a considerable variety of aspects related to the forest. This includes orally transmitted traditions and expressions, performing arts, social practices, rituals and festive events, knowledge and practices concerning nature and the universe or specialist knowledge about traditional craftmanship (Table 6.11.1). These are all living traditions and qualities that contribute to a sense of local and regional cultural identity and continuity. Examples are the so-called co-operatives for regulating the use of forest commons in Canton Valais, charcoal production in Entlebuch, Canton Lucerne, and shingle making, in particular in Canton Freiburg and Canton Vaud. Some social practices are particularly important for the local community, such as Woldmanndli (men of the forest) in Canton Uri, the Pfingstblitter (young men who go into the forest on Whitsunday) and May trees in Cantons Aargau and Basel-land or Scheibenschlagen (disk flinging) in Untervaz, Canton Grisons. During Silvesterchlausen, an old wintertime custom in Canton Appenzell Ausserrhoden, groups of men get dressed up as 'Waldkläuse' – also locally called the beautifully ugly. They use fir, moss, lichen and cone scales for their costumes. They go from farm to farm, rhythmically swinging their bells, singing 'Zäuerli' (a traditional natural yodelling) and wishing everyone well for the New Year (Fig. 6.11.1). The old craft of rafting was the most common method of transporting wood throughout Europe. In Switzerland Lake Ägeri (Canton Zug) is the only place where it is still practised today. Up to 400 felled trees from a steep mountain forest with no access roads are tied together to form a massive raft and steered across the lake.

These examples, and many more, are on the list of 'living traditions in Switzerland', produced by the Federal Office of Culture (FOC) in co-operation with the cultural offices in the cantons and the Swiss UNESCO Commission. The list was published for the first time in 2012 (FOC 2012) and currently has 167 entries, 11 of which are directly related to the forest or to wood. It is planned to periodically up-date the list. The list was initiated as a result of the UNESCO Convention for the Safeguarding of the Intangible Cultural Heritage, which was ratified by Switzerland in 2008. The convention does not aim to turn the individual elements into museum pieces. Rather, it wants to ensure the intangible cultural heritage survives by being able to adapt and by maintaining its dynamic character.

Other projects and research in addition to the list of living traditions also contribute to keeping further aspects the intangible cultural heritage alive and prevent it being forgotten. These projects include one entitled 'Hüeterbueb und Heitisträhl' (information about old traditions from an oral history of the Swiss forest), which documents the manifold uses of the forest between 1800 and 2000 (Stuber und Bürgi 2011). Traditional knowledge – including knowledge about collecting leaves and fir needles as litter for the stall, cutting branches as fodder or harvesting resin for lotions – was collected in interviews with historical witnesses from the dif-

Table 6.11.1
The two categories of cultural heritage.
Source: UNESCO (SR 0.440.6, Art. 2, SR 0.520.3 Art. 1)

Intangible cultural heritage	Tangible cultural heritage
Oral traditions and expressions	Immovable cultural property such as monuments or archaeological sites
Performing arts	Movable cultural property such as paintings, sculptures or coins
Social practices, rituals and festive events	
Knowledge and practices concerning nature and the universe	
Traditional craftsmanship	

ferent regions. Other examples of projects include making an inventory of forest names (e.g. Gregori et al. 2005), documenting and maintaining legends and fairy tales with forests as their main elements (e.g. Domont und Montelle 2008) or making an inventory of traditional types of forest management such as coppices, coppices with standards, chestnut orchards or wooded pastures (Brändli 2010b).

How long the intangible cultural heritage can be kept alive and how well will depend on how long those who have the knowledge continue to practise the traditions, and whether they still see some sense in them and pass on their knowledge to younger people. Competency centres for folk culture – for example the Swiss open-air museum Ballenberg – help to keep the traditional craftmanship.

Fig. 6.11.1 *Silvesterchlausen in Urnäsch (Canton Appenzell Ausserrhoden) 2012. Men and boys dress up in costumes made of fir, moss, lichen and cone scales ('Waldkläuse').*
Photo: Sandra Limacher

Tangible cultural heritage

Tangible cultural heritage consists of man-made immovable and movable cultural property related to the forest (Table 6.11.1). They are manifest witnesses to culture and history and visible in the cultural landscape.

Protecting cultural property is a national obligation that Switzerland took on when it ratified the Hague Convention. The Swiss inventory of cultural property with a national and regional importance was revised in 2000 and in 2008 (FOCP 2009). The current third version contains 3,202 objects of national importance, including monuments and historical and archaeological sites. The forest is a silent preserver of about 100 of these objects. These include the pre-historic barrows in the two forests Chlosterwald (Jolimont, Canton Bern) and Aeschertenwald forest (Grossaffoltern, Canton Bern), as well as the forest cemeteries in Davos (Canton Grisons) and Schaffhausen (Canton Schaffhausen).

No inventory exists of the so-called moveable cultural property that have something to do with the forest in collections in Switzerland – even though the forest has always served as one of the most inspirational sources for artists such as sculptors, painters, poets or composers, sometimes even providing the raw materials for their work.

Also of cultural-historical importance are the paths and roads listed separately in the Federal Inventory of Historic Transport Routes in Switzerland – an inventory in accordance with Article 5 of the Federal Act on the Protection of Nature and the Cultural Heritage (FEDRO). The 'Hohle Gasse' (hollow alley), which is one of the most popular cultural historical paths in central Switzerland, is one such example. It was originally simply a narrow path in the forest between the Fraumünster Abbey in Zürich and its possessions and land in Canton Uri. It later became an important route between Zürich and Northern Italy (FEDRO 2007).

6.12 Forest-related education

Katharina Maag Merki

> *Forest-related education encourages children and adults to think about the forest as a place for great experiences, and as something they can use and learn from.*
> *People can research and discover forest habitats by themselves. This makes them particularly useful for reaching the curricula goals related to the topics 'environment and sustainable development'.*
> *In Switzerland, many forest-related learning opportunities are available for school children, as well as training courses for teachers.*
> *Since the last Forest Report in 2005, forest-related education has become more visible in society, school and research.*

The forest as a classroom

The forest is like a large classroom in which pupils can experience habitats that are of great importance, both for them and for society. These habitats can be experienced directly as learners can explore and research them on their own. This provides opportunities for very intensive experiences that support learning. The forest is therefore particularly suitable for focussing on important goals in school education, as formulated in primary school curricula. These goals include getting to know the forest as an ecosystem, grasping this knowledge holistically and understanding and reflecting on the many mutual benefits and interdependencies between humans and the forest. Additionally, schoolchildren can use the 'forest classroom' to reflect on how they and others may use nature to pursue their own interests and needs. They can think about how much their use respects flora and fauna and how humans, animals and plants can constructively co-exist. This requires learning about the economic use of the forest and considering how much their own behaviour supports the forest's sustainable development.

Learning opportunities

Forests have been recognised as places of learning for many years. A range of learning opportunities have been developed focussing on different topics and target groups. These help children and adults to think about the forest as a place where they can have experiences, and something they can use and learn from. 'Education for a sustainable development' and 'Environmental education', which also include forestry-related topics, are part of teaching curricula and teacher training courses. The UNO Decade of Education for Sustainable Development 2005–2014 played a large role in this. Various institutions have become involved in its implementation, for example, the Swiss UNESCO Commission or the Conference of Cantonal Ministers of Education (Erziehungsdirektorenkonferenz, EDK) or the Swiss Coordination Conference Education for a Sustainable Development (Schweizerische Koordinationskonferenz Bildung für eine nachhaltige Entwicklung, SK BNE).

A range of learning activities provide insights into educational topics. For example, children can learn to decipher animal tracks or understand plants' survival strategies on learning trails. Many municipalities now have forest playgroups or kindergartens where small groups live, learn, eat and play

Fig. 6.12.1 *Forest playgroups allow children to use all their senses to discover the forest habitat. Photo: Ulrich Wasem*

Table 6.12.1
Forest-related educational topics for teacher training and schools and in research.

Professional support, further education for teachers or courses for groups of pupils, e.g. > WWF > Pro Natura > Silviva > SVS/BirdLife Schweiz.
Adult education courses that, in addition to other topics, focus on questions of forest education, e.g. Certification (CAS) 'nature-related environmental education' from SILVIVA.
National competence centre for primary schools and for some classes in secondary schools for embedding the topic 'education for sustainable development' at a national level, e.g. Stiftung éducation21.
Education for sustainable development (ESD) as a research field, e.g. Kommission BNE der Deutschen Gesellschaft für Erziehungswissenschaften DGfE (Commission ESD of the German Society for Education).

outdoors and enjoy the peace and quiet in (almost) any type of weather (Fig. 6.12.1). To complement school lessons, children can go to forest schools, nature conservation centres, nature discovery parks, such as the Wildnispark Zürich, and engage in a range of other activities such as those provided by SILVIVA. They are run by professionals and enable teachers and their classes to work on exciting topics. Primary school children can, for example, take part in the project 'forester's world' and experience first-hand the world of those working in the forest. Under the guidance of a forester, they take care of a patch of forest close to where they go to school. Other educational topics are covered in different ways in school, as part of further training for teachers, in research, as well as in society. Table 6.12.1 shows some of the different activities and themes on offer and who is providing them.

Forest-related education has become generally more important, as well as in relation to regional, national and international developments. This is gratifying because forest habitats can only be protected if the next generation values them and how they are used. Forest-related educational themes should, however, be given more weight and support in future. Currently, in comparison with other issues, they often take a back seat.

> Glossary

A

Abiotic
Describes processes and factors that do not involve living organisms. Abiotic > site factors are environmental factors and factors that are not caused or influenced by living organisms, for example, precipitation or bedrock (> biotic).

Acid
Chemical compound that releases > protons in aqueous solution (counterpart: > base).

Acidification
Process in which the concentration of > acids in the soil increases. Soils can neutralise > acids to a certain degree through the > weathering of buffer substances and through > cation exchange. If the soil is fed more acid (e.g. through air pollutants) than it can buffer, this reduces its buffering capacity; the > pH value falls and the soil becomes acidified (> critical load). The > protons released from the acids can displace nutrients from the soil. An acidic soil does not therefore nourish plants as well as a neutral or basic soil.

Act on Forest, Forest Act
Federal legislation on the forest dating from 4 October 1991, which became effective on 01.01.1993, including the Forest Ordinance (Waldverordnung, WaV) of 30 November 1992. The first Swiss Forest Act was, however, the Federal Law concerning the confederation's supervision of the forest police in high mountain regions ('Bundesgesetz betreffend die Oberaufsicht des Bundes über die Forstpolizei im Hochgebirge') of 1876, which already contained the principles for sustainable forest management.

Aerosol
Mixture of solid or liquid matter and a gas in air. Primary aerosol particles are emitted directly in the air, whereas secondary aerosol particles are newly formed in the atmosphere from primary gaseous matter.

Air pollutants
Pollutants transported by the air. They include gases like > ozone, > ammonia, > nitrogen oxide or sulphur dioxide, as well as fine particles (> aerosol).

Ammonia (NH_4^+)
Pungent, poisonous, gaseous nitrogen compound. Ammonia is released into the environment through, for example, agriculture (liquid manure, livestock).

Ammonium (NH_4^+)
A form of > ammonia dissolved in water. Ammonium salts are used as fertilizer in agriculture. Ammonium forms under natural conditions in soil or water, for example, primarily through the decomposition of animal or plant proteins. Microorganisms can convert ammonium in soil or water into > nitrate, setting free > acids.

Anion
Negatively charged > ion.

B

Basal area
The total area of the stem cross-sections of all living trees.

Base
A chemical compound that can absorb > protons is known as a base. It can neutralise an > acid, and is in this sense the opposite of an acid.

Base cation
Positively charged > ion whose hydroxide is a weak > base: Ca, Mg, K, Na. Abbreviated as BC.

Base saturation
Percentage of > base cations (Ca, Mg, K, Na) of the > cation exchange capacity.

BC/Al ratio
Ratio of the > base cations (BC) calcium, magnesium and potassium to aluminium (Al).

Beetle-infested wood quantity
Quantity of all trees in > solid cubic metres infested by bark beetles.

Biodiversity
Synonym for biological diversity. Diversity of habitats and > ecosystems, as well as species and genetic diversity, including all varieties of cultivated plants and farm animals. In the course of the earth's history, evolution has brought to life an incredibly rich variety of life forms. Scientists estimate that this has resulted in around 10 million species.

Biodiversity monitoring BDM
A project of FOEN, the Federal Office for the Environment, to monitor biodiversity in Switzerland. In the framework of the BDM, experts regularly record the number of selected animal and plant species on sample plots. This reveals how biodiversity in Switzerland is developing.

Biomass
All organic matter in an > ecosystem. It includes both living and dead material produced by organisms.

Biotic
Processes and factors involving living organisms. Biotic site factors are environmental factors and conditions caused or influenced by living organisms, for example, competition, harmful organisms or browsing (> abiotic).

Black List
List of the invasive > neophytes in Switzerland that cause damage to biodiversity, health and/or the economy. The spread of these plant species must be prevented (> Watch List, > invasive species).
Online: www.infoflora.ch

Browsing intensity
Proportion of woody plants between 10 and 130 centimetres tall whose apical shoots have been browsed in a year.

C

Carbon (C)
Basic building component of all organic compounds. On burning carbon or carbonaceous compounds, > carbon dioxide is formed.

Carbon dioxide (CO_2)
Colourless gas that is part of air (0.03 per cent). Forms on combustion or decomposition of carbonaceous substances like wood or oil. As a greenhouse gas, carbon dioxide is responsible for much of today's global warming. Plants absorb carbon dioxide from the air and integrate the > carbon in their biomass (> photosynthesis).

Carbon sink
Reservoir that absorbs and stores carbon. Forests take up carbon during their growth and through the increase in carbon stored in the organic layer, in the soil and in deadwood. Forests release carbon into the atmosphere when wood is harvested and through decay. If the uptake of carbon is higher than its loss, the result is a carbon sink, whereas if the loss is greater, the forest becomes a carbon source. This definition applies to the forest without taking into consideration the storage capacity of wood used for construction.

Carbon source
Opposite of > carbon sink.

Cascade use
Use like a cascade means that the wood is first used as material, for example, to build houses or processed to make furniture, and only later at the end of the life cycle is it used energetically, for example, when it is burned to produce heat.

Cation
Positively charged > ion.

Cation exchange capacity
Measure of the > cation storage potential of soil, calculated as the quantity of exchangeable cations (Ca, Mg, K, Na, H, Al, Fe > base cation).

Climax tree species
Tree species that persists towards the end of the > succession unlike > pioneer species.

Clone archive
Collection of vegetatively (= clonally) reproduced individuals, for example, from cuttings.

Combined heat and power plant (CHP plant)
CHP plants produce electricity from a fuel (e.g. wood) and, at the same time, generate considerable waste heat that can be used for other purposes (e.g. industrial processes or heating). The overall efficiencies are very favourable in comparison with the separate generation of heat and electricity, and determine the exploitability of the heat produced.

Coppice forest
Forest grown from > coppice sprouts or root shoots with a short > rotation period. Oldest form of regulated forest use, mostly to obtain firewood. This management system favours tree species that can develop coppice sprouts like hornbeam and oak. Coppice forests are regularly (every 10–30 years) clear-cut.

Coppice with standards
Forest structured in two layers, where the lower layer consists of > coppice sprouts as in a > coppice forest. These are regularly (every 20 to 30 years) cut to provide firewood. The upper layer consists of > standards as in a > high forest, which can be used, for example, in the production of construction timber. Typical management method from the Middle Ages until the 19th century. Seldom used today. Further development of a > coppice forest.

Coppice sprout
Coppiced tree that develops or has emerged from the formation of shoots on a rootstock. Coppice sprouts are used in some forms of management for the > regeneration of the > stand (> coppice forest, > coppice with standards).

Criterion
In the Forest Report, criterion refers, according to > Forest Europe, to a topic area or an aspect of the forest whose condition or characteristics can be described or evaluated with several > indicators.

Critical load
Rate of pollution an > ecosystem can tolerate without suffering long-term damage. Ecosystems are capable of transforming and decomposing harmful substances up to a certain level and of repairing the damage suffered. If the input of harmful substances (sulphur and nitrogen compounds, and heavy metals) exceeds the critical load, the ecosystem will be damaged (> acidification, > nitrogen saturation).

Critical value
Concentration of a substance in an environmental medium (e.g. water, soil or air) above which adverse effects on humans and the environment can be expected.

Culture
All the unique spiritual, material, intellectual and emotional aspects that characterise a society or a social group. It includes not only art and literature, but also life forms, people's fundamental rights, value systems, traditions and belief systems.

Cultural heritage
Intangible: orally transmitted traditions and forms of expression, performing arts, social practices, rituals and festivals, traditional knowledge and practices about how to relate to nature and the universe, as well as technical expertise in traditional handicrafts.

D

Deadwood
Dead trees or parts of trees with varying quality and dimensions.

Debris flow
Slow- or fast-flowing movement of a mixture of water and solid material (e.g. stones) with a high proportion of solid material (> hillslope debris flow).

Defoliation
Deviation in the foliage of a tree from a reference value, where the observer considers the origin of the deviation to be unknown. The reference value corresponds to the species-specific foliage, which is referred to as the maximum.

Diameter at breast height DBH
Diameter of a tree stem 1.3 metres aboveground (convention on standardized measurement of stem thickness).

Disturbance
Abnormal event with considerable impact.

E

Ecosystem
Dynamic, functional unit consisting of all living organisms together with their habitat. The organisms interact with their > abiotic and > biotic surroundings (soil, water, air, competitors, harmful organisms and so on) and exchange energy, material and information.

Ecosystem service
Function of an ecosystem that contributes to human well-being, for example, biomass production or carbon storage.

Embodied energy
Amount of energy needed to produce, transport, store, sell and dispose of a product. It takes into account all the input material required including their extraction, as well as the energy used in all production processes applied. Embodied energy is thus the indirect energy needed to produce a consumer good or a service, in contrast with the direct energy consumed when using the product or service.

Energy transition
Transition towards a sustainable energy supply by reducing final energy and electricity use, increasing the proportion of renewable energy and reducing the CO_2 emissions connected with energy.

Energy wood
Wood that can be used for energy. It is classified according to its origin: > forest wood, > woodland fragments, > residuals (from processing), plantation wood and > waste wood.

Energy wood potential
Amount of wood that can potentially be used energetically according to the type of wood or source used: > forest wood, > woodland fragments, > residuals (from processing), > plantation wood or > waste wood. The potentials are subclassified according to availability, for example, into what is: (i) theoretical, (ii) the total sustainable, (iii) already used or (iv) usable. Theoretical potential (i) refers to an upper limit that is only theoretically obtainable, for example, the total quantity of forest wood within a perimeter. Subtracting from the theoretical potential the quantities of wood that cannot be used due to various restrictions on using them for energy results in the total sustainable potential (ii). Such restrictions may be technical, economic, ecological, political or legal and are often interrelated.

Export quota
Proportional relationship of exports to the gross domestic product. The export quota of > sawn timber refers, for example, to the ratio of sawn timber annually exported to that annually produced in the country. The export quota is an indicator of the volume of trade, of how open a national economy is, and of the competitiveness and market orientation of a particular sector or company.

Ex-situ conservation
Conservation of a species outside its natural habitat, for example, in specially established collections of living specimens or as seeds in a gene bank (> in-situ conservation).

F

Final harvest
Harvest (clearance) of a forest stand that has reached the planned harvesting age, i.e. the so-called > rotation period. The final harvest is a type of use according to the group selection silvicultural system in > high forest.

Forest area
Total area classified as forest according to the definition of forest in > NFI. It includes forest and > shrub forest.

Forest boundary, static
Fixed forest border recorded in the zoning plan. > Stockings growing beyond this border are not classified legally as forest, and therefore can be cut down without a permit.

Forest community
A > plant community dominated by trees.

Forest Development Plan WEP
The WEP (in some cantons also the regional forest plan RWP) is the management and coordination instrument for the cantonal > forest service. It specifies which forest services (> forest functions) are in the public interest, and provides guidelines on sustainable forest management. The WEP should, together with the cantonal structural plan, be coordinated with spatial planning law and cover a region or a canton. It is binding for the public authorities.

Forest edge
Border or transitional area between the vegetation form forest and other elements of the landscape. The forest edge includes the > forest mantle, > shrub belt and > herb fringe.

Forest enterprise
Organisational unit, which, as a public or private legal entity or natural person, manages forests strategically and operatively. It can consist of one or more forest owners. In Switzerland, it is usually supported by a public authority, for example, by a municipality (Gemeinde or commune).

Forest Europe
(Formerly The Ministerial Conference on the Protection of Forests in Europe MCPFE). The 46 member countries and the EU Commission aim to protect and improve the sustainable management of forests in Europe.

Forest functions
Tasks performed solely or partly by the forest, or which could or should be performed by the forest. Important forest functions in Switzerland include: protection against natural hazards, timber production, > biodiversity, recreation, protection of drinking water, and filtering of air. For the distinction from forest services, see Graphic I, p. 12.

Forest mantle
Several single or ordered rows of typical border trees (one-sided rather long crowns) > diameters at breast height larger than 12 centimetres, including the shrub layer beneath on the > forest edge.

Forest service
Federal and cantonal administrative agencies that ensure forest legislation is implemented. The cantons divide up their areas into forestry districts and forestry sections. Forestry districts are managed by qualified forest engineers who are elected (district forester), and forestry sections by qualified foresters.

Forest services
See Graphic I, p. 12.

Forest target species
> Target species occurring in the forest.

Forest wood
All wood grown, produced and harvested in the forest.

Forestry service entrepreneur
Private provider of forest services (a contractor), who does not own any forest, but manages forests on behalf of the forest owners, carrying out, in particular, wood harvesting.

FSC Forest Stewardship Council
International organisation of representatives from the forestry profession, the timber industry, environmental groups and indigenous people's organisations. It has promoted the ecologically and socially sustainable use of the forest since 1993 and certifies appropriately produced timber with the FSC Label (> PEFC).

G

Gene flow
Exchange of genetic material (in plants through pollen and seeds) within and between populations.

Genetic resources
Genetic diversity found in natural stands or ex-situ collections.

Gross increment
Increase in the stemwood volume (> stemwood) of trees. In the > NFI, increment refers to the increase in the stemwood volume of all living trees, the stemwood volume of all newly recorded (ingrowth) trees, and the modelled increase in the stemwood volume of all used trees or dead trees.

Gross output
Total value of all products and services produced in a country per year.

Gross value added GVA
The gross value added results from deducting the input costs, i.e. the cost of products and services used, processed or transformed during the production process, from the > gross output.

Groundwater protection zone
The Waters Protection Ordinance distinguishes between the zones S1, S2 and S3 (groundwater protection zones) and zone Zu (catchment area) to protect drinking-water intake facilities. In > NFI, samples are taken to determine which parts of the > forest area are within a catchment area of a drinking-water intake facility (zone Zu) and which in a groundwater protection zone (zones S1, S2, or S3).

Group-selection forest
Forest managed according to the group-selection silvicultural system. This involves regenerating the stands by thinning small patches of the overstory irregularly in a spatially organised sequence. The technique combines strip cutting with the clear-cutting of small areas and shelterwood cutting (> shelterwood forest).

Growing stock
Synonym for wood stock. According to the > NFI, this is the volume of > stemwood with bark of all living trees and shrubs (standing and lying) more than 12 centimetres in > diameter at breast height in a > stand or area. The NFI also includes in the > total wood volume all dead trees, both lying and standing. The growing stock is usually given in cubic metres of wood per hectare forest.

H

Habitat tree
Synonym 'biotope tree': living tree with microhabitat structures like dead branches, holes and cavities, fissures and cracks, rough pockets or injuries in the bark, ivy cover, tree fungi, or hollow trees. These habitat structures can harbour numerous specialised organisms.

Harmful organism
Especially dangerous: non-native organism that is potentially very harmful, particularly for plants.

Herb fringe
Buffer zone between the > shrub belt, which is in the front of the > forest mantle, and the intensively cultivated farmland. It is either extensively used or not used at all.

High forest
Group selection: a high forest consists mainly of > standards. > Regeneration in a high forest is managed according to the group selection system, which involves felling all trees on certain areas (> final harvest) at the end of the > rotation period.

Hillslope debris flow
> Debris flow formed on a slope.

Humus
Organic substance in the organic layer and in the soil (0–100 cm deep).

Hydrocarbons
Group of chemical compounds made up of carbon and hydrogen only.

I

Increment
Increase in diameter, height, circumference, basal area, volume or value of a > stand or individual tree within a defined time interval (> gross increment, > net increment).

Indicator
A simple, measurable parameter for complex issues, systems or processes (> criterion).

Industrial wood
Raw wood that is mechanically shredded or chemically pulped. It is used to produce pulp wood, cellulose, wood shavings, particle- and fibreboards, as well as other industrial products.

Infestation site
Spatially restricted infestation of living plants with a harmful organism.

In-situ conservation
Targeted conservation of a species within its natural habitat (> ex-situ conservation).

Invasive species, non-native
Alien species with the potential to cause economic or ecological damage.

Ion
Electrically charged atom or molecule (> cation, anion).

K

Kyoto Protocol
Additional protocol to implement the United Nations Framework Convention on Climate Change (UNFCCC) that came into force in 2005 with the aim to protect the climate.

L

Landslide
Downhill movement of earth, rock and/or loose stones.

Long-term Forest Ecosystem Research Programme LWF
Research programme to investigate how pollution of natural or human origin affects the forest in the long term, and what the associated risks for people are. It is based on a network of different categories of plots, which are part of the > UNECE network, consisting of 49 > Sanasilva plots on a systematic 16x16 km grid and 19 long-term research plots, supplemented with other experimental sites. The LWF research programme provides data from long-term measurement series and interprets them scientifically for national and international decision-makers. The resulting data and the modern infrastructure of the LWF research platform provide attractive conditions for cooperating with national and international partners.

Lothar
Name of a storm depression that formed over the Bay of Biscay and passed over Western and Central Europe on 26 December 1999. The storm caused great damage, especially in France, Switzerland, Southern Germany and Austria. Until then, no natural disaster had ever caused so much damage in Switzerland: it amounted to almost 1.8 billion Swiss francs.

M

Millennium Ecosystem Assessment MEA
Study commissioned by the United Nations to systematically assess the condition of > ecosystem services and associated global development trends.

Molluscs
Molluscs (snails and shell-fish) form an animal phylum with many different species and shapes. They occur in the sea, on land and in freshwater.

Mountain plenter forest
Forest with a stratified structure and trees of different ages or clustered forest in the upper montane or sub-alpine altitudinal belt, where forestry treatments are carried out on individual trees or on small groups of trees (> plenter forest).

N

National accounts
Way of calculating and presenting a country's annual economic activity for statistical measurement. The origin, distribution and use of the total values of all goods produced and services are statistically recorded and assessed.

National Forest Inventory NFI
Sampling inventory of roughly 6,500 sample plots. It periodically records the condition of the Swiss forests and any changes that have taken place. On the basis of these data, statistically reliable conclusions can be drawn for the whole of Switzerland and for the larger cantons and regions. The first inventory (NFI1) was made in 1983–1985, the second (LFI2) in 1993–1995 and the third (LFI3) in 2004–2006. Since 2009, the data have been continuously collected, and one ninth of the sample plots throughout the country are surveyed each year. The primary sources of data are aerial images, data collected in forests and surveys of the > forest service.

Natural forest
Forest developed from > natural regeneration without human intervention for a long time. Also: a forest that is no longer actively managed with near-natural tree stands.

Natural regeneration
> Regeneration through seeding or vegetative propagation.

Natural selection
Survival of those individuals genetically adapted to the local environmental conditions.

Near-natural silviculture
Management of the forest oriented towards its natural development. Unlike > natural forest, near-natural forests are used, but care is taken to avoid having too much impact. The aim is to have mixed stands of tree species adapted to the site. It is based as a rule on > natural regeneration, and creates stands that are richly structured, both horizontally and vertically.

Neobiota species
Organism that is not native.

Neophyte
Non-native plant intentionally or unintentionally introduced from a foreign region after the year 1492.

Net increment
> Gross increment minus the natural mortality (e.g. > deadwood).

Nitrate (NO_3^-)
Nitrogen-oxygen compound easily soluble in water. Plants satisfy their need for nitrogen by, among other things, absorbing nitrates from the groundwater. > Nitrogen oxides (NO_X) and other nitrogen compounds can be converted into nitrates in the air. With high nitrate concentrations in water, nitrite (NO_2^-) may be formed. It is poisonous even in low concentrations, especially for small children.

Nitrate leaching
Annual quantity of > nitrate leached from the root zone into watercourses or into the groundwater.

Nitrogen (N)
Important nutrient. It is the main ingredient of air (78 % N_2) in the form of a colourless and odourless gas. For it to be taken up by plants, this form of nitrogen must be transformed into either > nitrate or > ammonium.

Nitrogen oxides (NO_X)
Precursor chemicals for the formation of > ozone close to the ground, which play a part in the creation of acid rain. They are formed from the > nitrogen in the air during combustion processes.

Nitrogen saturation
Condition in which additional > nitrogen deposition is not absorbed by the vegetation or retained in the soil, but mostly released through > seepage into the groundwater in the form of > nitrate.

O

Old growth patch
> Forest area in the development stage of > old timber stands where, for nature conservation reasons, use of wood is banned for a certain time. For a stand to qualify as an old growth patch, it must consist of indigenous tree species adapted to the site, with trees that are already old and a relatively large quantity of > deadwood.

Old timber stand
Forest management: development stage of a stand, where the 100 strongest trees per hectare are on average at least 50 cm in > diameter at breast height. It corresponds to the development stage 'old timber' in the > NFI.

Orchard
Park-like meadow with chestnut or walnut trees, used not only for wood and fruit, but also for hay or grazing. Most widespread in Switzerland on the Southern slopes of the Alps.

Overbank sedimentation
Process of deposition of mostly coarse solid material that spills out of a watercourse bed during flooding.

Ozone (O_3)
Strongly oxidising oxygen compound. High in the stratosphere, the ozone layer shields the Earth against harmful ultraviolet rays. Close to the ground, however, even low ozone concentrations may be harmful, irritating human respiratory systems and attacking the cell membranes of plant cells.

P

Particulate matter
The finest particles in air produced through different processes (e.g. combustion, road abrasion, quarrying, wind erosion or formed from > aerosols). Particulate matter is classified according to its diameter as PM10 (particulate matter, diameter ≤10 micrometres), PM2.5 (≤2.5 micrometres) and UFP (ultrafine particles, ≤0.1 micrometres). Particulate matter may contain very different chemical substances.

PEFC Programme for the Endorsement of Forest Certification Schemes
Independent certification system to ensure forest management is sustainable and to continually improve it (> FSC).

Permanent forest
Forest managed according to natural processes without patch cutting. A permanent forest is continuously stocked (without bare areas), and is continually regenerated naturally by cutting single trees or tree groups.

Photosynthesis
Biochemical process in which plants use the energy from sunlight to produce organic compounds from > carbon dioxide and water, thereby forming > biomass.

pH-Value
Measure of the concentration of > protons in an aqueous environment, for example, in a soil solution. Liquids with a pH-value of 7 are classified as neutral, over 7 as alkaline and under 7 as acid.

Pioneer species
Species that is especially competitive in early stages of > succession. Pioneer species of woody plants normally produce large quantities of seeds capable of flying and are not sensitive to climate extremes. Young plants grow quickly, are short-lived and not very shade-tolerant (> climax tree species).

Plant community
Combination of plant species that depends on the environment and the competition.

Planting
Planting of young trees in a forest to regenerate it, for example, after storm damage (> regeneration).

Plenter forest
Form of > permanent forest with continual > regeneration in which single stems are used ('plentering'). It is structured in levels with trees of all sizes next to each other as single stems or within small areas (> mountain plenter forest).

Primary function
If a forest or woodland has several forest functions, the most important of these functions is called the primary function. In the > National Forest Inventory NFI, this is the forest function that has priority should the district foresters find conflicts over use and the one to which most attention should be paid in use and treatment (management). Where possible, the other forest functions are also considered.

Proton
> Ion of the chemical element hydrogen (H). Protons are released in aqueous solutions from > acids and absorbed by > bases. Acid soils contain high concentrations of protons.

Provenance
Designated origin of > seed or of young trees for > planting. For example, beech trees from the Sihl Forest are considered a valuable provenance because of their growth characteristics. With climate change, provenances from drier and warmer regions are becoming important.

Public goods
Goods or services to which, unlike private goods, the exclusion principle does not apply and where, at the same time, there is no rivalry over use. Examples are street lighting and climate protection.

Q

Quality target
Target value for measures in, for example, water protection areas.

R

Regeneration
Establishment and growth of young trees. Regeneration that takes place without human involvement is called > natural regeneration. Regeneration can be promoted via silvicultural measures (e.g. secondary felling) (> natural regeneration) or occur as the result of intentional human actions (> planting). Also: collective of young trees.

Residuals
Forest residues: part of timber harvest that cannot be used as > roundwood, i.e. stems and branches that do not have the lengths and diameters required for the roundwood assortment, as well as brushwood. It can be used as a material (seldom) or to produce energy.

Residuals
Industrial: residues such as wood shavings and sawdust from wood processing, for example, in saw-mills, planing mills and carpenter's workshops. Used both as a material and for energy production.

Risk management
Integrated: > risk management that takes into consideration all kinds of natural hazards and measures, and works towards ecological, economic and social > sustainability, and in which all those responsible for planning and implementation are involved.

Risk management
Regular systematic monitoring and assessment of risks, as well as planning and implementing measures in order to be able to respond to any risks detected.

Rotation period
Regular specified time period between the establishment and clearing (final harvest) of a > stand. Corresponds to the time interval between two final cuts (> final harvest, > coppice forest, > high forest, group selection).

Roundwood
Cover term for the raw and unworked wood produced in the forest during > harvesting in the form of > stemwood logs, > industrial and > energy wood. A distinction is made between broadleaf and conifer roundwood according to the tree species.

S

Sanasilva Inventory
Annual inventory of the needle/leaf thinning and mortality rate in Swiss forests as an indicator of its general vitality condition. The around 50 plots are on a systematic subnet of the > NFI, which is part of the 16x16 km representative network of UNECE/ICP Forests Level I for the whole of Europe.

Saproxylic species
Species that feeds on or lives in wood, or uses it for at least one of its life phases. The term is mostly used for insects.

Sawn timber
Products produced in saw-mills by cutting > stemwood and logs to produce, for example, boards for building, packaging or furniture production.

Seed
Seed used to grow young tree seedlings, which is collected directly from mother trees in nets or on the ground.

Seed-harvesting stand
> Stand of at least 100 trees selected for their quality from which > seed is obtained.

Seed plantation
Ex-situ collection of trees selected on the basis of certain characteristics, which are used for producing seed.

Seepage
Water that flows through the soil profile (seeps).

Segregation
Spatial separation of primary functions in the forest. For example, certain forest areas are used mainly for timber production, whereas others are principally used for nature conservation.

Shelterwood forest
Forest managed according to the shelterwood system, where the stands are regenerated in patches with one or several selective fellings and then harvested once the > regeneration is established.

Shrub belt
Border of woody plants (not including dwarf shrubs) under 12 centimetres > diameter at breast height in front of the > forest mantle.

Shrub forest
Forest area where more than two thirds of the stand is covered with shrubs according to the definition in > NFI. Typical examples of shrub forest are forests of green alder and dwarf mountain pine, as well as hazel (coppice) forests and similar > stockings.

Site
Entirety of all the environmental factors that affect > plant communities (> abiotic, > biotic, including anthropogenic factors).

Site factors
Environmental factors influencing plants, either > biotic (e.g. vegetation competition and harmful organisms) or > abiotic (e.g. geology and weathering). These factors taken together define the > site.

Snag
Standing dead tree.

Solid cubic metre
Unit of measure for > roundwood. A solid cubic metre (scm) corresponds to one cubic metre of solid wood mass, usually without bark. The unit of measure is used in harvesting and selling roundwood.

Special furnaces
Furnace in which > energy wood in the form of pellets or chips is burnt to obtain heat and/or electricity. Unlike single-room stoves and log stoves, they are usable in both small and large dimensions.

Stand
> Tree collective with a homogeneous structure and tree species composition. It represents the smallest spatial unit for silvicultural activities.

Stand, dense or crowded
> Stand in which the tree crowns are in close contact and influence each other, often resulting in deformed and not rounded crowns.

Standard
Tree that developed from seed > regeneration, in contrast to > coppice sprouts.

Stemwood
Aboveground wood of the tree stem (without branches, but with bark).

Stemwood log
The more valuable > roundwood that can be used for sawn timber or veneers. Normally in the form of > stemwood.

Stocking
> Collective of trees or shrubs in a forest or non-forest area.

Stocking, open
Stand that has a degree of coverage, according to the > NFI, of 20 to 60 per cent due to site factors or type of forest use. Examples are > wooded pastures and > stockings close to the upper timberline.

Subsidy
Governmental financial support without any immediate service in return.

Succession
Natural sequence of plant or animal communities on one site. The forest succession is a sequence of so-called pioneer communities with light-demanding trees to climax forest communities with shade-tolerant tree species (> pioneer species, > climax tree species).

Sustainability
Principle that no more should be consumed than can be regrown, regenerated, or made available in future.

Swiss Bird Index SBI
Indicator of the Swiss Ornithological Institute, Sempach, which has recorded the development of breeding birds in Switzerland since 1990. In the Index for the forest, 57 forest bird species on which enough data on their population development is available are monitored.

T

Target species
National priority species whose survival depends on specific measures.

Thinning
Felling of trees to use their wood or as a silvicultural measure with the aim to improve the structure, stability and/or quality of the rest of the remaining > stand.

Threshold value, deadwood
Minimum amount of > deadwood needed to maintain specialised species.

Timber or wood harvest
Domestic: volume of wood in cubic metres (> stemwood without bark, > industrial wood with bark) sold in the year in question (from forest roads, timber yards, or stockpiles), as well as that given to procurers of loose wood and that used for own consumption. For sales from stock-piles or private forest, an estimate of the assortment is made based on a marking protocol, i.e. a list of the trees to be harvested.

Timber harvest
Process: procedure for preparing timber and wood on the forest road or in the plant (place where it is then used as a material or energy source). The process of harvesting includes processing the wood, as well as off- and on-road hauling. Processing involves cutting the trees, removing their branches and cross-cutting the wood. Off-road hauling involves moving and stacking the stems, i.e. transporting the trees or stems to the forest roads and storing them at suitable sites for the following road transport to the plant.

Total wood volume
Stemwood volume of all living and dead trees and shrubs larger than 12 centimetres > diameter at breast height. The total wood volume is the sum of the > growing stock (volume of living wood) and the volume of deadwood.

U

UNECE United Nations Economic Commission for Europe
The UNECE was founded in 1947 as one of the UN's 5 regional organi-sations. Its primary goal is to promote economic cooperation among its 56 member countries. To this end, it performs economic and political analyses and develops standards.

V

Vegetation zone, altitudinal
All > sites with similar vegetation conditions (> forest community) taking into account the critical site factors, in particular altitude.

Virgin forest
Forest unused by humans as far as is known or can be seen, or where such use was so insignificant and so long ago that it no longer appears to influence the current tree composition, forest structure, quantity of deadwood or forest dynamics. A virgin forest typically contains large quantities of > deadwood because the wood from dead trees remains in the forest.

Vivian
Name of an intensive low-pressure system that caused great damage in Europe and Switzerland in February 1990. In Switzerland the storm mostly affected the northern Pre-Alps, where large areas of mountain forest were destroyed.

Volatile Organic Compounds (VOC)
> Group of organic compounds that are volatile. They may contain toxic components.

W

Waste wood
Energy and material: wood that is no longer part of the use processes. It stems, for example, from demolished buildings and the disposal of furniture and packaging. Waste wood may be treated or natural, i.e. untreated, depending on its origin.

Watch List
List of the invasive > neophytes in Switzerland with the potential to cause harm and whose spread must therefore be monitored (> Black List, > neophyte). Online: www.infoflora.ch

Weathering, chemical
Disintegration/dissolving and transformation of rocks and minerals. Chemical weathering is the most important acid-neutralising process in soil and the most important source of nutrients.

Wild ungulates
Cloven-hoofed animals subject to hunting law. They include deer-like species and animals with horns. In Switzerland, these are mainly roe and red deer, as well as chamois, ibex and wild boar.

Wood harvesting expenses
Cost and effort involved in preparing the wood (> timber harvest).

Woodland fragments
Wood that grows outside the forest in open country, for example, in pat-ches of woodland, as shrubs or as hedges. Wood growing on the edges of transport infrastructure like, for example, motorways, is often consid-ered a woodland fragment. During landscape maintenance outside the for-est, woodland fragments that can be used for energy accumulate.

Wood mould
Mixture of strongly decomposed soft wood, as well as plant and animal excrement residues (detritus).

Wood stock
Synonym for > growing stock.

Wooded pasture
Pasture stocked with forest trees, subject to federal forest legislation. Open forest landscape with a characteristic pattern of small patches of pasture and forest. It is very valuable for nature conservation and de-velops through extensive grazing. Those most attractively developed in Switzerland can be found in the Jura highlands and in the Central Alps.

Y

Young growth
Development stage of a > stand in which the 100 tallest trees per hectare are, on average, at most 1.3 metres tall. The young forest trees do not form a closed stand and belong to the herb or shrub layer.

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> Web links

Campaign "Respect to Protect"
www.respect-to-protect.ch

Deadwood
www.totholz.ch

Deutsche Gesellschaft für Erziehungswissenschaft DGfE, Kommission Bildung Nachhaltige Entwicklung BNE der Deutschen Gesellschaft für Erziehungswissenschaften
www.dgfe.de > Sektionen | Kommissionen > Sektion 3 – Interkulturelle und International Vergleichende Erziehungswissenschaft > Kommission Bildung für nachhaltige Entwicklung

éducation 21
www.education21.ch

Europäische Holzhandelsverordnung EUTR
www.bafu.admin.ch > Forest and timber > European Timber Regulation

Federal Office for the Environment FOEN, Division Forest
www.bafu.admin.ch > The FOEN > Divisions and sections > Forest

Forest Knowledge
www.waldwissen.net

Forestry statistics of the Swiss Federal Statistical Office FSO
www.pxweb.bfs.admin.ch > 07 Land- und Forstwirtschaft > 07.3 Forstwirtschaft

FSC certification system
www.fsc.org; www.fsc-schweiz.ch

ICP Forests
www.icp-forests.net

Info species
www.infospecies.ch

Institute for Applied Plant Biology IAP
www.iap.ch

Lignum
www.lignum.ch

Long-term Forest Ecosystem Research Programme LWF
www.lwf.ch

National Forest Inventory NFI
www.lfi.ch

PEFC certification system
www.pefc.org; www.pefc.ch

Pro Natura
www.pronatura.ch

Silviva
www.silviva.ch

SVEB Certificate course Environmental Adult Education
www.wwf.ch > Aktiv werden > Sich engagieren > Weiterbildungsangebot > Umweltbildung SVEB

Swiss Federal Institute for Forest, Snow and Landscape Research WSL
www.wsl.ch

UNECE
www.unece.org > Forestry and Timber

Waldschutz Schweiz
www.wsl.ch > Research Units > Forest Dynamics > Swiss Forest Protection

Wildnispark Zurich
www.wildnispark.ch

WWF Switzerland (World Wide Fund for Nature)
www.wwf.ch

> Authors

Achermann Beat, Federal Office for the Environment FOEN, Bern
Augustin Sabine, Federal Office for the Environment FOEN, Bern
Bauer Nicole, Swiss Federal Research Institute WSL, Birmensdorf
Bolliger Markus, Federal Office for the Environment FOEN, Bern
Bollmann Kurt, Swiss Federal Research Institute WSL, Birmensdorf
Brändli Urs-Beat, Swiss Federal Research Institute WSL, Birmensdorf
Brang Peter, Swiss Federal Research Institute WSL, Birmensdorf
Braun Sabine, Institute for Applied Plant Biology IAP, Schönenbuch
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Huber Markus, Swiss Federal Research Institute WSL, Birmensdorf
Hug Christian, Swiss Federal Research Institute WSL, Birmensdorf
Hunziker Marcel, Swiss Federal Research Institute WSL, Birmensdorf
Imesch Nicole, Federal Office for the Environment FOEN, Bern
Kammerhofer Alfred W., Federal Office for the Environment FOEN, Bern
Kienast Felix, Swiss Federal Research Institute WSL, Birmensdorf
Kläy Matthias, Swiss Federal Research Institute WSL, Birmensdorf
Krafft Ulrike, Federal Office for the Environment FOEN, Bern
Küchli Christian, Federal Office for the Environment FOEN, Bern
Lachat Thibault, Swiss Federal Research Institute WSL, Birmensdorf
Landolt Daniel, Federal Office for the Environment FOEN, Bern
Limacher Sandra, WaldKultur – Beratung und Forschung, Vitznau
Maag Merki Katharina, University of Zurich
Manser Rolf, Federal Office for the Environment FOEN, Bern
Meier Franz, Swiss Federal Research Institute WSL, Birmensdorf
Olschewski Roland, Swiss Federal Research Institute WSL, Birmensdorf
Pasi Tatiana, Federal Office for the Environment FOEN, Bern
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Rihm Beat, Meteotest, Bern
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Rogiers Nele, Federal Office for the Environment FOEN, Bern
Röösli Bruno, Federal Office for the Environment FOEN, Bern
Sandri Arthur, Federal Office for the Environment FOEN, Bern
Schaffer Hans Peter, Federal Office for the Environment FOEN, Bern
Schaub Marcus, Swiss Federal Research Institute WSL, Birmensdorf
Scheidegger Christoph, Swiss Federal Research Institute WSL, Birmensdorf
Schmid Silvio, Federal Office for the Environment FOEN, Bern
Schwyzer Andreas, Swiss Federal Research Institute WSL, Birmensdorf
Senn-Irlet Beatrice, Swiss Federal Research Institute WSL, Birmensdorf
Stofer Silvia, Swiss Federal Research Institute WSL, Birmensdorf
Suter Thalmann Claire-Lise, Federal Office for the Environment FOEN, Bern
Thees Oliver, Swiss Federal Research Institute WSL, Birmensdorf
Thimonier Anne, Swiss Federal Research Institute WSL, Birmensdorf
Thürig Esther, Swiss Federal Research Institute WSL, Birmensdorf
von Lindern Eike, Swiss Federal Research Institute WSL, Birmensdorf
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Wohlgemuth Thomas, Swiss Federal Research Institute WSL, Birmensdorf
Zimmermann Erica, Federal Office for the Environment FOEN, Bern
Zimmermann Stephan, Swiss Federal Research Institute WSL, Birmensdorf
Zimmermann Willi, ETH Zurich